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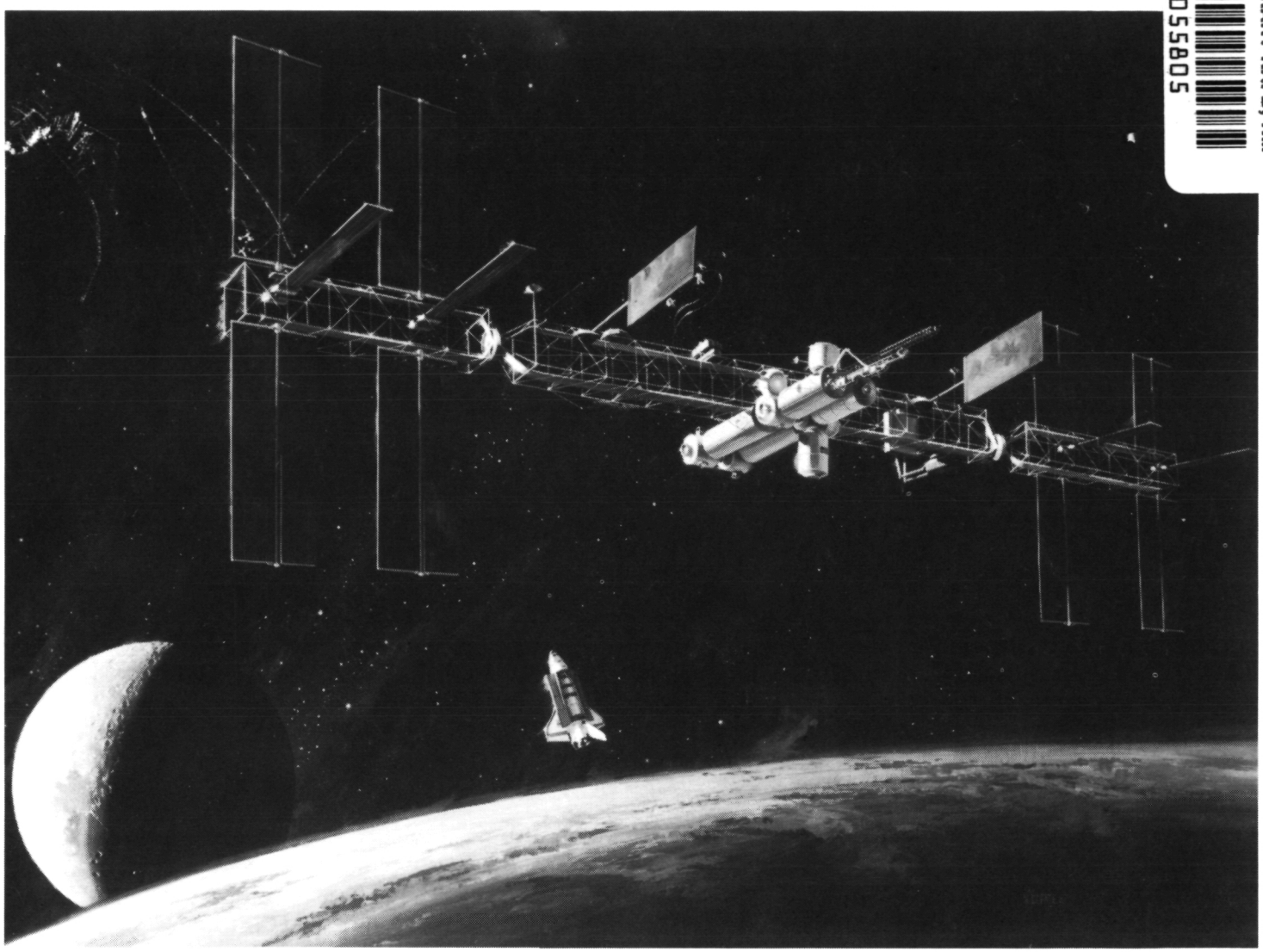

Large Space Structures & Systems in the Space Station Era

A Bibliography with Indexes

Cover photo by NASA

NASA SP-7085 (01)
NOVEMBER 1990

Large Space Structures & Systems in the Space Station Era

A Bibliography with Indexes

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National Aeronautics and Space Administration
Office of Management
Scientific and Technical Information Division
Washington, DC 1990

NOTE TO AUTHORS OF PROSPECTIVE ENTRIES:

This bibliography compiles results from a complete search of the *STAR* and *IAA* files of the NASA STI Database, supplemented with a perusal of their printed versions. Although many technical areas relate to Large Space Structures and Space Stations, only those reports which directly address these subjects are included. To insure the inclusion of your work in this bibliography, use the words large space structure or space station in the title, abstract or suggested key words.

This supplement is available from the National Technical Information Service (NTIS), Springfield , Virginia 22161 at the price code A16.

INTRODUCTION

This bibliography is designed to aid researchers and managers engaged in the development of technology, configurations and procedures that enhance the efficiency of current and future versions of space stations or other large space structures. It merges two earlier semi-annual NASA Special Publications, NASA SP-7046, *Technology for Large Space Systems*, produced 1979-1989, and NASA SP-7056, *Space Station Systems*, produced from 1983-1989.

This literature survey lists 1372 reports, articles, and other documents announced between January 1, 1990 and June 30, 1990 in *Scientific and Technical Aerospace Reports (STAR)*, and *International Aerospace Abstracts (IAA)*.

The coverage includes references that define major systems and subsystems, servicing and support requirements, procedures, operations, and missions. It also includes analytical and experimental techniques and mathematical models required to investigate the different systems/subsystems, and to conduct trade studies of different configurations, designs, and scenarios.

The references appear in categories which are described with scope notes in the Table of Contents. These categories are unique to this publication only and differ from those found in *STAR* and *IAA*.

Each reference consists of a bibliographic citation and an abstract, if available, and appears with the original accession numbers from the respective announcement journals.

References appear in each category in this order:

(1) *IAA* entries in ascending accession number order with the form A90-10000, followed by,

(2) *STAR* entries in ascending accession number order with the form N90-10000.

After the abstract section there are seven indexes, viz., subject, personal author, corporate source, foreign technology, contract number, report number, and accession number. The subject index terms are from the *NASA Thesaurus*, NASA SP-7064.

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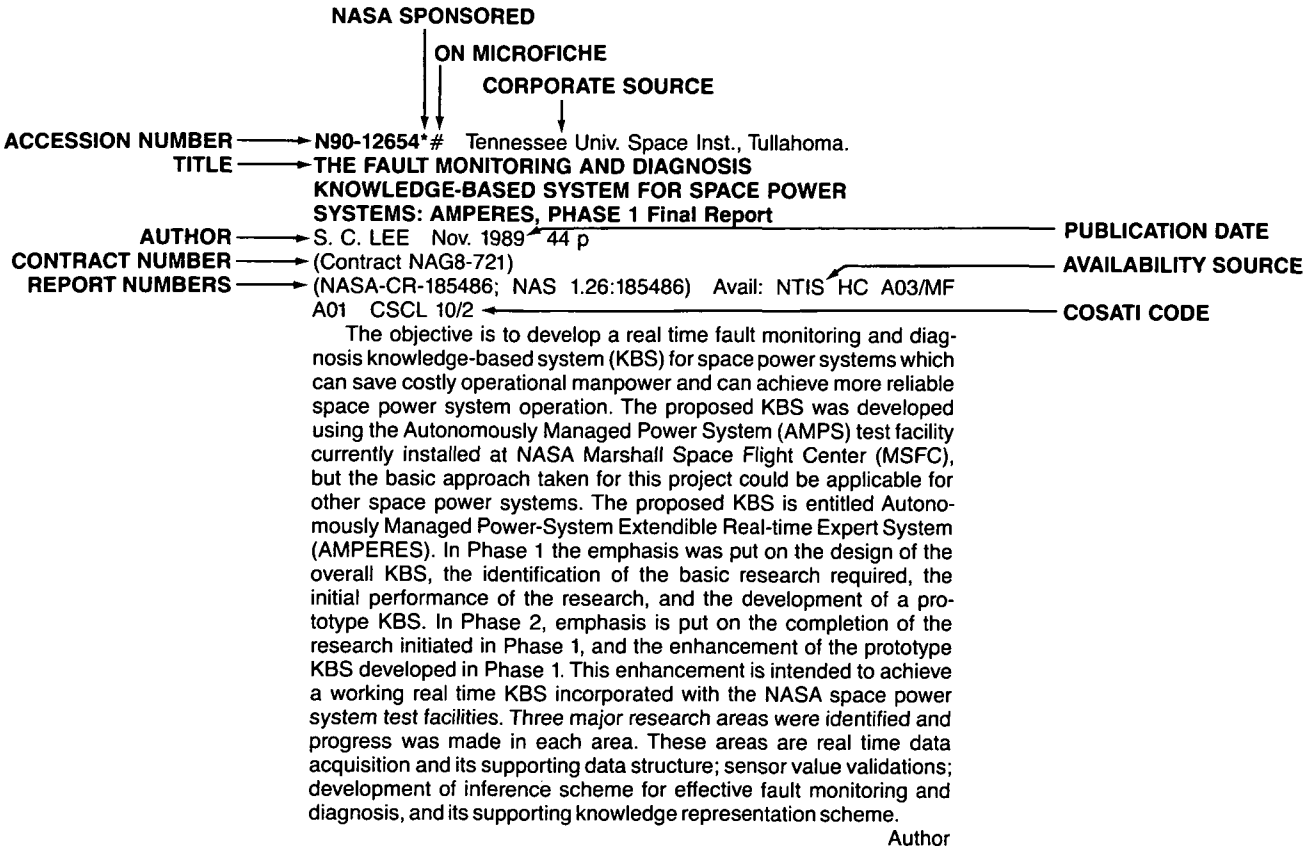
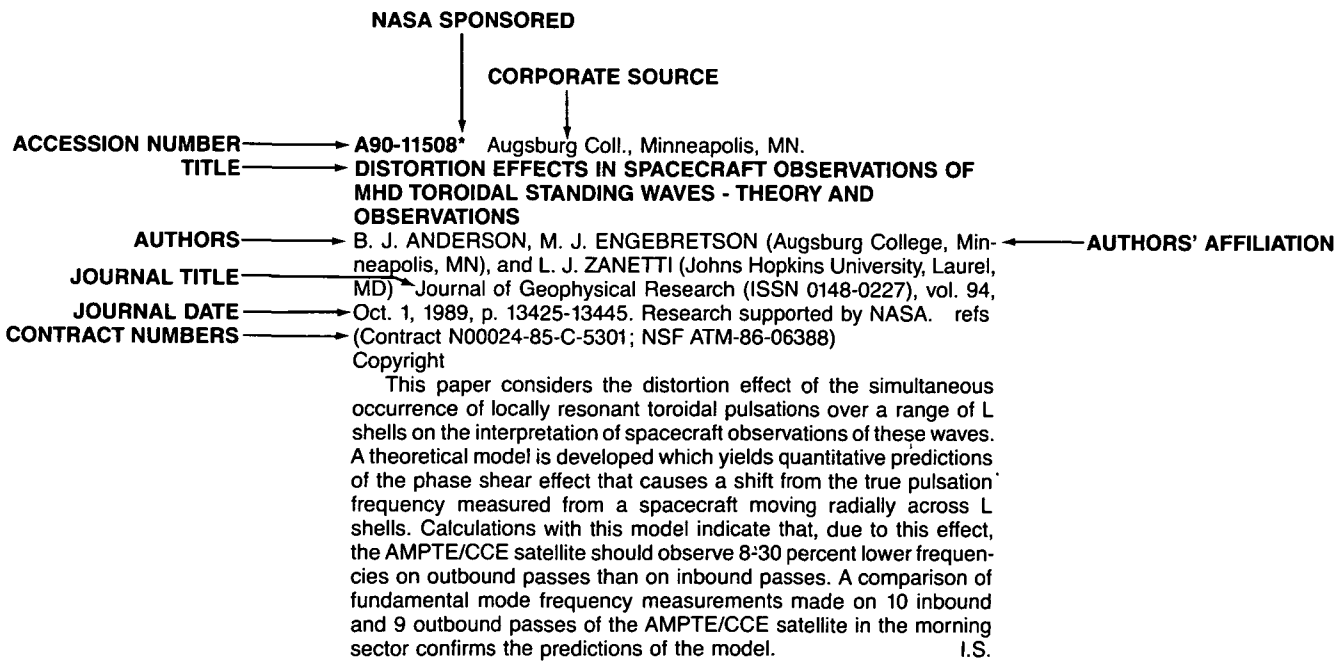


TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA

A Bibliography (Suppl. 01)

NOVEMBER 1990

01

OVERALL DESIGN AND EVOLUTIONARY GROWTH

System requirements for proposed missions, mission models, overall conceptual configuration and arrangement studies. Analyses for future required technology. Identification and description of technology for the elements of a complete space station.

A90-10078
ESTIMATION OF ATMOSPHERIC WINDS BY SATELLITE - STATUS, POTENTIAL AND OUTLOOK
J. MORGAN (EUMETSAT, Darmstadt, Federal Republic of Germany) (COSPAR, IAMAP, Scientific Committee on Oceanic Research, et al., Plenary Meeting, 27th, Symposium 1 and Topical Meeting on the Remote Sensing of Atmosphere and Oceans, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 7, 1989, p. 15-22.
Copyright

The global observation of atmospheric wind vectors is a primary goal for studies of the atmosphere, for climatology and for operational meteorology. This is especially true in the tropics where atmospheric dynamics cannot be inferred through knowledge of atmospheric temperature structures or realistic networks of land-based conventional measurements. An operational system already exists for the generation of cloud track winds from geostationary satellites. This provides many estimates of atmospheric winds in cloudy areas throughout most of the tropical and near-tropical latitudes but does not provide information on the vertical structures of the wind fields. New satellites to be flown in the early 1990s primarily for oceanographic purposes will provide estimates of winds close to the ocean surface. New satellite instruments capable of resolving the full three-dimensional structure of the wind fields are technically feasible and may be deployed on the large Space Station elements planned for the late 1990s. Author

A90-10107* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
USEFULNESS OF SPACE STATION OBSERVATIONS TO MONITOR THE HYDROLOGICAL CYCLE
V. SALOMONSON (NASA, Goddard Space Flight Center, Greenbelt, MD) (COSPAR, IAMAP, Scientific Committee on Oceanic Research, et al., Plenary Meeting, 27th, Symposium 1 and Topical Meeting on the Remote Sensing of Atmosphere and Oceans, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 7, 1989, p. 221-228. refs
Copyright

The Space Station is a major project being undertaken in the United States that will provide major advances in the development and implementation of observations from space. In particular, the Space Station Manned Base (SSMB) and the attendant attached payload capability offers an opportunity for testing new observing concepts and observing hydrological phenomena in the low latitudes. Ample power, thermal, data, serviceability and other support services are being designed in Phase 1 of the SSMB. It is concluded that the hydrological community should study the SSMB and utilize the opportunity to advance the utility of space observations for studies of the hydrological cycle. Author

A90-13241*# National Aeronautics and Space Administration, Washington, DC.
EARTH ORBITING TECHNOLOGIES FOR UNDERSTANDING GLOBAL CHANGE
LEONARD A. HARRIS, GORDON I. JOHNSTON, WAYNE R. HUDSON, and LANA M. COUCH (NASA, Office of Aeronautics and Space Technology, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-001) Copyright

This paper considers the technology requirements needed to support the Mission to Planet Earth concept, which will consist of several sun synchronous polar platforms; a series of low-earth orbit equatorial missions, such as Space Shuttle payloads, Space-Station-attached payloads, and the Explorer-class Earth Probes; and five geostationary platforms. In particular, the technology requirements in the areas of space-based observation, data/information, and spacecraft operation are examined. I.S.

A90-13242#
ASSESSMENT OF TECHNOLOGIES FOR FUTURE ORBITAL SYSTEMS - A GERMAN VIEW
W. LEY, J. FROMM, and W. SEBOLDT (DLR, Cologne, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-002) Copyright

Critical technology tasks pertaining to future scenarios for orbital infrastructure and associated systems are identified, specified, and evaluated from a German point of view and with a European orientation. Three scenarios representative of potential development trends in spaceflight at the beginning of the 21st century are addressed: (1) expansion of the low-earth orbit infrastructure, (2) buildup of geostationary orbit and infrastructure, and (3) development of lunar/planetary infrastructure. The technology assessment is used to derive possible incremental steps for expanding the infrastructure represented by Columbus-IOC. Key technologies whose application potential extends beyond LEO infrastructure are considered. C.D.

A90-13290*# National Aeronautics and Space Administration, Washington, DC.
DESIGNING SPACE STATION FREEDOM FOR EVOLUTION
EARLE K. HUCKINS, III (NASA, Office of Space Station, Washington, DC) and E. BRIAN PRITCHARD (NASA, Langley Research Center, Hampton, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p.
(IAF PAPER 89-070) Copyright

The requirements for using the Space Station for research and development and to support human missions to the Moon and Mars are examined. Space Station configurations are presented for these two cases. It is suggested that, by the year 2010, the Space Station requirements for research and development should include 275 kW of average power, a crew of 24, 5 full laboratory modules, and 3 pocket labs. For supporting the Lunar/Mars program as a transportation node facility, the Space Station should

require 175 kw of average power, 16 crew members, 3 full laboratory modules, and 1 pocket lab. R.B.

A90-13293*# NASA Space Station Program Office, Reston, VA.
SPACE STATION FREEDOM PROGRAM PRELIMINARY DESIGN REVIEW PROCESS
R. F. CARLISE and BILLY ADAIR (NASA, Space Station Freedom Program Office, Reston, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-076)

To conduct the Program Requirements Review of the Space Station Freedom, a Preliminary Design Review Board (PDR) has been established. The PDR will assess the preliminary design of the assembled manned base including the assembly process, the launch, and on-orbit stage configuration, the design approach, the on-orbit verification plans, supportability, reliability, safety, interfaces with the NASA infrastructure (the NSTS, TDRSS, and Ground operations) and international partners. Issues such as the coordination of a common interpretation of design requirements, coordination of interfaces, and convergence of design perspectives vs. proper allocation of resources are discussed. The impact of the resolution of the secondary ripple effect of design decisions which may cause programmatic difficulties is also addressed. C.E.

A90-13294*# NASA Space Station Program Office, Reston, VA.
UPDATE OF SPACE STATION FREEDOM DESIGN
JAMES M. SISSON and RICHARD TINIUS (NASA, Space Station Freedom Programme Office, Reston, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p.
(IAF PAPER 89-077) Copyright

The Space Station system baseline concept and various development scenarios that would meet the Space Station design requirements are examined. Consideration is given to the rephrasing of the Space Station assembly process to provide a permanently-manned station with reduced early year funding, resulting in a completed assembly which includes the expected station capabilities. The contents of the baseline concept and the proposed assembly plan are compared. Configurational, functional, and assembly tradeoffs are discussed. The baseline configuration and rephased configurations are illustrated and the flight sequence and launch dates of the rephased assembly sequence are listed. R.B.

A90-13468#
DEVELOPMENT OF LARGE ORBITAL STRUCTURE SYSTEMS
H. OERY, M. MENKING (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany), E. HORNUNG, and E. ERBEN (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 18 p.
(IAF PAPER 89-340) Copyright

This paper illustrates the tasks of the development of large platforms in order to compare the advantages and shortcomings of different structural concepts. Some aspects considered for comparison are: the transport, the required characteristics to fulfill the objectives during long-term operation, and the optimization between structural strength, flexibility, and active vibration control. Attention is paid to the reduction of environmental pollution by reusing launcher structural elements. Two alternative structural configurations providing a support for a 95 sq km area with 0.435 kg/sq m energy-producing mass have been investigated. Author

A90-13568#
POSSIBLE APPLICATIONS OF TETHERED SYSTEMS TO MARS EXPLORATION MISSIONS
FRANCO BEVILACQUA and STEFANO CESARE (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 16 p. refs
(IAF PAPER 89-489) Copyright

The aim of this paper is to discuss some possible applications of tethers to the Mars exploration mission, both manned and unmanned. A brief analysis concerning the sizing of a tether system for generating artificial gravity inside a spaceship was performed together with a preliminary evaluation of the system dynamical stability and the overall vehicle configuration. In addition, the behavior of a carrier-tether-probe system orbiting in the Martian middle atmosphere is investigated by means of simplified models to assess the lowest altitude toward which the tethered probe can be deployed to perform atmospheric measurements. A description of the ideas for the use of tethered systems for sampling the surface of Martian satellites and performing aerobraking maneuvers is then presented. Author

A90-13641*# National Aeronautics and Space Administration, Washington, DC.
THE SPACE STATION FREEDOM - INTERNATIONAL COOPERATION AND INNOVATION IN SPACE SAFETY
GEORGE A. RODNEY (NASA, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p.
(IAF PAPER 89-615) Copyright

The Space Station Freedom (SSF) being developed by the United States, European Space Agency (ESA), Japan, and Canada poses novel safety challenges in design, operations, logistics, and program management. A brief overview discloses many features that make SSF a radical departure from earlier low earth orbit (LEO) space stations relative to safety management: size and power levels; multiphase manned assembly; 30-year planned lifetime, with embedded 'hooks and scars' forevolution; crew size and skill-mix variability; sustained logistical dependence; use of man, robotics and telepresence for on-orbit maintenance of station and free-flyer systems; closed-environment recycling; use of automation and expert systems; long-term operation of collocated life-sciences and materials-science experiments, requiring control and segregation of hazardous and chemically incompatible materials; and materials aging in space. Author

A90-13682#
GEOSTATIONARY SERVICE VEHICLE (GSV) FOR ECONOMICAL ON-ORBIT SERVICING
TETSUO YASAKA and YOSHITSUGU YASUI (NTT Public Corp., Radio Communication Systems Laboratories, Yokosuka, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-696)

The geostationary service vehicle (GSV) is intended to provide a commercially viable on-orbit servicing system by confining the customers to the GEO satellites only, and by eliminating those services which require a large amount of consumables. GSV drifts along the GEO and meets customer satellites on demand. It is capable of operating for multiple of years without retrieval or supply, making more than 200 rendezvous during its own life. The primary service is the visual and remotely obtained data transmission by approaching the customer satellite as near as tens of meters. The secondary services are provided through the grapple operation for mechanical failure recovery and satellite orbit transfer assists. Author

A90-13704#
EARLY ENGINEERING DESIGNS OF SPACE STATIONS IN THE UNITED SATES
SAUNDERS B. KRAMER IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-730) Copyright

The early designs of manned space stations designated for low earth orbits are described, including the early design by Kramer and Byers (1958) as well as the later concepts of the 1960s and the variations of these designs. Attention is given to the 1960 Modular Space Station, the 1958 Reentry Vehicle, the Astrocommuter for the 1960 Space Station, a space station designed for the USAF, and the four-spoke and three-spoke space station configurations. Particular consideration is given to the efforts

aimed to resolve problems that may arise due to the presence of a human crew and the need to assemble a space station from many separate modules. I.S.

A90-13710#
THE WERNHER VON BRAUN-FRED FREEMAN COLLABORATION
RANDY LIEBERMANN IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p.
(IAF PAPER 89-744)

The paper describes the working relationship between the astronautical engineer von Braun and the Collier's illustrator Freeman. The two collaborated on a series of articles published in 1952 and 1953 on such topics as the wheel-form space station, a manned lunar mission, and the manned exploration of Mars. Also discussed are design drawings for a shuttle emergency escape system produced in 1953. B.J.

A90-16550
MODELING AND SIMULATION OF ADVANCED SPACE SYSTEMS
CURT BILBY and STEWART NOZETTE (Large Scale Programs Institute, Austin, TX) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 323-336. refs
(AAS PAPER 87-251) Copyright

This paper addresses the methodology developed by the Large Scale Programs Institute (LSPI) and NASA Johnson Space Center as applied to modeling and simulation of advanced space systems. Specifically, the methodology as applied to a lunar base program is discussed. Also, the past and current lunar base modeling efforts at LSPI are addressed. Applications of such a model to Mars exploration program and its impacts on the lunar base are identified. Author

A90-17728
ANNUAL SPACE: TECHNOLOGY, COMMERCE AND COMMUNICATIONS CONFERENCE, 2ND, HOUSTON, TX, NOV. 1-4, 1988, PROCEEDINGS
Boston, MA, T. F. Associates, Inc., 1988, 224 p. For individual items see A90-17729 to A90-17733.

Papers on space technology, commerce, and communications are presented covering topics such as space insurance considerations, the selection of a commercial launch site in Hawaii, the development of a spaceport in Florida, and satellites and the television industry. Other topics include research in the LEO environment, the commercial space market in West Germany, risk management for space ventures and the Hermes program. Additional topics include marketing space services, Radarsat remote sensing system, sources of capital for commercial space ventures, research at the Center for Low-Gravity Fluid Mechanics and Transport Phenomena, and the development of large inflatable/rigidized structures. R.B.

A90-18844*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OVERVIEW OF SDCM - THE SPACECRAFT DESIGN AND COST MODEL
MELVIN J. FEREBEE, JEFFERY T. FARMER, GREGORY C. ANDERSEN (NASA, Langley Research Center, Hampton, VA), JEFFERY D. FLAMM (Georgia Institute of Technology, Atlanta), and DEBORAH M. BADI (Polytechnic University, New York) IN: AIAA/DARPA Meeting on Lightweight Satellite Systems, Monterey, CA, Aug. 4-6, 1987, Collection of Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 137-153. refs

The Spacecraft Design and Cost Model (SDCM) is a computer-aided design and analysis tool for synthesizing spacecraft configurations, integrating their subsystems, and generating information concerning on-orbit servicing and costs. SDCM uses a bottom-up method in which the cost and performance parameters for subsystem components are first calculated; the model then sums the contributions from individual components in order to obtain an estimate of sizes and costs for each candidate configuration within a selected spacecraft system. An optimum spacraft configuration can then be selected. O.C.

A90-19843*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE TRANSPORTATION SYSTEMS SUPPORTING A LUNAR BASE
C. C. PRIEST (NASA, Marshall Space Flight Center, Huntsville, AL) and GORDON WOODCOCK (Boeing Aerospace and Electronics, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 13 p.
(AIAA PAPER 90-0422) Copyright

Results are presented on preliminary design studies conducted by NASA and its contractors to define the transportation vehicle for the support of a human return to the moon mission. Attention is given to the transportation needs and requirements, the design solutions to meet these requirements, the rationale for the selection of the designs, and the ground/orbital support facilities for placing these systems into routine earth-moon transportation service. The reference system includes a partially reusable lunar transfer vehicle that operates between the earth and lunar orbits and a fully reusable lunar excursion vehicle that operates between the lunar orbit and the lunar surface. The system can deliver 27 metric tons of cargo to the lunar surface in an automated flight mode, and can transport a crew of four and deliver 15 tons of cargo in a piloted mode. I.S.

A90-20387
THE OUTPOST CONCEPT, A TECHNOLOGY DEVELOPMENT PLATFORM IN LOW EARTH ORBIT
THOMAS C. TAYLOR, WILLIAM A. GOOD, and JOHN D. HODGE (Global Outpost, Inc., Alexandria, VA) Huntsville Association of Technical Societies, Annual Technical and Business Exhibition and Symposium, 5th, Huntsville, AL, May 16, 17, 1989. 7 p. refs
(TABES PAPER 89-904) Copyright

This paper examines the concept of a simple commercial space service platform to be used by industry and government, that is anticipated to be in orbit in the early to mid 1990s. The concept, based on salvaging the External Tank of the Space Shuttle, is a simple platform providing subsystems compatible with the Space Station. Two types of platform subsystems are anticipated, those required to produce revenue and those required for the usual platform housekeeping functions such as power, communications, attitude and deorbit control, safety, avionics, thermal control, and orbital maintenance. A diagram of the platform using the External Tank is presented. I.S.

A90-21726#
MANNED SPACE FLIGHT AND SPACE STATIONS [BEMANDE RUIMTEVAART EN RUIMTESTATIONS]
D. DE HOOP (Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart, Delft, Netherlands) Ruimtevaart, vol. 38, Oct. 1989, p. 5-12. In Dutch.

The history and current status of manned space flight are reviewed, and plans for future manned missions are discussed and illustrated with drawings and diagrams. The advantages of a manned presence for specific missions are considered; the early U.S. and Soviet manned missions are recalled; and particular attention is given to the NASA International Space Station, the ESA-NASA agreements on Space Station utilization, the ESA Columbus program and its components, and the Space Station ground segment. T.K.

A90-21729#
THE SCIENTIFIC UTILIZATION OF COLUMBUS [HET WETENSCHAPPELIJK GEBRUIK VAN COLUMBUS]
F. B. VISSER (Nationaal Lucht- en Ruimtevaartlaboratorium, Delft, Netherlands) Ruimtevaart, vol. 38, Oct. 1989, p. 31-44. In Dutch.

Plans for basic and applied scientific research on the International Space Station are discussed, with an emphasis on components to be contributed by ESA (Columbus Attached

Laboratory, Columbus Free-Flying Laboratory, and Polar Platform). The program includes fluid physics, material science, life science, space science, earth observation, communication, and space technology. The Columbus-related programs underway in the Netherlands are briefly characterized, and particular attention is given to the role of the Columbus User Support Organization in guiding users through the various phases of a Columbus experiment (familiarization, development, execution, data acquisition, data analysis, and designing follow-on experiments). Block diagrams, photographs, and drawings are included. T.K.

A90-24525
THE NEXT 40 YEARS IN SPACE
THOMAS O. PAINE Spaceflight (ISSN 0038-6340), vol. 32, Jan. 1990, p. 14-17.
Copyright

NASA and international plans for space missions in the period 1990-2030 are discussed in a shortened version of a lecture presented at the 40th IAF Congress (Malaga, Spain, October 1989). Topics addressed include orbital observatories, solar studies, missions to Venus and Mercury, the Mission to Planet Earth in 1992, the Mars Observer, ESA Mars orbiters and the Soviet Phobos program, and the Comet Rendezvous Asteroid Fly-by mission. Consideration is given to the Galileo probe to Jupiter, the Cassini mission to Saturn and Titan, proposed Pluto probes, the NASA-ESA Rosetta comet sample-return mission, plans for a manned lunar presence beginning in 2004, and proposals for the exploration and settlement of Mars. The need for more extensive international cooperation is stressed, and the organization of an advanced Space Federation to coordinate national efforts is recommended. T.K.

A90-24766
THE SPACE STATION
HANS MARK (Texas, University, Austin) IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 99-104.
Copyright

Policy issues related to the development of the Space Station are considered. The history of the U.S. space program is reviewed, focusing on the evolution of the Space Station concept. The political and military issues related to the adoption of plans for the Space Station and the prospects for future policy issues are discussed. R.B.

A90-24780#
SALVAGING SPENT EXTERNAL FUEL TANKS TO SUPPORT THE INFRASTRUCTURE IN THE ORBITAL ENVIRONMENT
RONALD D. JONES (Phillips Petroleum Co., Robotics Group, Bartlesville, OK) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 57-59. refs
Copyright

Proposed uses for orbiting Space Shuttle External Tanks are examined. Consideration is given to the use of residual oxygen and hydrogen in spent External Tanks, using the tanks for Space Station waste disposal, linking the tanks with cables to make a gravity research facility, and outfitting a tank with solar arrays and an attitude control system to serve as a mounting platform for Shuttle launched instrument pallets or commercial systems. Other possible uses include tethering an external tank to a satellite and using the tanks' aluminum for constructing the future orbital infrastructure. R.B.

A90-29279#
WHAT IS AN OPTIMAL SPACECRAFT STRUCTURE?
H. R. GROOMS, C. F. DEBARRO, and S. PAYDARFAR (Rockwell International Corp., Downey, CA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 547-552. refs
(AIAA PAPER 90-1051) Copyright

A new method for evaluation of spacecraft structure design, based on a multidiscipline approach incorporating such criteria as operations, producibility, test requirements, operations schedule, in addition to weight and cost considerations, is presented. An overview of classical structural optimization methods is followed by examples of the application of the new approach. An objective function that incorporates issues important for the design evaluation of a spacecraft when it is actually being manufactured and flown, such as weight, full production and recurring cost, ease of fabrication and assembly, and build time, has been developed and applied. The application of the new method makes it possible to simultaneously consider and evaluate many aspects of a design. N.B.

A90-29701* BDM Corp., Albuquerque, NM.
SCIENCE AND ENGINEERING FOR SPACE - TECHNOLOGIES FROM SPACE 88
STEWART W. JOHNSON and JOHN P. WETZEL (BDM International, Inc., Albuquerque, NM) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 3, April 1990, p. 91-107. Research supported by BDM International, Inc. refs
(Contract NAG9-245)
Copyright

This paper highlights technology development for space exploration. It draws on the proceedings of Space 88, Engineering, Construction, and Operations in Space, which includes 125 papers providing in-depth discussions of space policy, extraterrestrial basing, space stations and orbiting structures. In the space station and orbiting structures (orbital facilities) section, papers discuss the engineering, construction, and operations of orbiting space systems. Papers in the extraterrestrial basing section deal with the engineering, construction, and operations challenges faced in development of bases and operations on extraterrestrial bodies. The special interest (interacting disciplines) section provides a discussion of challenges facing us in meeting needs for space power, life support, human factors, astronomy, education, and management. Author

N90-10129*# Teledyne Brown Engineering, Huntsville, AL.
SPACE STATION RT AND E UTILIZATION STUDY
P. K. WUNSCH and P. H. ANDERSON Sep. 1989 102 p
(Contract NAS1-18228)
(NASA-CR-181707; NAS 1.26:181707) Avail: NTIS HC A06/MF A01 CSCL 22/2

Descriptive information on a set of 241 mission concepts was reviewed to establish preliminary Space Station outfitting needs for technology development missions. The missions studied covered the full range of in-space technology development activities envisioned for early Space Station operations and included both pressurized volume and attached payload requirements. Equipment needs were compared with outfitting plans for the life sciences and microgravity user communities, and a number of potential outfitting additions were identified. Outfitting implementation was addressed by selecting a strawman mission complement for each of seven technical themes, by organizing the missions into flight scenarios, and by assessing the associated outfitting buildup for planning impacts. Author

N90-10907*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION FREEDOM: A FOOTHOLD ON THE FUTURE
1989 48 p Original contains color illustrations
(NASA-NP-107/10-88; NAS 1.83:107/10-88) Avail: NTIS HC A03/MF A01 CSCL 22/1

An overview of the Space Station Freedom is given. Its modules are discussed and illustrated along with its microgravity research facilities. These facilities include the advanced protein crystal growth facility, the containerless processing facility, a furnace facility, a combustion facility, and a fluid physics/dynamics facility. The topic of living in space is also addressed. K.C.D.

N90-11059# Boeing Aerospace Co., Huntsville, AL. Space Station Program WP01.
SDM CHALLENGES FOR SPACE STATION
EUGENE G. COWART *In* ESA, Spacecraft Structures and Mechanical Testing p 557-569 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

Various SDM (systems design methods) challenges in the design analysis of the Space Station are presented. The design areas considered include: thermal, load and stress analysis, mode shapes/dynamic excursions, atomic oxygen effects, radiation protection, acoustic drivers, and microgravity measurement. Design solutions and the rationale for their implementation are presented. The fabrication techniques for the various components used in the prototype module are described. ESA

N90-13449*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
REPORT OF THE ASILOMAR 3 LDR WORKSHOP
M. J. MAHONEY, ed. 15 Aug. 1988 153 p Workshop held in Asilomar, CA, 7-10 Sep. 1987
(NASA-CR-184656; JPL-PUBL-88-23; NAS 1.26:184656) Avail: NTIS HC A08/MF A01 CSCL 22/2

The conclusions and recommendations of the workshop held to study technology development issues critical to the Large Deployable Reflector (LDR) are summarized. LDR is to be a dedicated, orbiting, astronomical observatory, operating at wavelengths from 30 to 1000 microns, a spectral region where the Earth's atmosphere is almost completely opaque. Because it will have a large, segmented, passively cooled aperture, LDR addresses a wide range of technology areas. These include lightweight, low cost, structural composite reflector panels, primary support structures, wavefront sensing and adaptive optics, thermal background management, and integrated vibration and pointing control systems. The science objectives for LDR present instrument development challenges for coherent and direct arrayed detectors which can operate effectively at far infrared and submillimeter wavelengths, and for sub-Kelvin cryogenic systems.

N90-13450*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
INTRODUCTION TO THE REPORT OF THE ASILOMAR 3 LDR WORKSHOP
In its Report of the Asilomar 3 LDR Workshop p 1-49 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

The Large Deployable Reflector (LDR) is a system concept for a dedicated, orbiting, submillimeter, far infrared, astronomical observatory. The purpose of the 3rd conference was to review the latest system concepts for LDR, update the science requirements, and assess the status of the technology development that was recommended at Asilomar 2. The technology development assessment included ongoing work within NASA, the DOD, and various universities. Problem areas and technologies not being adequately addressed were to be identified and prioritized. In particular, the CSTI program in Sensors and Precision Segmented Reflectors was reviewed for appropriateness and progress relative to LDR technology needs. Author

N90-13492*# National Academy of Sciences - National Research Council, Washington, DC.
SPACE STATION ENGINEERING DESIGN ISSUES
DUANE T. MCRUER, BARRY W. BOEHM, DANIEL B. DEBRA, C. CORDELL GREEN, RICHARD C. HENRY, PAUL D. MAYCOCK, JOHN H. MCELROY, CHESTER M. PIERCE, THOMAS P. STAFFORD, LAURENCE R. YOUNG (Massachusetts Inst. of Tech., Cambridge.) et al. 1989 85 p Workshop presented in Irvine, CA, 7-11 Nov. 1988
(Contract NASW-4003)
(NASA-CR-185978; NAS 1.26:185978; LC-89-62778;
ISBN-0-309-04083-3) Avail: NTIS HC A05/MF A01 CSCL 22/2

Space Station Freedom topics addressed include: general design issues; issues related to utilization and operations; issues related to systems requirements and design; and management issues relevant to design. B.G.

N90-14275*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DESIGN CONSIDERATIONS FOR SPACE FLIGHT HARDWARE
DANIEL GLOVER Jan. 1990 23 p
(NASA-TM-102300; E-4979; NAS 1.15:102300) Avail: NTIS HC A03/MF A01 CSCL 22/1

The environmental and design constraints are reviewed along with some insight into the established design and quality assurance practices that apply to low earth orbit (LEO) space flight hardware. It is intended as an introduction for people unfamiliar with space flight considerations. Some basic data and a bibliography are included. Author

N90-15129# Air Force Systems Command, Wright-Patterson AFB, OH. Foreign Technology Div.
MANNED SPACECRAFT
A. N. PONOMAREV 14 Sep. 1989 375 p Transl. into ENGLISH of Pilotiruyemyye Kosmicheskiye Korabli (Moscow, USSR, Voyennoye), 1968 p 1-222
(AD-A214218; FTD-ID(RS)T-0592-89) Avail: NTIS HC A16/MF A02 CSCL 22/5

The book discusses the Soviet spacecraft of the type Vostok, Voskhod, and about American ships Mercury, Gemini, and Apollo, which are intended to be used for the delivery of man to the Moon; about future spacecraft for flight to other planets of solar system; orbital flight vehicles, intended for studying space, engines of space vehicles, are examined. The problems which appear with mastery/adoption of outer space, are briefly illuminated. In description of specific samples and schematics of foreign flight vehicles, their equipment, which relate to the theme in question, there are used data published in the foreign press. The data published in the open Soviet press are used for the examination of Soviet samples of space technology. GRA

N90-18437# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.).
SPACE ORIENTATION AND ORBITAL TECHNOLOGY [ORIENTIERUNGSRAHMEN ORBITALTECHNOLOGIEN]
May 1989 106 p In GERMAN
(ISBN-3-89100-015-4; ETN-90-96282) Avail: NTIS HC A06/MF A01

The results of research conducted by study groups, industry, high school students and the DLR are presented. The research presented is in the fields of automation and robotics, communication technologies, materials science and human factor engineering. Diagrams of various antennas, capsules, spacesuits, and lunar vehicles are shown. The problems specific to various areas of space research are described. Possible answers to these problems are presented. ESA

N90-19389*# National Aeronautics and Space Administration, Washington, DC.
AEROSPACE SAFETY ADVISORY PANEL Annual Report
Mar. 1989 105 p
(NASA-TM-101748; NAS 1.15:101748) Avail: NTIS HC A06/MF A01 CSCL 13/2

This report provides findings, conclusions and recommendations regarding the National Space Transportation System (NSTS), the Space Station Freedom Program (SSFP), aeronautical projects and other areas of NASA activities. The main focus of the Aerospace Safety Advisory Panel (ASAP) during 1988 has been monitoring and advising NASA and its contractors on the Space Transportation System (STS) recovery program. NASA efforts have restored the flight program with a much better management organization, safety and quality assurance organizations, and management communication system. The NASA National Space Transportation System (NSTS) organization in conjunction with its prime contractors should be encouraged to continue development and incorporation of appropriate design and operational improvements which will further reduce risk. The data from each Shuttle flight

should be used to determine if affordable design and/or operational improvements could further increase safety. The review of Critical Items (CILs), Failure Mode Effects and Analyses (FMEAs) and Hazard Analyses (HAs) after the Challenger accident has given the program a massive data base with which to establish a formal program with prioritized changes. K.C.D.

02

POLICIES AND INTERNATIONAL COOPERATION

Descriptions, interfaces and requirements of international payload systems, subsystems and modules considered as part of the space station system and other international space station activities such as Soviet Salyut.

A90-10291#
THE EUROPEAN LONG-TERM SPACE PLAN - A BASIS FOR AUTONOMY AND COOPERATION
REIMAR LUEST (ESA, Paris, France) ESA Bulletin (ISSN 0376-4265), no. 59, Aug. 1989, p. 11-16.
Copyright

The ESA resolution on the European Long-Term Space Plan is discussed. The boundary conditions and cornerstones of ESA programs are outlined. The goals and contents of the Long-Term Plan are examined, including the science, earth observation, telecommunications, and microgravity research programs. The plan includes the development of the Ariane-5 launcher, the Columbus program, the Hermes vehicle, and an orbital communications system. Plans for improvements to the ground infrastructure are given, including expansion of the European Space Operation Center, a control center for manned space laboratories, a Hermes Control center, an Astronaut Training Center, and a Control Center for the Data-Relay Satellite. R.B.

A90-10300#
ESA CONSULTANCY TO THE ITALIAN SPACE PROGRAMME
L. M. PALENZONA (ESA, Systems Engineering and Programmatics Dept., Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 59, Aug. 1989, p. 81-87.
Copyright

Italian space programs for which ESA has provided technical and managerial support are discussed. The programs include the Italsat telecommunications satellite, the Italian Research Interim Stage orbital propulsion system, the Tethered-Satellite System, the Lageos-II satellite, the SAX X-ray astronomy satellite, and the Deployable/Retrievable Boom System. The contractual agreement between ESA and the Italian Space Agency and the standards for system development and operation are examined. R.B.

A90-10694#
MULTISPECTROSCOPY AND LOW RESOLUTION SPECTROSCOPY
F. BERTOLA, G. CHINCARINI, E. TANZI, and G. ZAMORANI (Societa Astronomica Italiana, Annual Meeting, 32nd, Catania, Italy, May 4-7, 1988) Societa Astronomica Italiana, Memorie (ISSN 0037-8720), vol. 60, no. 1-2, 1989, p. 367-375.

In order to identify the direction of the Italian optical astronomy in the next few years, topics and research fields considered to be among the most scientifically productive are discussed. It is noted that particular attention is given to the Columbus, VLT, and intermediate-class telescope programs. Important problems can be solved, or better understood by taking advantage of the characteristics of large telescopes (larger collecting area and better resolution). In low-resolution spectroscopy, most of the research fields are part of a more general research area in which Italian astronomy is highly competitive: cosmological evolution of galaxies and quasars; luminosity functions of these objects at different frequencies; and clustering of galaxies. The relationship between the research programs and the required characteristics of a large telescope is investigated. In the field of low-resolution spectroscopy, a large fraction of the forseeable applications concern the study of faint objects. As far as participation in the Columbus project, the large 8 m telescope would be dedicated to infrared studies and to the spectroscopy of single objects or to multiobjects spectroscopy in relatively small fields, while the Italian 4 m telescope would be dedicated to imaging and to studies which require a large field, both in photometry and spectroscopy. C.E.

A90-11649
REPORT FROM BAIKONUR COSMODROME. II - SOVIETS UPGRADING SPACE TRANSPORTS TO SUPPORT MANNED STATION ACTIVITIES
JEFFREY M. LENOROVITZ Aviation Week and Space Technology (ISSN 0005-2175), vol. 131, Oct. 23, 1989, p. 49.
Copyright

The USSR's Progress and Soyuz spacecraft are undergoing design upgrading which will enhance their value as support vehicles for the Soviet manned space station program. The Soyuz TM spacecraft will be a modernized version of the basic vehicle incorporating automated docking guidance. The Progress M vehicle represents a significant improvement of this automatic cargo transport, with an increase in payload capacity to about 100 kg; it is expected to be used for the first time toward the end of 1990, in association with the newly reactivated Mir space station. O.C.

A90-13283#
FRENCH 'PLATFORM-RELATED' TECHNOLOGICAL EXPERIMENTS ON-BOARD SOVIET SPACE STATIONS
J. J. RUNAVOT (CNES, Toulouse, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-059) Copyright

Technological experiments conducted by French cosmonauts on board Soviet space stations in the context of the Aragatz program are reviewed, and experiments planned for 1992 flights are discussed. The development and in-flight performance of the unfurlable truss structure ERA are described, and failures that occurred during this experiment are summarized along wih the results of analyzing those failures. The Amadeus experiment is briefly addressed, as are experiments planned for 1992 flight aboard Soviet space stations and possible experiments farther in the future. C.D.

A90-13284*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPLOITING OPERATIONAL VEHICLES FOR IN-FLIGHT RESEARCH - SPACE SHUTTLE AND SPACE STATION FREEDOM
PAUL F. HOLLOWAY and ROGER A. BRECKENRIDGE (NASA, Langley Research Center, Hampton, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p. refs
(IAF PAPER 89-060) Copyright

Five Orbiter Experiments in which NASA's Langley Research Center has had significant involvement are described. These experiments are the Shuttle Infrared Leeside Temperature Sensing experiment, the Shuttle Upper Atmosphere Mass Spectrometer experiment, the High Resolution Accelerometer Package experiment, the Orbital Acceleration Research experiment, and the Space Station structural characterization experiment. The Shuttle Entry Air Data System is also described. C.D.

A90-13285#
SFU MISSION ONE EXPERIMENTS
MICHIHIRO NATORI and KYOICHI KURIKI (Institute of Space and Astronautical Science, Sagamihara, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-061) Copyright

Various aspects of the in-orbit experiments onboard the Space Flyer Unit (SFU) on its first flight are introduced. These include the Two-Dimensional High Voltage Solar Array Experiment, the

Infrared Telescope in Space, the Electric Propulsion Experiment, material and space biology experiments under microgravity, the Space Plasma Diagnostic Package, the Exposed Facility Flyer Unit, the Gradient Heating Furnace, Mirror Heating Furnace, and the Isothermal Heating Furnace. An outline of the SFU system is also given. C.D.

A90-13287#
THE JEM PROGRAM - START OF DEVELOPMENT
K. MATSUMOTO, N. SAITO, and M. SAITO (National Space Development Agency of Japan, Tokyo) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-067)

Recent progress of the JEM program and near-term future activities are described. The revised Japanese national space development policy is reviewed. The elements of the JEM PM(pressurized module)/ELM(experiment logistics module) pressurized section are shown, a program documentation tree is presented, and the JEM development schedule and the NASDA flight experiment schedule are depicted. Design reference missions and the Japanese crew operations schedule are outlined. C.D.

A90-13288#
SPACE STATION FREEDOM - A CANADIAN PERSPECTIVE
W. M. EVANS (Canadian Space Agency, Ottawa, Canada) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-068)

This paper descibes the objectives which Canada established for its participation in the Space Station and overviews the activities that are underway to pursue these objectives. The Canadian elements will predominantly involve the following functions of the Space Station: (1) the attached payload servicing (external), (2) the Space Station assembly, (3) the Space Station maintenance (external), (4) transportation on the Space Station, (5) the deployment and retrieval functions, and (6) EVA support. At present, Canada is in the process of developing the Mobile Servicing System (MSS) for the Space Station, which comprises both on-orbit elements, which include the Mobile Servicing Center (MSC), the MSS Maintenance Depot, and the Special Purpose Dexterious Manipulator (SPDM) and ground support facilities. Diagrams of the MSC and the SPDM are included. I.S.

A90-13291#
THE GERMAN SPACELAB MISSION D-2 - AN INTERNATIONAL MISSION AND ANOTHER STEP TOWARDS COLUMBUS
HAUKE DODECK (DLR, Cologne, Federal Republic of Germany) and GUENTHER BRANDT (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 13 p. refs
(IAF PAPER 89-072) Copyright

The Spacelab mission D-2, which is under German management, is discussed. The mission goals, which were reoriented following the Shuttle accident, are outlined. The mission parameters and payload composition are also outlined, including both the microgravity research and observational experiments. The international participation and industrialization aspects of the D-2 mission are briefly discussed, as well as the mission support to users in the field of microgravity research. Four new technology examples applied in the D-2 payload instrumentation and infrastructure design are discussed: (1) the measurement of micro-g environment, (2) miniaturized CCD image sensors, (3) 3-D image sensors in hybrid technology, and (4) the application of high density programmable gate arrays. Finally, the D-2 integration and data transfer concepts are examined. S.A.V.

A90-13298#
EQUIPMENT EXCHANGE SYSTEM FOR JAPANESE EXPERIMENT MODULE OF SPACE STATION
GAKUMEI HATTORI (National Space Development Agency of Japan, Tokyo), FUMIAKI SANO, KATSUMI FUSEGI, SHINICHI MORI, YOSHITERU YAMAMOTO (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-082) Copyright

A preliminary design study established the baseline configuration of the equipment exchange system and equipment exchange unit (EEU) for the Japanese experiment module of the Space Station (Phase B). The EEU research and development project started in July 1985. In 1986, preliminary tests were carried out to study the feasibility of the EEU concept and operation of resource connectors used in the EUU in a vacuum environment. The EUU's technical feasibility and basic performance were verified by the model test results. Various test will proceed to solve the technical issues which are already identified (Phase C/D). C.E.

A90-13299#
LONG CYCLE PRESSURIZED LOGISTICS MODULE - AN ITALIAN CONTRIBUTION TO THE SPACE STATION FREEDOM LOGISTICS SCENARIO
ERNESTO VALLERANI, LUCIANO BASILE (Aeritalia S.p.A., Turin, Italy), and GIOVANNI RUM (Agenzia Spaziale Italiana, Rome, Italy) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p.
(IAF PAPER 89-083)

Aeritalia conducted a study on the concept of the Long Cycle Pressurized Logistics Module (LCPLM) with the following goals: review the Space Station Freedom logistics scenario; identify key element functions; and propose candidate design solutions. Results indicated that the LCPLM concept should be derived from the Columbus pressurized module design solution and should be able to provide: (1) greater storage capacity for the Station; (2) staging for required but seldom used tools and support facilities; (3) skipped cycle supply storage; and (4) the possibility of using a flexible storage volume for tools, facilities, and spares combined with a dedicated area for work-around activities to extend/optimize equipment utilization. C.E.

A90-13309*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION FREEDOM - ITS ROLE AS AN INTERNATIONAL RESEARCH LABORATORY AND OBSERVATORY
CAROLYN GRINER (NASA, Office of Space Station, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p.
(IAF PAPER 89-099) Copyright

The international partnership agreed to just a year ago among the United States, Canada, Japan and nations participating in the European Space Agency bring us one giant leap closer to unprecedented opportunities in space science and observation. While the driving force of Space Station Freedom has been and continues to be an expansion of human presence in space, the goals of the program go far beyond support of exploration. Integral to the international program is research, conducted on four spacecraft, centering on laboratory and observatory experiments. Research onboard the station's manned base, two polar orbiting observation platforms and the Columbus Free Flying Laboratory will offer research opportunities never available before in life sciences, materials sciences, earth observation, astrophysics and planetary sciences for a wide variety of users over a period of three decades. As such, Space Station Freedom, the world's largest and most useful facility in space, is expected to stimulate advanced technologies, promote the commercial use of space, and increase international cooperation in the peaceful utilization of outer space. Author

A90-13310#
PREPARING FOR CANADIAN USE OF THE SPACE STATION
P. E. KUMAR, M. Z. SAGHIR, and A. L. VANKOUGHNETT (Canadian Space Agency, Ottawa, Canada) IAF, International

Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p.
(IAF PAPER 89-100) Copyright

Canada is a partner in the Space Station 'Freedom' Program, spear-headed by the United States, and will be supplying the Mobile Servicing System and a Special Purpose Dexterous Manipulator for use on the manned base. In return Canada has the rights to 3 percent of all station resources for its User Community. Unlike the other partners, Canada's budgets for its User Community are extremely modest - $75 million for the User Development Program between 1986 and the year 2000 and, an as yet unapproved funding requirement for utilization of the Space Station. This paper provides an overview of the possible utilization scenarios which the Canadian Program will support starting in the 1993 time-frame. Author

A90-13311#
UTILIZATION STUDY ON JEM UNDER THE INTERNATIONAL UTILIZATION FRAMEWORK
YOSHINORI FUJIMORI, KIYOSHI HIGUCHI, KIWAO SHIBUKAWA, SHINICHI YODA (National Space Development Agency of Japan, Tokyo), HIROAKI HASHIMOTO (Japan Space Utilization Promotion Center, Tokyo) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-101) Copyright

A reference mission study was conducted and a mission set was developed for JEM (Japanese Experiment Module) utilization. The established mission set covers six disciplines required by the Japanese users, and satisfies the resources allocated to experiments on the JEM. The reference mission set was utilized to (1) identify experiment equipments for implementing the missions, (2) specify hardware used for experiment themes, (3) clarify functional requirements of the hardware, and (4) conduct resource analysis, payload layout and payload/system interface analyses. In this study, the international utilization activities have been closely reviewed and reflected. Author

A90-13312*# National Aeronautics and Space Administration, Washington, DC.
USING SPACE FOR TECHNOLOGY DEVELOPMENT - PLANNING FOR THE SPACE STATION ERA
JUDITH H. AMBRUS, LANA M. COUCH, ROBERT R. ROSEN (NASA, Office of Aeronautics and Space Technology, Washington, DC), and CHARLES F. GARTRELL (General Research Corp., McLean, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 13 p. refs
(IAF PAPER 89-102) Copyright

Experience with the Shuttle and free-flying satellites as technology test-beds has shown the feasibility and desirability of using space assets as a facility for technology development. Thus, by the time the Space Station era will have arrived, the technologist will be ready for an accessible engineering facility in space. As the 21st century is approached, it is expected that virtually every flight to the Space Station Freedom will be required to carry one or more research, technology, and engineering experiments. The experiments planned will utilize both the pressurized volume, and the external payload attachment facilities. A unique, but extremely important, class of experiments will use the Space Station itself as an experimental vehicle. Based upon recent examination of possible Space Station Freedom assembly sequences, technology payloads may well utilize 20-30 percent of available resources. Author

A90-13313#
WHAT PREPARATORY PROGRAMS FOR THE INTERNATIONAL SPACE STATION UTILIZATION? EMPHASIS ON THE FRENCH PROGRAM
ALAIN ESTERLE and RICHARD BONNEVILLE (CNES, Paris, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-103)

A comprehensive preparatory program for the utilization of the International Space Station (ISS), developed by the French Space Agency (CNES), is briefly reviewed. In particular, attention is given to the instrumentation, crew, user's interface, operation strategy, and characteristics of the existing space systems. The flight program proposed by CNES is discussed with reference to manned flights, microgravity experiments, U.S. Shuttle, MIR missions, and retrievable capsules. V.L.

A90-13314*# National Aeronautics and Space Administration, Washington, DC.
A SMALL AND RAPID RESPONSE RESEARCH PROGRAM FOR SPACE STATION FREEDOM
W. VERNON JONES (NASA, Space Physics Div., Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-104) Copyright

A small and rapid response research capability is being studied as a potential means of accommodating small, low cost instruments on Space Station Freedom. The objective is to have an orbital analog to the balloon and sounding rocket programs, whose rapid turn-around and relatively low cost encourage participation by small research groups involving young scientists. The program's most important single characteristic would be the frequency of flight opportunities. The goal is to achieve a change-out rate of about 15 experiments per year in an international program committed to standardization of canisters, interfaces, carriers, and all Space Shuttle-Space Station procedures. Although not yet approved, this program is imbedded in the plans being developed for scientific use of the Space Station. Author

A90-13315#
ACTIVITIES AND PLANNING FOR COLUMBUS UTILIZATION PREPARATION
H. ANTON, H. BINNENBRUCK, and F. UNZ (DLR, Cologne, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-105) Copyright

The joint effort by ESA and the nine Columbus member states to develop concepts for a User Support Organization (USO) are reviewed. This task includes the development of functional and technical specifications for user centers, description of their organizational interrelations, the interface to the Space Station In-Orbit Infrastructure, and the development of an implementation plan for the USO. The German Microgravity Program to be implemented on Columbus is outlined. V.L.

A90-13344#
THE PROPOSED ITALIAN CONTRIBUTION TO THE POLAR PLATFORMS FOR EARTH OBSERVATION
L. GUERRIERO (Agenzia Spaziale Italiana, Rome, Italy) and B. BIZZARRI (Italian Meteorological Service, Rome, Italy) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-157) Copyright

Italian plans in contributing to the future polar platforms for earth observation are reported. The plans discussed include an advanced microwave imaging radiometer, an IR spectrometer for atmospheric sounding, and contributions to the NASA SAR and spectroscopy of the atmosphere using FIR emission. Initiatives related to second-generation Meteosat and the development of ground segment activities are also mentioned. S.A.V.

A90-13350*# American Inst. of Aeronautics and Astronautics, Washington, DC.
THE NEXT 40 YEARS IN SPACE STANDARDS
H. J. SHEETZ (AIAA, Washington, DC), CHUN CAO (China Astronautics Standards Institute, Beijing, People's Republic of China), and M. S. REID (JPL, Pasadena, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(IAF PAPER 89-169) Copyright

Methods used in producing, introducing, and using standards for civilian space research are examined, with special consideration given to the recommendations of the Consultative Committee for

Space Data Systems (CCSDS) as an example of a set of standards best coordinated through the International Standard Organization (ISO). The paper uses an example of earth-observation data as a CCSDS application for an international coordination effort within the ISO and describes progress in achieving this objective. Lists of CCDSD member agencies and CCSDS observer agencies are included. I.S.

A90-13403#
REVIEW OF THE GAAS SOLAR CELL ITALIAN NATIONAL PROGRAMME
F. SVELTO (Agenzia Spaziale Italiana, Rome, Italy), C. FLORES, F. PALETTA, D. PASSONI (CISE S.p.A., Segrate, Italy), C. SIGNORINI (Fabbrica Italiana Apparecchiature Radioelettriche S.p.A., Milan, Italy) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-248) Copyright

This paper reviews the activities performed by CISE and Fiar in the last six years under the aegis of the Italian Space Agency (ASI), in establishing a reliable and qualified technology for GaAs space solar cells and modules. The aim of this industrial initiative is to produce advanced space solar cells for the future National Satellites and to create a European capability. Details are given concerning some recent technological achievements: 4 x 4 sq cm, 18.4 percent AMO LPE solar cells, 2 x 2 and 2 x 4 sq cm MOVPE solar cells approaching 20 percent AMO of efficiency, and assembling of GaAs flight panels for in-orbit demonstration programs. Author

A90-13712#
MAJOR SCIENCE MISSIONS
REIMAR LUEST (ESA, Paris, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p.
(IAF PAPER 89-750)

Prospects for major science missions in the International Space Year context and beyond are discussed. Special attention is given to the 'Mission to Planet Earth', a continuous study of the earth from space using data obtained by the ERS, SPOT, Radarsat, and Landsat satellites by the earth scientists, particularly by climatologists and oceanographers. The Mission to Planet Earth should increase the public awareness of the contribution that space observations can make to the formidable task of understanding the earth system, and should be a first step in making the earth sciences community as strong and well organized as the space scientists are today. I.S.

A90-13714#
NEAR-EARTH ORBIT RESEARCH
IU. P. SEMENOV, V. V. RIUMIN, and M. IU. BELIAEV (Nauchno-Proizvodstvennoe Ob'edinenie Energiia, USSR) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. refs
(IAF PAPER 89-752) Copyright

This paper discusses the near-earth-orbit research programs carried out by the Soviet Union, beginning with the first manned mission and including research carried out aboard the Mir orbital station. Many of these programs, which include programs in the fields of astronomy, geophysics, the earth's natural resources exploration, space technology, and medicine and biology, involve international cooperation. The paper briefly describes the major stages and records obtained while performing these investigations I.S.

A90-13732#
EUROPEAN INTEGRATION AND SPACE COMMERCIALIZATION - AN AMERICAN PERSPECTIVE
MICHAEL POTTER and DEREK LANG IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p. refs
(IAF PAPER ST-89-020) Copyright

Space commercialization in Europe is discussed, focusing on the effects that the elimination of trade barriers within the European Community in 1992 might have on the European aerospace industry. Current European space activities and plans for future programs are reviewed. The relationship between national space programs and the ESA is examined, focusing on the development of European autonomy in space. Consideration is given to the impact of European integration and autonomy in space on international competition in commercial space activities. R.B.

A90-13733#
THE NEXT 40 YEARS IN SPACE
THOMAS O. PAINE IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989, Paper. 19 p. refs
Copyright

Plans for the next forty years of U.S. space activities are reviewed. The history of space achievements since 1957 is outlined. Plans for robotic exploration of each planet in the solar system, asteroids, comets, and the interstellar space beyond the heliopause are discussed. Consideration is given NASA strategy for Mars exploration using orbiting spaceports and a lunar base. An extensive bibliography on the history of astronautical technology and missions is included. R.B.

A90-15885
AN EXPANDED SPACE INFRASTRUCTURE
C. M. HEMPSELL (British Aerospace /Space Systems/, Ltd., Stevenage, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Nov. 1989, p. 521-532. refs
Copyright

The policy options open to the UK for space infrastructure development are reviewed. Timescale considerations, long-term space infrastructure goals, and cost considerations are discussed. The policy options are compared with U.S. space policy. It is suggested that British space policy should stimulate rapid industrialization of space and construction of facilities in earth orbit, on the moon, on Mars, and in the Jovian system. R.B.

A90-16000* National Aeronautics and Space Administration, Washington, DC.
TECHNOLOGY AND THE CIVIL FUTURE IN SPACE; PROCEEDINGS OF THE TWENTY-SIXTH GODDARD MEMORIAL SYMPOSIUM, GREENBELT, MD, MAR. 16-18, 1988
LEONARD A. HARRIS, ED. (NASA, Office of Aeronautics and Space Technology, Washington, DC) Symposium sponsored by AAS. San Diego, CA, Univelt, Inc. (Science and Technology Series. Volume 73), 1989, 246 p. No individual items are abstracted in this volume.
Copyright

Reviews, reports, lectures, and panel discussions on technological aspects of current and planned NASA space missions are presented. Included are the viewpoints of NASA, the U.S. aerospace industry, potential commercial users of the civil space infrastructure, and university scientists and engineers. Sections are devoted to technology policy and plans, technology needs, technology directions, and the Astronautical Society student program. T.K.

A90-16048
THE GAGARIN SCIENTIFIC LECTURES ON ASTRONAUTICS AND AERONAUTICS, 1988 [GAGARINSKIE NAUCHNYE CHTENIIA PO KOSMONAVTIKE I AVIATSII 1988 G.]
V. S. AVDUEVSKII, ED. Moscow, Izdatel'stvo Nauka, 1989, 280 p. In Russian. No individual items are abstracted in this volume.
Copyright

Papers given at the 1988 Gagarin lectures are presented. Particular attention is given to the longest manned orbital flight (326 days) on the Mir/Kvant/Soyuz TM-2 complex (1987); the investigation and protection of the ozone layer; radiative and conductive heat transfer in high-porosity composite materials; and the aerodynamic interaction of bodies in a a steady supersonic flow. Consideration is also given to the structure of a viscous shock layer near a blunt body in the case of the distributed injection of cold gas; the use of the gyroscopic properties of rocket engines

to control their structural vibrations; and a systems analysis of the feasibility of organizing a program for the study of Mars in the 1990-2000 time frame. B.J.

A90-16653
DECISIONS ON SPACE INITIATIVES
RADFORD BYERLY, JR. (Colorado, University, Boulder) IN: The case for Mars III: Strategies for exploration - General interest and overview. San Diego, CA, Univelt, Inc., 1989, p. 19-25. refs (AAS PAPER 87-177) Copyright

Issues related to the process of making decisions on major space initiatives are discussed. The decision-making processes for the Apollo, Space Shuttle, and Space Station programs are reviewed. Consideration is given to current political support for the Space Station and the question of whether the moon or Mars should be the next goal of the space program. R.B.

A90-22277
PLANS FOR THE UK GROUND SEGMENT IN A EUROPEAN CONTEXT
D. W. S. LODGE (British National Space Centre, London, England) IN: Spacecraft ground operations and data handling; Proceedings of the Conference, London, England, Feb. 23, 1988. London, Royal Aeronautical Society, 1988, p. 1.1-1.10. refs
Copyright

The managerial tasks facing UK planners with respect to UK participation in the ground segment activities of Columbus and ERS-1, as well as in the accommodation of Canadian participation in Radarsat and Anglo-Norwegian common interest in a Polar Platform spacecraft ground segment, are presently discussed in the context of ministerial-level decisions being made by ESA member states. Attention is given to the status of existing ground facilities in the UK, namely Lasham, Oakhanger, and the Science and Engineering Research Council's Rutherford Appleton Laboratory. O.C.

A90-24760
SPACE: NATIONAL PROGRAMS AND INTERNATIONAL COOPERATION
WAYNE C. THOMPSON, ED. (Virginia Military Institute, Lexington) and STEVEN W. GUERRIER, ED. (James Madison University, Harrisonburg, VA) Boulder, CO, Westview Press, 1989, 213 p. For individual items see A90-24761 to A90-24772.
Copyright

Papers on national and international programs in space are presented, covering topics such as U.S. launch capability, the Space Station, NASA and international cooperation, and the national space programs of West Germany, Canada, France, China, Japan, and Indonesia. Papers on the scientific and commercial uses of space are given, including papers on medical challenges to human activity in space, conducting business and scientific experiments in space, glass science in extraterrestrial environments, and future trends in space commercialization. Also, papers are presented on the early history of military activity in space, the history of the Apollo program, the U.S. manned space program, the role of the military in space commercialization, and other space activities of the military. R.B.

A90-24762
WEST GERMANY'S SPACE PROGRAM AND THE EUROPEAN EFFORT
WAYNE C. THOMPSON (Virginia Military Institute, Lexington) IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 33-62. Research supported by the Virginia Military Institute. refs
Copyright

The space program of the FRG is examined, emphasizing the role of the FRG in European cooperative space endeavors. The administration of the West German space program and West German contributions to the ESA are described. The European manned space program is discussed, focusing on the Hermes program and the Columbus module. The development of the Saenger space transport system is noted. Also, political issues related to the German space program are reviewed. R.B.

A90-24764
THE CANADIAN SPACE PROGRAM
WILLIAM F. COCKBURN (Embassy of Canada, Washington, DC) IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 79-90.
Copyright

An historical overview of the Canadian space program is given, including Canadian remote sensing activities, the Canadian role in Cospas/Sarsat, the Canadarm developed for the Space Shuttle, and the Canadian astronaut program. Current programs are described, focusing on the Msat Mobile Satellite program, Canadian participation in the Space Station, and the construction of Radarsat, a polar-orbiting remote sensing satellite. R.B.

A90-24765
ASIA IN SPACE - THE PROGRAMS OF CHINA, JAPAN, AND INDONESIA
PATRICK M. MAYERCHAK (Virginia Military Institute, Lexington) IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 91-98. refs
Copyright

The space programs of China, Japan, and Indonesia are reviewed. Chinese satellites, the Long March rocket launcher series, and Chinese commercial space ventures are discussed. The Japanese programs considered include the H-II launch vehicles, the Marine Observation Satellite, Spacelab projects, and astronaut training. The economic aspects of Japanese space activities are noted. Consideration is given to the Indonesian Palapa communications satellites, the development of an Indonesian aerospace technology center, and the Tropical Earth Resources Technology Satellite. R.B.

A90-24767
THE NEED FOR MORE INTERNATIONAL COOPERATION IN SPACE
JOHN RHEA IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 111-114.
Copyright

Issues related to international cooperation in space endeavors are reviewed. The development of separate national space programs are compared. The benefits of international cooperation for the U.S. space program are outlined. The role of international cooperation in a manned mission to Mars and the construction of the Space Station are briefly discussed. R.B.

A90-24794#
POLITICAL, ECONOMIC, AND LEGAL CONSIDERATIONS IN INTERNATIONAL COOPERATION ON A LUNAR BASE
RONALD S. MCCANDLESS (U.S. Navy, Naval Surface Warfare Center, Dahlgren, VA) and LORI B. GARVER (National Space Society, Washington, DC) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 173-177.
Copyright

An international lunar base consisting primarily of Space Station Freedom partners is recommended as a goal. Political and economic issues are examined; key aspects of a future legal regime regarding lunar resource use is given. Author

A90-24796#
FUNDING THE HIGH FRONTIER - OLD LESSONS WE MUST ONCE AGAIN LEARN
JAMES E. DUNSTAN (Haley, Bader, and Potts, Washington, DC) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 183-190. refs
Copyright

Consideration is given to possible ways of lowering the cost of commercial space endeavors. It is suggested that there are three ways of reducing costs: (1) the use of the U.S. tax code to encourage private investment in space, (2) the use of NASA to create government/industry cooperatives, and (3) generating short term revenues by commercializing space enterprises. Also, a model for a space consortium between NASA, academia, and private industry is presented. R.B.

A90-28903
INTERNATIONAL PARTICIPATION IN AOS STANDARDS DEVELOPMENT
KLAUS G. LENHART (ESA, European Space Operations Centre, Darmstadt, Federal Republic of Germany) IN: ITC/USA/'89; *Proceedings of the International Telemetering Conference*, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 865-870.
Copyright
Some of the international missions which will cooperate in the Advanced Orbiting System (AOS) Space Station Freedom project are described. The background for the international participation in the AOS recommendation development is described. The main functions and goals of the AOS and the Consultative Committee for Space Data Systems are summarized. C.D.

A90-30900
INTERNATIONAL LAW REGARDING OUTER SPACE - AN OVERVIEW
JOSEPH A. BOSCO (John J. Kennelly and Associates, Chicago, IL) *Journal of Air Law and Commerce* (ISSN 0021-8642), vol. 55, Spring 1990, p. 609-651. refs
Copyright
The history and current status of international space law are reveiwed. The treaties adopted by the UN Committee on the Peaceful Uses of Outer Space are examined, including the Outer Space Treaty of 1967, the Rescue Agreement (1968), the Liability Convention (1972), the Registration Convention (1975), and the Moon Treaty (1979). International telecommunications law and the legal aspects of the militarization of outer space are discussed in detail. Issues that may be important in future international space law are considered, including the aerospace vehicle, space debris, and nuclear contamination of space. R.B.

N90-10905# Joint Publications Research Service, Arlington, VA.
USSR AND INTERNATIONAL COOPERATION IN SPACE
S. A. NIKITIN *In its* JPRS Report: Science and Technology. USSR: Space p 64-69 28 Jun. 1989 Transl. into ENGLISH from Novoye v Zhizni, Nauke, Tekhnike: Seriya Kosmonavtika, Astronomiya (Moscow, USSR), No. 12, Dec. 1988 p 32-47
Copyright Avail: NTIS HC A06/MF A01
In 1988 cooperation was successfully pursued in the framework of the multilateral program Intercosmos with nine socialist countries (Bulgaria, Hungary, Vietnam, East Germany, the Republic of Cuba, Mongolia, Poland, Rumania, Czechoslovakia) and on a bilateral basis with Austria, Great Britain, India, the United States, Finland, France, West Germany, Switzerland, Sweden and other nations, as well as the European Space Agency. Joint projects in the Intercosmos program are being carried out in the area of space physics (including space materials science), space meteorology, communications, space biology and medicine, as well as remote sensing of the Earth for purposes of studying its natural resources. Joint projects in space on a bilaterial basis with the aforementioned countries have covered practically all main areas of cosmonautics. In 1988 the main events in the international cooperation of the USSR in space were: international experiments aboard the Mir orbital scientific research complex, flights of Soviet-Bulgarian and Soviet-Afghan international crews, the launching of two unmanned interplanetary Phobos vehicles, and the launching of the Indian satellite IRS-1A on a commericial basis. K.C.D.

N90-10908# European Office of Aerospace Research and Development, London (England).
AERITALIA SPACE SYSTEMS GROUP, TURIN, ITALY
VINCENT DONLAN Feb. 1989 13 p
(EOARD-LR-89-041; AV-235-4376) Avail: NTIS HC A03/MF A01
Aeritalia has been involved in European space programs since the early 1960's. Space activities grew to the point that in 1984 Aeritalia established a separate Space Systems Group (SSG), located in Turin. Today, SSG is involved in dozens of projects, some of them jointly with NASA and U.S. aerospace companies. Here, several of the major projects, such as the Tethered Satellite system, HIPPARCOS, Columbus Pressurized Module, Italian Research Interim Stage, and others are briefly described. Author

N90-13282# Committee on Appropriations (U.S. House).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
In its Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Bill, 1990 p 60-67 1989
Avail: Document Room, House of Representatives, Washington, DC 20515 HC free
The House budget recommendations are presented for appropriations for the National Aeronautics and Space Administration for the fiscal year 1990. The recommendations cover research and development, construction of facilities, space flight and communications, and research and program management. B.G.

N90-13283# Committee on Science, Space and Technology (U.S. House).
FISCAL YEAR 1990 AUTHORIZATION REQUEST AND BUDGET ESTIMATES FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
1989 367 p
(GPO-96-945) Avail: Document Room, House of Representatives, Washington, D.C. 20515 HC free; SOD HC $11.00 as 552-070-06558-0
A draft bill was submitted to the subcommittee on the House Committee on Science, Space, and Technology to authorize appropriations to the National Aeronautics and Space Administration for research and development; space flight, control, and data communications; construction of facilities; and research and program management. B.G.

N90-13285# Committee on Science, Space and Technology (U.S. House).
THE 1990 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION
1989 1287 p
(GPO-98-466) Avail: Subcommittee on Space Science and Applications, House of Representatives, Washington, DC 20515 HC free; SOD HC $31.00 as 552-070-068-50-3
Hearings before a subcommittee of the House Committee on Science, Space, and Technology are presented along with the budget estimates for the National Aeronautics and Space Administration for the fiscal year 1990. All written testimony and submittals for the record are also included. The budget estimates provide a detailed outline of budgetary information and justifications for research and development, construction of facilities, space flight and communications, and research and program management. B.G.

N90-13287# Congress of the United States, Washington, DC.
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
In its Department of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations Act, 1990 p 67-76 28 Sep. 1989
Avail: Document Room, House of Representatives, Washington, DC 20515 HC free
House committee recommendations for appropriations for the National Aeronautics and Space Administration for the fiscal year ending September 30, 1990 are presented. The budget recommendations provide an outline of budgetary information for research and development, construction of facilities, space flight

and communications, and research and program management.
B.G.

N90-13288# Committee on Commerce, Science, and Transportation (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, FISCAL YEAR 1990
Washington GPO 3 Jan. 1989 32 p A bill, S.916, referred to the Committee on Commerce, Science and Transportation, 101st Congress, 1st Session, 3 May 1989
(S-REPT-101-157) Avail: Document Room, Senate, Washington, DC 20510 HC free

A bill was presented to the Senate to authorize appropriations to the National Aeronautics and Space Administration for research and development, space flight, control and data communications, construction of facilities, and research and program management, and for other purposes. B.G.

N90-13289# Committee on Commerce, Science, and Transportation (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, FISCAL YEAR 1990
Washington GPO 1989 70 p Report on S.916 presented to the Committee on Commerce, Science and Transportation, 101st Congress, 1st Session, 3 Oct. 1989
(S-REPT-101-157; GPO-22-382) Avail: Document Room, Senate, Washington, DC 20510 HC free

The report on the appropriations to the National Aeronautics and Space Administration by the Committee on Commerce, Science, and Transportation was submitted to the Senate. The budgetary estimates provide a detailed outline of budgetary information and justifications for research and development, construction of facilities, space flight and communications, and research and program management. B.G.

N90-13493*# National Aeronautics and Space Administration, Washington, DC.
SCIENCE AND APPLICATIONS ON THE SPACE STATION: A STRATEGIC VISION
Mar. 1988 18 p
(NASA-TM-101863; NAS 1.15:101863) Avail: NTIS HC A03/MF A01 CSCL 22/2

The central themes relating to science and applications on the Space Station for fiscal year 1989 are discussed. Materials science research is proposed in a wide variety of subfields including protein crystal growth, metallurgy, and properties of fluids. Also proposed are the U.S. Polar Platform, an Extended Duration Crew Operations Project, and a long-range Space Biology Research Project to investigate plant and animal physiology, gravitational biology, life support systems, and exobiology. The exterior of the Space Station will provide attachment points for payloads to study subjects such as the earth and its environment, the sun, other bodies in the solar system, and cosmic objects. Examples of such attached payloads are given. They include a plasma interaction monitoring system, observation of solar features and properties, studies of particle radiation from the sun, cosmic dust collection and analysis, surveys of various cosmic and solar rays, measurements of rainfall and wind and the study of global changes on earth. J.P.S.

N90-14148# Committee on Commerce, Science, and Transportation (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MULTIYEAR AUTHORIZATION ACT OF 1989
1989 50 p An act, H.R. 1759, referred to the Committee on Commerce, Science and Transportation, 101st Congress, 1st Session, 25 Sep. 1989
Avail: Document Room, House of Representatives, Washington, D.C. 20515 HC free

A bill was submitted to the Senate of the United States to authorize appropriations to the National Aeronautics and Space Administration (NASA) for research and development, space flight, control and data communications, construction of facilities, and research and program management, and for other purposes.
B.G.

N90-14149# Committee on Commerce, Science, and Transportation (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION
1989 594 p
(S-HRG-101-348; GPO-99-657) Avail: Subcommittee on Science, Technology, and Space, Senate, Washington, D.C. 20510 HC free; SOD HC $17.00 as 552-070-073-40-0

Hearings before a subcommittee of the Senate Commitee on Commerce, Science, and Transportation are presented for the National Aeronautics and Space Administration budget requests for FY 1990 and FY 1991. All written testimony and submittals for the record are also included. The budget estimates provide a detailed outline of budetary information and justifications for reserach and development, construction of facilities, space flight and communications, and research and program management.
B.G.

N90-14248# Joint Publications Research Service, Arlington, VA.
JPRS REPORT: SCIENCE AND TECHNOLOGY. USSR: SPACE. SOVIET SPACE PROGRAM TO THE YEAR 2000
YURIY IVANOVICH ZAYTSEV 30 Aug. 1989 28 p Transl. into ENGLISH of Kosmicheskaya Programma SSSR do 2000 Goda (Moscow, USSR), p 3-64
(JPRS-USP-89-008) Avail: NTIS HC A03/MF A01

The principal space research projects planned by the Soviet Union for the period up to the year 2000 are presented. The range of tasks can be divided into several major fields. One of them is the space nearest earth. This field includes studies of the upper atmosphere, the radiation belts, the earth's magnetosphere, the interplanetary medium, and variations in their parameters as a function of solar activity. In addition to near space, studies will be conducted of the solar system including the moon, Venus, Mars, its moon Phobos, and other celestial objects. In this area, the advantages of international cooperation are pointed out with the study of Halley's Comet cited as an example. Deep space and the development of extra-atmospheric telescopes and astronomical instruments are also of interest to the Soviets. Studies will include X-radiation, gamma astronomy, and radio astronomy. Finally, the Soviet Union plans to continue its study of how to make man at home in space. This will include new materials, new modules, and further expansion of the Mir space station. J.P.S.

N90-15966# Congress of the United States, Washington, DC.
ROUND TRIP TO ORBIT. HUMAN SPACEFLIGHT ALTERNATIVES: SPECIAL REPORT
1989 127 p
(OTA-ISC-419; LC-89-600744) Avail: NTIS HC A07/MF A01

Technologies and systems are examined for transporting astronauts and scientists to and from low-earth orbit, and some of the policy choices that Congress faces in this critical aspect of the U.S. Government's space program are explained. A variety of ways are analyzed to make the Space Shuttle system safer and more reliable. It also explores several proposed systems to replace the Shuttle early in the next century, and examines proposals for a Space Station crew escape system. Finally, the National Aerospace Plane is discussed, and it is compared with other potential future launch systems. Cargo-only launch vehicles are not examined except insofar as their use may affect the need for crew-carrying launchers. Author

N90-15989# European Space Agency, Paris (France).
COLUMBUS: A USER'S INTRODUCTION
JOCELYNE LANDEAU, ed. and NORMAN LONGDON, ed. Sep. 1989 33 p Original contains color illustrations
(ESA-BR-62; ISBN-92-9092-027-0; ISSN-0250-1589; ETN-90-96206) Copyright Avail: NTIS HC A03/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 30 Dutch guilders

Basic information about Columbus elements and their

operations are given. Columbus is the program by which ESA participates in the international space station Freedom, which is based on a manned core station. The station is planned to be launched and assembled from 1995 onwards. The main objectives of the Columbus program are to: provide an in-orbit and a ground infrastructure which are compatible with the needs of European and international users from the mid-1990s onwards; develop further European capabilities in manned spaceflight: co-operate with the U.S. and other partners in an international space station in which Columbus is Europe's contribution; ensure the development of a European capability; ensure that the technological research and key technological development required for manned space flight and for the in-orbit operations, both manned and automatic, are carried out. The possibilities that Columbus offers to the users, and the user support access to Columbus, are considered. ESA

N90-16706# European Space Agency, Paris (France).
FOCUS 88: THE ACTIVITIES OF THE EUROPEAN SPACE AGENCY Annual Report, 1988
VALERIE DAVID, comp. and NORMAN LONGDON, comp. Sep. 1989 60 p Original contains color illustrations
(ESA-BR-43; ISSN-0250-1589; ETN-90-96204) Copyright Avail: NTIS HC A04/MF A01

The 1988 activities of ESA are summarized. The research programs are carried out in the following areas: solar-terrestrial physics, Earth observations, microgravity, telecommunications, space transportation systems and space stations and platforms. The research activities are split into three parts: the generation of new technology needed for future missions; the program which demonstrates the flight worthiness of the systems; and the program providing in-orbit demonstration opportunities. The support areas, including satellite operations, ground facilities, technical infrastructure, data handling and archiving, are considered. ESA

N90-16783# Bundesministerium fuer Forschung und Technologie, Bonn (Germany, F.R.).
KEYNOTE ADDRESS
HEINZ RIESENHUBER *In* ESA, Progress in Space Transportation p 7-8 Aug. 1989
Copyright Avail: NTIS HC A22/MF A03

The success of the Ariane space venture is discussed. Plans for Ariane 4 and 5 are outlined. The importance of the Hermes space shuttle and of the Columbus space station is stressed. The specific plans of the Federal Republic of Germany in meeting these aerospace challenges is outlined. ESA

N90-16784# European Space Agency, Paris (France).
THE EUROPEAN LONG-TERM SPACE PLAN: A BASIS FOR AUTONOMY AND COOPERATION
REIMAR LUEST *In its* Progress in Space Transportation p 9-13 Aug. 1989 Previously announced in IAA as A90-10291
Copyright Avail: NTIS HC A22/MF A03

The long term space mission plans of ESA are outlined. The present status of the long term plan execution is presented. The Solar-Terrestrial Science program, the Hipparcos satellite, the Earth Remote Sensing satellite, the Ariane 5, Columbus, and Hermes programs are all looked at, and the progress made in each described. ESA

N90-16841# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.).
THE DLR TECHNOLOGY PROGRAMME ON SPACE TRANSPORTATION
MARTIN MAILAENDER and C.-J. WINTER *In* ESA, Progress in Space Transportation p 479-483 Aug. 1989
Copyright Avail: NTIS HC A22/MF A03

Three DLR (German Aerospace Research Establishment) programs related to the Hermes project, the Saenger project, and the Columbus and Ariane projects, are described. Selected examples of recent achievements and plans for future research in these three projects are presented. Relations with national and international partners are outlined. Various aspects of participation in current programs and the development of future technologies are discussed. ESA

N90-18338*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
RECOMMENDATIONS FOR THE FUTURE
In its Solar-Terrestrial Science Strategy Workshop p 65-66 Sep. 1989
Avail: NTIS HC A04/MF A01; 4 functional color pages CSCL 03/2

The workshop explored four major areas of concern to solar-terrestrial science. Looking across the discipline reports given previously, it is possible to find common threads that can contribute to the development of NASA's programmatic strategy for the solar-terrestrial sciences. The following areas are outlined: scientific balance; previously gathered information; imaging; impact of the space station and related platforms; vitality and relevance; and future studies. Author

03

MANAGEMENT SYSTEMS AND LOGISTICAL SUPPORT

Scheduling and logistical support for space systems. Includes descriptions of ground-based support and research facilities.

A90-10294#
USE OF SPACECRAFT SIMULATORS AT ESOC
J. J. GUJER and E. JABS (ESA, Computer Dept., Darmstadt, Federal Republic of Germany) ESA Bulletin (ISSN 0376-4265), no. 59, Aug. 1989, p. 41-48.
Copyright

One of the critical keys to space-mission success is a well-prepared ground segment. All ground-segment elements have to undergo a series of test and validation procedures during the mission-preparation phase, and operations staff involved have to be adequately trained. After launch too, any modifications to the operational system must be thoroughly validated before implementation, and training activities must continue to maintain the requisite level of staff proficiency. The impossibility of having long periods of access to, or of performing the most critical tests with, the real spacecraft has prompted ESOC to develop dynamic (closed-loop) simulators for both pre- and post-launch test purposes. Author

A90-10356
MODEL-BASED APPROACH FOR INTELLIGENT CONTROL
JANOS SZTIPANOVITS, CSABA BIEGL, GABOR KARSAI (Vanderbilt University, Nashville, TN), and R. BYRON PURVES (Boeing Aerospace Co., Huntsville, AL) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 46-55. refs
Copyright

The paper discusses a comprehensive, model-based approach for the design and implementation of intelligent controllers. The system has been implemented in the framework of the Multigraph Architecture. The Multigraph Architecture is a layered system, which includes a parallel, graph computation model, the corresponding execution environment, and software tools supporting the interactive, graphical building of knowledge-bases. Author

A90-10368* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
AUTONOMY THROUGH INTERACTION - THE JPL TELEROBOT INTERACTIVE PLANNING SYSTEM
STEPHEN F. PETERS (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation

IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 173-178. refs
Copyright

The telerobot interactive planning system (TIPS) has been developed to provide automated task planning and reasoning for satellite servicing in NASA's Jet Propulsion Laboratory telerobot testbed. The strategy taken in this development is that an interface between a partially autonomous system and external sources of knowledge is a feature which enables application of technology not yet fully autonomous. Interactive features, both between the operator and TIPS and among the reasoning engines within TIPS, result in a system which has greater robustness than the reasoning engines alone could provide. C.E.

A90-10371* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A SPATIAL OPERATOR ALGEBRA FOR MANIPULATOR MODELING AND CONTROL
G. RODRIGUEZ, K. KREUTZ, and M. MILMAN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 194-208. refs
Copyright

A powerful new spatial operator algebra for modeling, control, and trajectory design of manipulators is discussed along with its implementation in the Ada programming language. Applications of this algebra to robotics include an operator representation of the manipulator Jacobian matrix; the robot dynamical equations formulated in terms of the spatial algebra, showing the complete equivalence between the recursive Newton-Euler formulations to robot dynamics; the operator factorization and inversion of the manipulator mass matrix which immediately results in O(N) recursive forward dynamics algorithms; the joint accelerations of a manipulator due to a tip contact force; the recursive computation of the equivalent mass matrix as seen at the tip of a manipulator; and recursive forward dynamics of a closed chain system. Finally, additional applications and current research involving the use of the spatial operator algebra are discussed in general terms. C.E.

A90-10372* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE SYSTEMS AUTONOMY DEMONSTRATION PROJECT - CATALYST FOR SPACE STATION ADVANCED AUTOMATION
KATHLEEN J. HEALEY (NASA, Johnson Space Center, Houston, TX) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 210-217. refs
Copyright

The Systems Autonomy Demonstration Project (SADP) was initiated by NASA to address the advanced automation needs for the Space Station program. The application of advanced automation to the Space Station's operations management system (OMS) is discussed. The SADP's future goals and objectives are discussed with respect to OMS functional requirements, design, and desired evolutionary capabilities. Major technical challenges facing the designers, developers, and users of the OMS are identified in order to guide the definition of objectives, plans, and scenarios for future SADP demonstrations, and to focus the efforts on the supporting research. C.E.

A90-10506*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
DEVELOPMENT OF AN AUTOMATED REQUIREMENTS MANAGEMENT SYSTEM FOR THE SPACE STATION FREEDOM PROGRAM
GEOFF GIFFIN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 247-256. refs
(AIAA PAPER 89-2998) Copyright

The Automated Requirements Management System, which is being developed to support traceability and documentation of Space Station Freedom requirements, is described. The objectives of requirements management are validation and verification. Other benefits include comprehensive analytical capabilities, commonality and timeliness of requirements information availability across the program, and the reduction of information duplication and overlap. K.K.

A90-10527*# National Aeronautics and Space Administration, Washington, DC.
APPROACH TO TRANSACTION MANAGEMENT FOR SPACE STATION FREEDOM
C. R. EASTON (McDonnell Douglas Space Systems Co., Huntington Beach, CA), PHIL CRESSY (NASA, Washington, DC), T. E. OHNESORGE, and GARLAND HECTOR (NASA, Johnson Space Center, Houston, TX) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 412-419.
(AIAA PAPER 89-3027) Copyright

An approach to managing the operations of the Space Station Freedom based on their external effects is described. It is assumed that there is a conflict-free schedule that, if followed, will allow only appropriate operations to occur. The problem is then reduced to that of ensuring that the operations initiated are within the limits allowed by the schedule, or that the external effects of such operations are within those allowed by the schedule. The main features of the currently adopted transaction management approach are discussed. V.L.

A90-10595*# Space Industries, Inc., Webster, TX.
THE MFIVE SPACE STATION CREW ACTIVITY SCHEDULER AND STOWAGE LOGISTICS CLERK
CLIFFORD R. KURTZMAN (Space Industries, Inc., Webster, TX) and DAVID L. AKIN (MIT, Cambridge, MA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 947-957. refs
(Contract NAG5-445; NAGW-21)
(AIAA PAPER 89-3118) Copyright

An interactive computer scheduling tool, the MFIVE Space Station Crew Activity Scheduler and Stowage Logistics Clerk, is described. The MFIVE employs the intelligent perturbation method, which was developed to schedule complex time and resource constrained problems. This algorithm was used to minimize the completion time of sample scheduling problems and solutions were derived which averaged within 7 percent of optimum where standard solution techniques gave solutions 23 percent longer than optimum. K.K.

A90-10597#
AI IN SPACE STATION FREEDOM PROGRAM PLANNING AND SCHEDULING
C. R. EASTON and J. J. L. DICKINSON (McDonnell Douglas Space Systems Co., Huntington Beach, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 962-969. refs
(AIAA PAPER 89-3120) Copyright

An AI approach to Space Station Freedom Program planning and scheduling that will support the operators in establishing their schedules and in responding to schedule changes and targets of opportunity is presented. This approach permits schedule integration to take place at a higher level by scheduling blocks of operating authority to perform operations with predefined potential for external effects. By using the present approaches in the program growth phase, it will be possible to ease scheduling problems, add flexibility, and reduce operating costs. K.K.

A90-12206
A STUDY OF A USER DATA PROCESSING CENTRE FOR EXPERIMENT SUPPORT IN THE SPACE STATION ERA

W. MARKWITZ and G. MAYER (DLR, Wessling, Federal Republic of Germany) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 449-458. refs
Copyright

The concept design of the future DFVLR User Data Processing Center (UDC) is reviewed, based on the present knowledge on the expected Space Station scenario, the relevant studies, and their model missions. The identified main areas of support will be remote sensing, space science, and space technology. The UDC as part of the European ground installations for space missions support fits well into the future planned European ground segment. The functions and functional elements of the UDC have been derived with reference to the end-to-end Space Station data systems architecture, the expected interagency cross support capabilities, the development of public and private data networks, and the state of the art in real-time data distribution and processing. Pilot projects to be carried out as experimental studies and demonstrations with impact on future space data systems are mentioned. Author

A90-13254#
IN-ORBIT OPERATIONS SIMULATION FACILITIES AT DLR
K. REINEL, G. HEIMBOLD, TH. LANGE, and B. SCHAEFER (DLR, Oberpfaffenhofen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-016) Copyright

This paper presents the design and development of simulation and test facilities for the in-orbit operation technology at the German Space Operation Center. The Servicing Test Facility, the European Proximity Operations Simulator, and the Test Facilty for Large Flexible Spacecraft Control are examined. The reasons for the design of these systems are explained and their functions are discussed. C.D.

A90-13292#
DESIGNING FOR 'AVAILABILITY' FOR SPACE STATION FREEDOM
DAVID C. WENSLEY and JOHN W. KRAUS (McDonnell Douglas Space Systems Co., Space Station Div., Huntington Beach, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p.
(IAF PAPER 89-073)

Techniques for optimizing the availability of systems and equipment on the Space Station are discussed. Availability is defined as the ratio of the time a system is capable of being operational to the total time of the mission. Consideration is given to factors that influence availability, such as quality and reliability standards, redundancy and backup features, maintainability and time-to-repair, on-board servicing capability, and logistics support. The resource and service requirements for the Space Station are outlined. Methods for maximizing on-line availability include the use of robotics for inspection and maintenance, automated redundancy switching, expert systems for diagnostics, performance monitoring, and trend analysis. R.B.

A90-13297*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE PRINCIPLE OF COMMONALITY AND ITS APPLICATION TO THE SPACE STATION FREEDOM PROGRAM
GEORGE D. HOPSON, L. DALE THOMAS, and CHARLES C. DANIEL (NASA, Marshall Space Flight Center, Huntsville, AL) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p. refs
(IAF PAPER 89-081) Copyright

The principle of commonality has achieved wide application in the communication, automotive, and aircraft industries. By the use of commonality, component development costs are minimized, logistics are simplified, and the investment costs of spares inventory are reduced. With space systems, which must be maintained and repaired in orbit, the advantages of commonality are compounded. Transportation of spares is expensive, on-board storage volume for spares is limited, and crew training and special tools needed for maintenance and repair are significant considerations. This paper addresses the techniques being formulated to realize the benefits of commonality in the design of the systems and elements of the Space Station Freedom Program, and include the criteria for determining the extent of commonality to be implemented. Author

A90-13307*# NASA Space Station Program Office, Reston, VA.
SPACE STATION FREEDOM OPERATIONS PLANNING
ANNE L. ACCOLA and BRYANT KEITH (NASA, Space Station Freedom Program Office, Reston, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-097)

The Space Station Freedom program is developing an operations planning structure which assigns responsibility for planning activities to three tiers of management. The strategic level develops the policy, goals and requirements for the program over a five-year horizon. Planning at the tactical level emphasizes program integration and planning for a two-year horizon. The tactical planning process, architecture, and products have been documented and discussed with the international partners. Tactical planning includes the assignment of user and system hardware as well as significant operational events to a time increment (the period of time from the arrival of one Shuttle to the manned base to the arrival of the next). Execution-level planning emphasizes implementation, and each organization produces detailed plans, by increment, that are specific to its function. Author

A90-13308*# Booz-Allen and Hamilton, Inc., Reston, VA.
SPACE STATION FREEDOM CREW TRAINING
KAROL J. BOBKO, EDWARD G. GIBSON, SUSAN A. MARONEY, and JAMES D. MUCCIO (Booz-Allen and Hamilton, Inc., Reston, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(Contract NASW-4300)
(IAF PAPER 89-098) Copyright

The nature of the Space Station Freedom Program presents an array of new and enhanced challenges which need to be addressed en route to developing an effective and affordabe infrastructure for crew training. Such an infrastructure is essential for the safety and success of the program. The three major challenges that affect crew training are the long lifetime of the program (thirty years), the interdependence of successive increments, and the participation of the three International Partners (Canada, European Space Agency, and Japan) and a myriad of experimenters. This paper addresses these major challenges as they drive the development of a crew training capability and the actual conduct of crew training. Author

A90-13373*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
DESIGNING THE SPACE TRANSFER VEHICLE (STV)
GENE AUSTIN (NASA, Marshall Space Flight Center, Huntsville, AL), ED BANGSUND, and TIM VINOPAL (Boeing Aerospace and Electronics, Seattle, WA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 14 p.
(IAF PAPER 89-209) Copyright

The most significant challenges facing the Space Transfer Vehicle (STV) program are making space basing affordable and developing an easily evolvable STV. Study efforts try minimizing the high cost of astronauts activities and Space Station modification to enhance affordability. Modularity, design margins, and simple interfaces are being evaluated to develop an evolutionary approach for space basing starting in the 1990's. In this STV study, the concept definition approach is presented, including concept optimization trades as well as concept selection and sensitivity analyses. C.E.

A90-13374#
ARIANE TRANSFER VEHICLE RECENT ACHIEVEMENTS

CHRISTOPHE BONNAL, PATRICK EYMAR (Aerospatiale, Les Mureaux, France), and DAVID SALT (British Aerospace, PLC, London, England) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p.
(IAF PAPER 89-211) Copyright

Studies started in 1986 by Aerospatiale and British Aerospace have been continued in 1988 and 1989 to refine the definition of Ariane Transfer Vehicle (ATV) to fill the gap between Ariane 5 primary launch orbit and any space orbiting element to be serviced. A viable concept resulted from these studies where emphasis was put on the requirements of supplies and spare parts transportation, payload delivery, and assembly missions to Space Station Freedom; the in depth analysis of the transportation of two unpressurized logistic carriers to Space Station Freedom; and the analysis of consequences stemming from recent modifications of Ariane 5 upper stage and HERMES Resource and Propulsion modules. Promising extensions of ATV functions have also been identified. C.E.

A90-13379#
A FRENCH STUDY ON AIRBREATHING LAUNCHERS - STAR H
M. RIGAULT (AMDBA, S.A., Saint-Cloud, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-218) Copyright

A French study on two-stages-to-orbit (TSTO) airbreathing launchers is presented as a preliminary data base for system studies and the definition of the technological effort to be implemented. It results from in-depth analyses of the critical problems encountered on some specific preliminary projects. Most of the work concentrated on aerodynamics/aerothermodynamics, structure and materials, propellant storage and management, safety and trajectory aspects. Sensitivity aspects have also been considered for the main design parameters, including propulsion characteristics. The work focused on a relatively conservative concept to demonstrate the potential benefits of the airbreathing launchers, notably the operational flexibility. The very difficult technical challenges to be mastered before these launchers become operational and competitive against current launchers are also discussed. C.E.

A90-13386*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
A VIEW TOWARD FUTURE LAUNCH VEHICLES - A CIVIL PERSPECTIVE
CHARLES R. DARWIN, GENE AUSTIN, LEE VARNADO, and GLENN EUDY (NASA, Marshall Space Flight Center, Huntsville, AL) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p.
(IAF PAPER 89-227) Copyright

Prospective NASA launch vehicle development efforts, which in addition to follow-on developments of the Space Shuttle encompass the Shuttle-C cargo version, various possible Advanced Launch System (ALS) configurations, and various Heavy Lift Launch System (HLLS) design options. Fully and partially reusable manned vehicle alternatives are also under consideration. In addition to improving on the current Space Shuttle's reliability and flexibility, ALS and HLLV development efforts are expected to concentrate on the reduction of operating costs for the given payload-launch capability. O.C.

A90-13521#
SCHEDULING SPACE EXPERIMENTS USING TELESCIENCE AND AN ADVANCED USER-INTERFACE
E. BENNETT, D. WILKE, and K. WITTMAN (DLR, Cologne, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p.
(IAF PAPER 89-416) Copyright

Experiments in the Space Station era will require the ability to schedule and re-schedule their activities by users of the facilities in a fast and easy way. The program Holop Scheduler is discussed as a prototype scheduling program which is planned to be used for the two-dimensional Spacelab facility HOLOP. Its advanced user-interface, integrating four separate Editors (the Schedule Editor, the Controls Editor, the Constraints Editor, and the Sequence Editor) on a microcomputer in conjunction with ARIADNE (an advanced scheduling relational database running on a minicomputer), provide end-users with the ability to plan, observe, and replan their experiments in a fast and simple manner. Author

A90-13525#
THE DECENTRALIZED GROUND INFRASTRUCTURE AND THE ROLE OF GROUND SUPPORT EQUIPMENT IN THE FUTURE TELESCIENCE ENVIRONMENT
CH. PUETZ and R. KLETT (Kayser-Threde GmbH, Munich, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. Research supported by BMFT. refs
(IAF PAPER 89-420)

The paper reflects some ideas for the improvement of the development and the operation of experiment facilities. The ideas are based on the experiences gained throughout various space projects, in which hardware and software have been developed for a number of scientific facilities. The paper includes also new experience gained in first telescience experiments, conducted in spring 1989. The paper points out that it is helpful, if not mandatory in future experiments, to realize in any phase of the lifetime of an experiment facility user interfaces, to which all engineers, operators, and scientists are trained. In order to ease remote diagnosis and maintenance, the user interface setup should, at least in one mode, be the same for all the different teams working with the facility. Author

A90-15311
CLASS 100 LARGE SPACECRAFT FACILITY
KEITH A. MARUYA, LORRAINE E. RYAN, and DONALD E. FRITZ (TRW, Inc., TRW Space and Defense Sector, Redondo Beach, CA) (NASA, Institute of Environmental Sciences, AIAA, and ASTM, Space Simulation Conference, 15th, Williamsburg, VA, Oct. 31-Nov. 3, 1988) Journal of Environmental Sciences (ISSN 0022-0906), vol. 32, Sept.-Oct. 1989, p. 17-21. refs
Copyright

A large spacecraft assembly-and-test facility that is fully clean-room compatible was designed and constructed. Features of this facility include a large assembly-and-test area and a smaller support room that have HEPA-filtered vertical flow; dedicated staging areas for garment application, storage, and equipment preparation; and an automated clean-room monitoring system (CRMS). A description of the design, construction, and certification process is given. Operational data from the CRMS and lessons learned are also presented. Author

A90-18030* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
SPACE APPLICATIONS OF ARTIFICIAL INTELLIGENCE; PROCEEDINGS OF THE ANNUAL GODDARD CONFERENCE, GREENBELT, MD, MAY 16, 17, 1989
JAMES L. RASH, ED. and CAROLYN P. DENT, ED. (NASA, Goddard Space Flight Center, Greenbelt, MD) Conference sponsored by NASA, Bendix Field Engineering Corp., Computer Sciences Corp., et al. Telematics and Informatics (ISSN 0736-5853), vol. 6, no. 3-4, 1989, 300 p. For individual items see A90-18031 to A90-18050.
Copyright

Theoretical and implementation aspects of AI systems for space applications are discussed in reviews and reports. Sections are devoted to planning and scheduling, fault isolation and diagnosis, data management, modeling and simulation, and development tools and methods. Particular attention is given to a situated reasoning architecture for space repair and replace tasks, parallel plan execution with self-processing networks, the electrical diagnostics expert system for Spacelab life-sciences experiments, diagnostic tolerance for missing sensor data, the integration of perception

and reasoning in fast neural modules, a connectionist model for dynamic control, and applications of fuzzy sets to the development of rule-based expert systems. T.K.

A90-18034
A HEURISTIC APPROACH TO INCREMENTAL AND REACTIVE SCHEDULING
JIDE B. ODUBIYI and DAVID R. ZOCH (Ford Aerospace Corp., Seabrook, MD) (NASA, Bendix Field Engineering Corp., Computer Sciences Corp., et al., Annual Goddard Conference on Space Applications of Artificial Intelligence, Greenbelt, MD, May 16, 17, 1989) Telematics and Informatics (ISSN 0736-5853), vol. 6, no. 3-4, 1989, p. 171-180. Previously announced in STAR as N89-26589. refs
Copyright

Incremental scheduling is the process of modifying an existing schedule if the initial schedule does not meet its stated initial goals. Reactive scheduling occurs in near real-time in response to changes in available resources or the occurrence of targets of opportunity. Only minor changes are made during both incremental and reactive scheduling because a goal of re-scheduling procedures is to minimally impact the schedule. The described heuristic search techniques, which are employed by the Request Oriented Scheduling Engine (ROSE), a prototype generic scheduler, efficiently approximate the cost of reaching a goal from a given state and effective mechanisms for controlling search. Author

A90-19893*# Booz-Allen and Hamilton, Inc., Reston, VA.
IMPACTING SPACE STATION FREEDOM DESIGN WITH OPERATIONS AND SAFETY REQUIREMENTS - AN AVAILABILITY PROCESS
JERRY J. GAREGNANI and STEVEN Y. SCHONDORF (Booz, Allen and Hamilton, Inc., Reston, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 6 p.
(Contract NASW-4300)
(AIAA PAPER 90-0518) Copyright

The unusually long mission duration of Space Station Freedom leads to operations costs that have significant impacts on life-cycle cost relative to previous manned space programs. Maintaining an affordable program requires that operations costs be considered throughout the design process. An appropriate means of impacting the design with operations concerns is to specify requirements that ensure operational effectiveness when implemented. The Space Station Freedom Program has developed a process defining such requirements. It focuses on specifying functional profiles and allocating resources such that designers gain a better understanding of the operational envelope in which their systems must perform. This paper examines the details of the process, where it came from, and why it is effective. Author

A90-20025#
MISSION PLANNING OPERATIONAL REQUIREMENTS TO SUPPORT USERS IN THE COLUMBUS SCENARIO
A. DAVIDSON, K. D. SCHMIDT (DLR, Cologne, Federal Republic of Germany), and G. T. BIDDIS ESA Journal (ISSN 0379-2285), vol. 13, no. 3, 1989, p. 241-248. refs
Copyright

A mission planning scheme that is useful for long-duration manned missions is proposed. The approach is applied to the proposed Freedom project. Particular attention is given to mission-preparation and mission-execution tasks. The effects of the resource users on the overall mission plan are discussed. It is noted that the planning system requires a degree of automation so that updated requirements can be tracked and incompatible operations discovered in real time. I.F.

A90-20384
LONG CYCLE PRESSURIZED LOGISTICS MODULE FOR SPACE STATION LOGISTICS SCENARIO
ERNESTO VALLERANI and LUCIANO BASILE (Aeritalia S.p.A., Settore Spazio, Turin, Italy) Huntsville Association of Technical Societies, Annual Technical and Business Exhibition and Symposium, 5th, Huntsville, AL, May 16, 17, 1989. 9 p.
(TABES PAPER 89-603) Copyright

Investigations of candidate design solutions to support the logistics-scenario critical aspects have identified the possibility of considering a new logistics element as part of the Space Station logistics system: the Long Cycle Pressurized Logistics Module (LCPLM). LCPLM was generated to provide the necessary support suitable for both storage and logistics ISS critical areas: to be compatible with ISS operations and NSTS constraints; to provide manned shirt-sleeve environment at 14.7 PSI; to minimize function needs for the ISS; to support the skipped-cycle event for critical items such as food conditioning via refrigerator/freezer accommodation; to provide dynamic storage volume to enhance the use of laboratory resources; and to optimize the resupply/return cargo scenario. Preliminary investigation of robotic system application for internal/external LCPLM automated operations has been performed in order to support crew activities and to limit possible perilous crew intervention. C.E.

A90-20385
SPACE TEST AND EVALUATION FACILITY (STEF)
RONALD E. GIUNTINI and KAREN M. SEISER (Wyle Laboratories, Huntsville, AL) Huntsville Association of Technical Societies, Annual Technical and Business Exhibition and Symposium, 5th, Huntsville, AL, May 16, 17, 1989. 9 p.
(TABES PAPER 89-704) Copyright

Most of this work is concentrated on a five-year development of system engineering processes necessary to identify a relative optimum STEF concept and to provide a ranking of associated concepts. In-house investigations at Wyle Laboratories resulted in numerous STEF concepts utilizing a variety of existing or planned space hardware systems and components. Various trades and analyses have been identified to assist in selecting the optimum STEF configuration. C.E.

A90-24761
RESTORING U.S. LAUNCH CAPACITY
ROBERT A. ZIRKLE IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 3-32. refs
Copyright

Issues related to the process of choosing the appropriate set of launch vehicles to meet the requirements of future U.S. space programs are discussed. The use of the Space Shuttle as a launch vehicle is discussed and the capacity of U.S. launch services is compared with the demand for launches. The commercialization of launch services is considered and the decision to close the Vandenberg Shuttle Complex is assessed. The role of launch services in developing the Space Station and space-based defense systems (SDI) is examined. R.B.

A90-26817#
LARGE ANGLE MANEUVER EXPERIMENTS IN GROUND-BASED LABORATORIES
ALOK DAS (USAF, Astronautics Laboratory, Edwards AFB, CA) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 431-442. refs
(AIAA PAPER 90-1236)

An evaluation is made of the development status of ground tests addressing problems which arise in the course of large space structures' rapid retargeting maneuvers, which can be a major source of disturbances. These experiments concern maneuvers and structures which range in complexity from the single-axis slewing of a flexible beam to realistic, three-dimensional structures and three rotational degrees-of-freedom. The dynamic characteristics of sensors, and especially of actuators, are noted to have a significant effect on control-law actuation. O.C.

A90-27422
DEVELOPMENT OF GRAPHIC DISPLAYS FOR SPACE STATION APPLICATIONS
RALPH A. CACACE and BRENDA M. ENGLAND (United

Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p.
(SAE PAPER 891452) Copyright

This paper presents basic approaches for achieving subsystem control for the Space Station and providing the status information in a straightforward and direct manner. The control technologies include high-resolution graphic displays, high-density memories, programmable keyboards, and a high-speed data bus. The resulting graphic display system enables the user to view the mechanical schematics of a process with real-time data overlays and animated functions. Diagrams pertaining to the display system and its control are presented. I.S.

A90-27445* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT OF THE CELSS EMULATOR AT NASA JSC
HATICE S. CULLINGFORD (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p.
(Contract NAS9-17900)
(SAE PAPER 891477) Copyright

The Controlled Ecological Life Support System (CELSS) Emulator is under development at the NASA Johnson Space Center (JSC) with the purpose to investigate computer simulations of integrated CELSS operations involving humans, plants, and process machinery. This paper describes Version 1.0 of the CELSS Emulator that was initiated in 1988 on the JSC Multi Purpose Applications Console Test Bed as the simulation framework. The run module of the simulation system now contains a CELSS model called BLSS. The CELSS Emulator makes it possible to generate model data sets, store libraries of results for further analysis, and also display plots of model variables as a function of time. The progress of the project is presented with sample test runs and simulation display pages. Author

A90-27516* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PHASE III INTEGRATED WATER RECOVERY TESTING AT MSFC - DESIGN, PLANS, AND PROTOCOLS
ROBERT M. BAGDIGIAN (NASA, Marshall Space Flight Center, Huntsville, AL) and GERALD A. WHITMAN (Boeing Aerospace Co., Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p. refs
(SAE PAPER 891554) Copyright

A series of tests is being conducted at the NASA Marshall Space Flight Center (MSFC) to evaluate the performance of a closed-loop water recovery system. Testing will be conducted at various levels of integration and loop-closure, culminating in complete closure of the water system with man-in-the-loop. This paper summarizes the test goals and objectives as well as the system design, plans, and protocols which have been established. Author

A90-27517* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM TEST FACILITY AT MARSHALL SPACE FLIGHT CENTER
DARLENE SPRINGER (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p.
(SAE PAPER 891555) Copyright

Different aspects of Space Station Environmental Control and Life Support System (ECLSS) testing are currently taking place at Marshall Space Flight Center (MSFC). Unique to this testing is the variety of test areas and the fact that all are located in one building. The north high bay of building 4755, the Core Module Integration Facility (CMIF), contains the following test areas: the Subsystem Test Area, the Comparative Test Area, the Process Material Management System (PMMS), the Core Module Simulator (CMS), the End-use Equipment Facility (EEF), and the Pre-development Operational System Test (POST) Area. This paper addresses the facility that supports these test areas and briefly describes the testing in each area. Future plans for the building and Space Station module configurations will also be discussed. Author

A90-27518
SPACE STATION PHASE III ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM, TEST BED CONTROL AND DATA ACQUISITION SYSTEM DESIGN
JAMES B. SCHULTZ and BOB M. THORNTON (Micro Craft, Inc., Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p.
(SAE PAPER 891556) Copyright

The design of a data acquisition and control system for the ECLSS testbed for the Space Station is examined. The phase III ECLSS is classified into air revitalizaiton systems and water reclamation and management systems. The system utilizes programmable logic controllers and personal communications software. The electrical hardware, logic controllers, and computer software needed to acquire the data and provide control system functions are described. Hardware/software interfacing techniques and methods for implementing both automatic and manual control using ladder logic and programmable logic controllers are discussed. Various system diagrams are provided. I.F.

A90-27547* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE CROP GROWTH RESEARCH CHAMBER - A GROUND-BASED FACILITY FOR CELSS RESEARCH
DAVID L. BUBENHEIM, PHIL M. LUNA, KIMBERLY M. WAGENBACH, MARK HASLERUD (NASA, Ames Research Center, Moffett Field, CA), and CHRISTIAN L. STRAIGHT (Bionetics Corp., Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. refs
(SAE PAPER 891588) Copyright

Crop Growth Research Chambers (CGRCs) are being developed as CELSS research facilities for the NASA/Ames Research Center. The history of the CGRC project is reviewed, noting the applications of CGRC research for the development of the Space Station. The CGRCs are designed for CELSS research and development, system control and integration, and flight hardware design and experimentation. The atmospheric and hydroponic environments of the CGRC system are described and the science requirements for CGRC environmental control are listed. R.B.

A90-27600#
SHUTTLING TO THE SPACE STATION
RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 28, March 1990, p. 44-47.
Copyright

Recommendations by Congress' Office of Technology Assessment regarding launch vehicles and their effect on the Space Station are discussed. It is proposed that a new fleet of launch vehicles and a Shuttle replacement are needed to expand the presence of humans in space. Upgrades for the Shuttle that would improve its support of the Space Station are described. I.F.

A90-27644*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE SUPERMODULE - A DESIGN DEPARTURE FROM THE SHUTTLE PAYLOAD PARADIGM
MARCUS S. MURBACH (NASA, Ames Research Center, Moffett Field, CA) and VLADIMIR M. GARIN (Bionetics, Inc., Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan., 8-11, 1990. 14 p. refs
(AIAA PAPER 90-0716) Copyright

An effort has been made to formulate a novel approach to the construction of manned orbital facilities, in the context of a long-term launch strategy. The pressurized volume component of a manned platform is the point of departure, and an integrated vehicle designated the 'Supermodule' is defined which replaces analogous Space Station Freedom pressurized volume components. A launch sequence encompassing one Supermodule,

one Shuttle Orbiter, and three Shuttle-Derived Vehicle cargo launchers, could reduce the number of launches needed to build a Space Station of the size of Freedom from 20 to merely five. O.C.

A90-28370
REAL-TIME COMPUTER CONTROL OF A FLEXIBLE SPACECRAFT EMULATOR
PETER C. HUGHES (Toronto, University, Downsview, Canada), GARY W. CROCKER, and TONY HONG IEEE Control Systems Magazine (ISSN 0272-1708), vol. 10, Jan. 1990, p. 3-8. Research supported by CDC, NSERC, and Institute for Space and Terrestrial Science. refs
Copyright

A description is given of a ground-based test facility named Daisy, which was established to study control issues for large flexible spacecraft. The validation of modern algorithms for system identification and shape and attitude control and the development of new control devices can be performed using Daisy. The experimental structure consists of a radial mesh of ribs attached flexibly to a rigid hub. The structure is instrumented with position and rate sensors and controlled by a real-time computer and data acquisition system by means of torque actuators. The more important aspects of these subsystems and their integration are presented along with experimental results for a baseline controller, consisting of a simple integral-derivative feedback control on the position of the hub. I.E.

A90-28711
MOSCOW'S PROTON FACTORY
STEPHANE CHENARD Interavia Space Markets (ISSN 0258-4212), vol. 6, Jan.-Feb. 1990, p. 10-12, 14.
Copyright

The paper covers details on a recent visit to the USSR's plant in Moscow where components of the Proton launch vehicle and space station modules undergo final integration and testing. Historically this plant goes back to the period following WW I when different types of aircraft designed by Tupolev and Myasishev, were built there. Activity resumed after WW II, with the TU-4 bomber and the early Mil helicopters. The transition to space systems manufacturing was made in the early 1960s with the development of the Proton launcher, and later with the development of all or most Proton payloads. Additional space vehicle development and manufacturing examples are presented. Now the overall impression is that the facilities have become too cramped to permit rational production at the rate currently required for the Proton. It is concluded that the plant is at a critical point in its history, as the pressure of economic crisis forces a slowdown in the Soviet space program. R.E.P.

A90-29280*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STRUCTURAL DESIGN CONSIDERATIONS FOR A PERSONNEL LAUNCH SYSTEM
LANCE B. BUSH, CHRISTOPHER A. LENTZ (NASA, Langley Research Center, Hampton, VA), JAMES C. ROBINSON (Old Dominion University Research Foundation, Norfolk, VA), and IAN O. MACCONOCHIE (Lockheed Engineering and Sciences Co., Hampton, VA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 553-567. refs
(AIAA PAPER 90-1052) Copyright

A vehicle capable of performing the transfer of eight people to and from the Space Station Freedom is currently in the conceptual/preliminary design stages at the NASA Langley Research Center. Structural definition of this Personnel Launch System (PLS) and the considerations leading to it are described. Issues such as cost, technology level, human factors, and maintainability are used as guidelines for the structural definition. A synergistic design technique involving aerodynamics, performance, mission, packaging, and weights and sizing analyses is utilized to evaluate the structural design. A closed-loop design is achieved when the mission requirements are met by each previously mentioned analysis for a particular vehicle weight. Although satisfactory, the structural concept presented herein is not to be treated as a final answer, but one promising solution. An examination of alternative designs and more detailed analyses can be undertaken in order to identify design inadequacies and more efficient approaches. Author

A90-30766#
THE SPACE LOGISTICS CHALLENGE
DAVID B. WILE (USAF, Integrated Logistics Support Directorate, Peterson AFB, CO) IN: NAECON 89; Proceedings of the IEEE National Aerospace and Electronics Conference, Dayton, OH, May 22-26, 1989. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 1239-1243.

The application of standard logistics analysis to military activities in space is discussed. Consideration is given to space-system segmentation, orbital placement, orbital maneuvers, and space assembly and maintenance options. It is argued that plans for a normalized space infrastructure should consider the total space support requirements and not be based on just the needs of a particular system. I.E.

N90-10081*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NASA'S CONTROLS-STRUCTURES INTERACTION PROGRAM
BRANTLEY R. HANKS *In its* Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 21-32 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A NASA program is about to start which has the objective to advance Controls-Structures Interaction (CSI) technology to a point where it can be used in spacecraft design for future missions. Because of the close interrelationships between the structure, the control hardware, and the analysis/design, a highly interdisciplinary activity is defined in which structures, dynamics, controls, computer and electronics engineers work together on a daily basis and are co-located to a large extent. Methods will be developed which allow the controls and structures analysis and design functions to use the same mathematical models. Hardware tests and applications are emphasized and will require development of concepts and test methods to carry out. Because of a variety of mission application problem classes, several time-phased, focus ground test articles are planned. They will be located at the Langley Researdh Center (LaRC), the Marshall Space Flight Center (MSFC) and at the Jet Propulsion Laboratory (JPL). It is anticipated that the ground tests will be subject to gravity and other environmental effects to the extent that orbital flights tests will be needed for verification of some technology items. The need for orbital flight experiments will be quantified based on ground test results and mission needs. Candidate on-orbit experiments will be defined and preliminary design/definition and cost studies will be carried out for one or more high-priority experiments. Author

N90-10911*# Southwest Research Inst., San Antonio, TX.
ADVANCED MANNED SPACE FLIGHT SIMULATION AND TRAINING: AN INVESTIGATION OF SIMULATION HOST COMPUTER SYSTEM CONCEPTS Final Technical Report
BRUCE C. MONTAG, ALFRED M. BISHOP, and JOE B. REDFIELD 10 Nov. 1989 53 p
(Contract NAG9-394; SWRI PROJ. 05-3050)
(NASA-CR-185998; NAS 1.26:185998) Avail: NTIS HC A04/MF A01 CSCL 14/2

The findings of a preliminary investigation by Southwest Research Institute (SwRI) in simulation host computer concepts is presented. It is designed to aid NASA in evaluating simulation technologies for use in spaceflight training. The focus of the investigation is on the next generation of space simulation systems that will be utilized in training personnel for Space Station Freedom operations. SwRI concludes that NASA should pursue a distributed simulation host computer system architecture for the Space Station Training Facility (SSTF) rather than a centralized mainframe based

arrangement. A distributed system offers many advantages and is seen by SwRI as the only architecture that will allow NASA to achieve established functional goals and operational objectives over the life of the Space Station Freedom program. Several distributed, parallel computing systems are available today that offer real-time capabilities for time critical, man-in-the-loop simulation. These systems are flexible in terms of connectivity and configurability, and are easily scaled to meet increasing demands for more computing power. Author

N90-11064# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
THE ENVIRONMENTAL TEST CENTRE AT ESTEC (AN OVERVIEW)
E. CLASSEN *In its* Spacecraft Structures and Mechanical Testing p 603-605 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The global tasks of the European Space Research and Technology Center (ESTEC) are outlined. The advantages of being able to carry out a wide series of tests all within one building complex are described. A diagram of the test center is provided. The test center will be capable of carrying out environmental tests on large satellites such as those to be launched on Ariane 4 and 5. ESA

N90-11065# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Testing Div.
TWO YEARS EXPERIENCE WITH THE ESTEC MULTISHAKER SYSTEM
P. BONNOT *In its* Spacecraft Structures and Mechanical Testing p 607-612 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The ESTEC (European Space Research and Technology Center) 280 kN multishaker system is described. The performance of the system is summarized. The initial design of the system is explained. The utilization program of the system is outlined. It is concluded that on the whole the design options chosen in constructing the system were appropriate. Improvements on the original design are outlined and experience gained in utilizing the system summarized. ESA

N90-11066# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Testing Div.
NEW DATA HANDLING SYSTEM (MDH) FOR MECHANICAL TESTS AT ESTEC
C. FRANSEN *In its* Spacecraft Structures and Mechanical Testing p 613-617 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The updated Mechanical Data Handling (MDH) system used for mechanical tests carried out at ESTEC (European Space Research and Technology Center) is described. The need for such a system in the analysis of larger and more complex space structures is outlined. During structural testing, fast processing of response data is required for a cost effective utilization of available test facilities. The planned capabilities, performance and methodologies applied in developing the updated MDH system are described. ESA

N90-11070# Intespace, Toulouse (France).
A NEW EUROPEAN VIBRATION TEST FACILITY FOR ARIANE 4 CLASS SATELLITES
JEAN-CLAUDE PASQUET and J. F. IMBERT *In* ESA, Spacecraft Structures and Mechanical Testing p 643-648 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A vibration test facility for Ariane 4 class satellites is described. The design of this facility is unique in that it allows for minimization of test duration for heavy specimens weighing up to 4000 kg. A safety system associated with this equipment enables the testing of specimens containing up to 1000 liters of isopropyl alcohol. The test facility consists of two vertical 150 kN electrodynamic shakers, coupled with an expansion head 2100 mm in diameter and a 150 kN electrodynamic shaker coupled with a horizontal table of the same dimensions. A control and command system offers 8 control channels and 17 notching channels. A new generation measurement system, with a 256 channel capability, developed by Intespace, is connected to this equipment. ESA

N90-14263*# Illinois Univ., Urbana-Champaign. Dept. of Aeronautical and Astronautical Engineering.
AEROSPACE VEHICLE DESIGN, SPACECRAFT SECTION. VOLUME 1: PROJECT GROUPS 3-5 Final Project Reports
May 1989 288 p
(Contract NASW-4435)
(NASA-CR-186053; NAS 1.26:186053; AAE-241-VOL-1) Avail: NTIS HC A13/MF A02 CSCL 22/2

Three groups of student engineers in an aerospace vehicle design course present their designs for a vehicle that can be used to resupply the Space Station Freedom and provide an emergency crew return to earth capability. The vehicle's requirements include a lifetime that exceeds six years, low cost, the capability for withstanding pressurization, launch, orbit, and reentry hazards, and reliability. The vehicle's subsystems are analyzed. These subsystems are structures, communication and command data systems, attitude and articulation control, life support and crew systems, power and propulsion, reentry and recovery systems, and mission management, planning, and costing. J.P.S.

N90-14264*# Illinois Univ., Urbana-Champaign. Dept. of Aeronautical and Astronautical Engineering.
AEROSPACE VEHICLE DESIGN, SPACECRAFT SECTION. VOLUME 1: PROJECT GROUPS 3-5 Final Project Reports
May 1989 272 p
(Contract NASW-4435)
(NASA-CR-186054; NAS 1.26:186054; AAE-241-VOL-2) Avail: NTIS HC A12/MF A02 CSCL 22/2

Three groups of student engineers in an aerospace vehicle design course present their designs for a vehicle that can be used to resupply the Space Station Freedam and provide emergency crew return to earth capability. The vehicle's requirements include a lifetime that exceeds six years, low cost, the capability for withstanding pressurization, launch, orbit, and reentry hazards, and reliability. The vehicle's subsystems are structures, communication and command data systems, attitude and articulation control, life support and crew systems, power and propulsion, reentry and recovery systems, and mission management, planning, and costing. Special attention is given to spacecraft communications. J.P.S.

N90-15124# Massachusetts Inst. of Tech., Cambridge.
INSTRUMENTATION FOR A FACILITY FOR THE TEST, ANALYSIS AND ACTIVE CONTROL OF SPACECRAFT TRUSS STRUCTURES Final Report, 1 Oct. 1987 - 31 Dec. 1988
ANDREAS H. VONFLOTOW 18 Aug. 1989 7 p
(Contract AF-AFOSR-0031-87; AF PROJ. 2917)
(AD-A213655; AFOSR-89-1265TR) Avail: NTIS HC A02/MF A01 CSCL 22/2

The report lists in detail the equipment purchased with this instrumentation grant (granted under the DoD-URIP program). Also summarized is the impact this equipment has had upon the work and the reputation of the affected group at MIT. The appendix includes numerous theses and papers which have benefited from the availability of this equipment. GRA

N90-16407*# Alabama Univ., Tuscaloosa. Dept. of Mathematics.
STOCHASTIC MODEL OF THE NASA/MSFC GROUND FACILITY FOR LARGE SPACE STRUCTURES WITH UNCERTAIN PARAMETERS: THE MAXIMUM ENTROPY APPROACH, PART 2 Final Report, 23 May 1988 - 22 Nov. 1989
WEI SHEN HSIA Nov. 1989 64 p

(Contract NAG8-081)
(NASA-CR-186009; NAS 1.26:186009) Avail: NTIS HC A04/MF A01 CSCL 09/2

A validated technology data base is being developed in the areas of control/structures interaction, deployment dynamics, and system performance for Large Space Structures (LSS). A Ground Facility (GF), in which the dynamics and control systems being considered for LSS applications can be verified, was designed and built. One of the important aspects of the GF is to verify the analytical model for the control system design. The procedure is to describe the control system mathematically as well as possible, then to perform tests on the control system, and finally to factor those results into the mathematical model. The reduction of the order of a higher order control plant was addressed. The computer program was improved for the maximum entropy principle adopted in Hyland's MEOP method. The program was tested against the testing problem. It resulted in a very close match. Two methods of model reduction were examined: Wilson's model reduction method and Hyland's optimal projection (OP) method. Design of a computer program for Hyland's OP method was attempted. Due to the difficulty encountered at the stage where a special matrix factorization technique is needed in order to obtain the required projection matrix, the program was successful up to the finding of the Linear Quadratic Gaussian solution but not beyond. Numerical results along with computer programs which employed ORACLS are presented. Author

N90-16826# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
HERMES GROUND OPERATION CONCEPTS
FRITZ GAMPE and PIERRE LETALLE (MATRA Espace, Toulouse, France) *In its* Progress in Space Transportation p 351-356 Aug. 1989
Copyright Avail: NTIS HC A22/MF A03

The Hermes ground operations, from touch-down to the following launch are described. The steps required to make the complete spaceplane vehicle ready for flight again are outlined. The accommodation of new cargo is described. The ground operations concept is designed to handle sixty flights by two spaceplanes over a series of fifteen years. Its missions include flights to the Columbus Free-Flying Laboratory, the Freedom Space Station (FSS), and crew rescue missions to the FSS. ESA

N90-18472*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCED APS IMPACTS ON VEHICLE PAYLOADS
STEVEN J. SCHNEIDER and BRIAN D. REED *In* Johns Hopkins Univ., The 1989 JANNAF Propulsion Meeting, Volume 1 p 209-218 May 1989 Previously announced as N89-25254
Avail: NTIS HC A25/MF A04 CSCL 21/8

Advanced auxiliary propulsion system (APS) technology has the potential to both, increase the payload capability of earth-to-orbit (ETO) vehicles by reducing APS propellant mass, and simplify ground operations and logistics by reducing the number of fluids on the vehicle and eliminating toxic, corrosive propellants. The impact of integrated cryogenic APS on vehicle payloads is addressed. In this system, launch propulsion system residuals are scavenged from integral launch propulsion tanks for use in the APS. Sufficient propellant is preloaded into the APS to return to earth with margin and noncomplete scavenging assumed. No propellant conditioning is required by the APS, but ambient heat soak is accommodated. High temperature rocket materials enable the use of the unconditioned hydrogen/oxygen in the APS and are estimated to give APS rockets specific impulse of up to about 444 sec. The payload benefits are quantified and compared with an uprated monomethyl hydrazine/nitrogen tetroxide system in a conservative fashion, by assuming a 25.5 percent weight growth for the hydrogen/oxygen system and a 0 percent weight growth for the uprated system. The combination and scavenging and high performance gives payload impacts which are highly mission specific. A payload benefit of 861 kg (1898 lbm) was estimated for a Space Station Freedom rendezvous mission and 2099 kg (4626 lbm) for a sortie mission, with payload impacts varying with the amount of launch propulsion residual propellants. Missions without liquid propellant scavenging were estimated to have payload penalties, however, operational benefits were still possible. Author

N90-19271*# Ball Aerospace Systems Div., Boulder, CO.
REMOTE ATTITUDE MEASUREMENT SENSOR (RAMS)
H. W. DAVIS *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 339-368 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 14/2

Remote attitude measurement sensor (RAMS) offers a low-cost, low-risk, proven design concept that is based on mature, demonstrated space sensor technology. The electronic design concepts and interpolation algorithms were tested and proven in space hardware like th Retroreflector Field Tracker and various star trackers. The RAMS concept is versatile and has broad applicability to both ground testing and spacecraft needs. It is ideal for use as a precision laboratory sensor for structural dynamics testing. It requires very little set-up or preparation time and the output data is immediately usable without integration or extensive analysis efforts. For on-orbit use, RAMS rivals any other type of dynamic structural sensor (accelerometer, lidar, photogrammetric techniques, etc.) for overall performance, reliability, suitability, and cost. Widespread acceptance and extensive usage of RAMS will occur only after some interested agency, such as OAST, adopts the RAMS concept and provides the funding support necessary for further development and implementation of RAMS for a specific program. Author

N90-19484*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
HIGH POWER, HIGH FREQUENCY COMPONENT TEST FACILITY
MARY ELLEN ROTH and WALTER KRAWCZONEK (Sverdrup Technology, Inc., Cleveland, OH.) Feb. 1990 12 p
(NASA-TM-102500; E-5297; NAS 1.15:102500) Avail: NTIS HC A03/MF A01 CSCL 09/1

The NASA Lewis Research Center has available a high frequency, high power laboratory facility for testing various components of aerospace and/or terrestrial power systems. This facility is described here. All of its capabilities and potential applications are detailed. Author

04

SPACE ENVIRONMENTS

The external environment of space including debris or meteoroid hazards, electrical and plasma interactions, and the presence of atomic oxygen or other chemical species.

A90-11020#
PHOTOCHEMICAL SPACECRAFT SELF-CONTAMINATION - LABORATORY RESULTS AND SYSTEMS IMPACTS
THOMAS B. STEWART, GRAHAM S. ARNOLD, DAVID F. HALL, DEAN C. MARVIN, WARREN C. HWANG (Aerospace Corp., El Segundo, CA) et al. Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Sept.-Oct. 1989, p. 358-367. Research sponsored by the Aerospace Corp. Previously cited in issue 18, p. 3015, Accession no. A88-44597. refs
(Contract F04701-85-C-0086)
Copyright

A90-11508* Augsburg Coll., Minneapolis, MN.
DISTORTION EFFECTS IN SPACECRAFT OBSERVATIONS OF MHD TOROIDAL STANDING WAVES - THEORY AND OBSERVATIONS
B. J. ANDERSON, M. J. ENGEBRETSON (Augsburg College, Minneapolis, MN), and L. J. ZANETTI (Johns Hopkins University,

Laurel, MD) Journal of Geophysical Research (ISSN 0148-0227), vol. 94, Oct. 1, 1989, p. 13425-13445. Research supported by NASA. refs
(Contract N00024-85-C-5301; NSF ATM-86-06388)
Copyright

This paper considers the distortion effect of the simultaneous occurrence of locally resonant toroidal pulsations over a range of L shells on the interpretation of spacecraft observations of these waves. A theoretical model is developed which yields quantitative predictions of the phase shear effect that causes a shift from the true pulsation frequency measured from a spacecraft moving radially across L shells. Calculations with this model indicate that, due to this effect, the AMPTE/CCE satellite should observe 8-30 percent lower frequencies on outbound passes than on inbound passes. A comparison of fundamental mode frequency measurements made on 10 inbound and 9 outbound passes of the AMPTE/CCE satellite in the morning sector confirms the predictions of the model. I.S.

A90-12224
SHUTTLE GLOW
DONALD E. HUNTON (USAF, Geophysics Laboratory, Hanscom AFB, MA) Scientific American (ISSN 0036-8733), vol. 261, Nov. 1989, p. 92-98. refs
Copyright

Consideration is given to the characteristics of the atmosphere in low earth orbit, which lead to material erosion and a glow above the Space Shuttle's tail and engine pods. The atmosphere at earth is compared to that at the level of Shuttle flight. Experiments showing the role of atomic oxygen in the erosion of Shuttle surfaces are reviewed. Also, experiments on Shuttle glow are reported, suggesting that the molecules responsible for Shuttle glow are NO and NO2 manufactured from N and O atoms adsorbed on the glow-producing surface. Plans for future experiments on surface erosion and Shuttle glow are outlined. R.B.

A90-13400*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
FUTURE SPACE TRANSPORTATION REQUIREMENTS FOR THE MANAGEMENT OF ORBITAL DEBRIS
ANDREW J. PETRO and JOSEPH P. LOFTUS, JR. (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-244)

Launch vehicle upper stages continue to contribute to future orbital debris scenarios whenever they undergo explosive propulsion system failures, as well as by remaining on orbit as potential collision targets for smaller orbiting bodies. No active measures have been instituted to date in order to remove nonfunctional satellites or spent rocket stages from earth orbit; they are nevertheless conceivable, and classifiable as (1) orbital-maneuvering retrieval; (2) self-disposal; and (3) propulsive deorbit or atmospheric drag augmentation. Illustrative cases and parametric assessments of these methods' feasibility and cost are presented. O.C.

A90-13455#
PREPARATION AND EVALUATION OF CONDUCTIVE THIN FILMS FOR CONTROLLING CHARGING STATE ON SPACECRAFT SURFACE
YUSUN LU and HUA LI (Lanzhou Institute of Physics, People's Republic of China) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-322) Copyright

A brief mathematical analysis of the charge accumulation state on a spacecraft surface is presented. The evaluation of charging state of thin coated films of ITO, IO, and TO on substrate was carried out in a simulated space environment. Results demonstrate the importance of the surface modification technique in reducing the difference in potential as well as in increasing the reactive sensitivity of voltage on spacecraft surfaces. The ITO, IO films possess excellent optical, electric, and thermodynamic properties suitable for material improvement on spacecraft surfaces. C.E.

A90-13648#
SPACE DEBRIS - STATUS, CONCERNS, AND SOLUTIONS
L. R. UTREJA (BDM International, Inc., Huntsville, AL) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. refs
(IAF PAPER 89-625) Copyright

The current man-made space debris environment is reviewed with special reference to the Space Station. Space debris safety regulations are discussed, and space debris warning and monitoring systems are described. Space Station design analysis approaches relevant to space debris hazards are addressed. Hypersonic test facilities and oblique impact testing are discussed. C.D.

A90-13649#
UNDERSTANDING THE TRUE EARTH SATELLITE POPULATION
D. S. MCKNIGHT (U.S. Air Force Academy, Colorado Springs, CO), N. L. JOHNSON (Teledyne Brown Engineering, Colorado Springs, CO), and F. K. SCHWETJE IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p.
(IAF PAPER 89-627)

Recent analysis now reveals that the accepted interpretation of the historical record of the cataloged on-orbit population grow this in error. The true growth of the detectable earth satellite population differs in a variety of substantial aspects from current interpretations. The single largest contribution to the earth satellite population, accounting for one-half of all cataloged satellites now in orbit, is the debris resulting from satellite fragmentations. Although the debris is instantly injected into the near earth environment, hardware and manpower resources dictate a more gradual official recognition of the change in the satellite population. To correct for this error, the cataloging history for all debris of each of the nearly 100 identified satellite fragmentations was examined and their addition to the population at the moment of creation was correctly modeled. The most important observation from this analysis is that there has been a steady negative growth rate in the true population since 1985, culminating in an actual decrease in population in 1988. Additionally, a linear growth of 240 objects per year provides good correlation with the true population evolution over the last twenty years leading to less pessimistic short-term predictions of debris growth. Author

A90-13650#
CHAIN REACTION OF DEBRIS GENERATION BY COLLISIONS IN SPACE - A FINAL THREAT TO SPACEFLIGHT?
P. EICHLER and D. REX (Braunschweig, Technische Universitaet, Brunswick, Federal Repubic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. Research supported by BMFT.
(IAF PAPER 89-628) Copyright

The present risk of collision with orbital debris is evaluated, and a program for simulating the collision risk is described. The risk is found to be about 20 percent a year for a collision among an assumed current population of about 35,000 objects larger than 1 cm in earth orbits. The evolution of the debris population is described, and it is estimated that an equilibrium population of about 150,000 to 200,000 objects larger than 1 cm could occur. The critical population for starting a chain reaction of collisions is estimated, as is the future increased risk of such a reaction and the altitude of the reaction. The importance of larger objects for collision risk is addressed, and measures for preventing a chain reaction are examined. C.D.

A90-13651#
DETECTING SPACE DEBRIS ABOVE 900 KM USING IRAS
L. WALSH, P. R. WESSELIUS (SRON, Laboratorium voor Ruimteonderzoek, Groningen, Netherlands), and H. OLTHOF (ESTEC, Noordwijk, Netherlands) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p. Research supported by ESA.
(IAF PAPER 89-629) Copyright

Survey data, collected during 1983 by the Infra-red Astronomical

Satellite (IRAS), has been used to construct several time-delayed images of a chosen sky region. These images have been compared in a search for transitory, earth-orbiting, solar system objects. Five such objects have been located and theory developed to relate their orbital elements to their IRAS detection parameters. These objects are considered to be man-made space debris candidates, and an assessment (with results) of the suitability of the IRAS data base for the extraction of space debris parameters is presented. Author

A90-13719#
SPACE DEBRIS AND ITS UTILISATION
RALPH D. LORENZ (Southampton, University, England) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. Research supported by the University of Southampton. refs
(IAF PAPER ST-89-001) Copyright

The space debris hazard is briefly described, and the sources of debris are identified. Debris may be effectively classified into three types: particles, fragments and artifacts. While it is only practicable to limit the hazard due to the third category, it is shown that collisions can generate further debris, so the future total debris population depends largely on the current artifact population. If the future hazard is to be minimized, the artifact population must be limited. A dedicated debris collection vehicle may offer the best method of achieving this and some design aspects of an outline of such a vehicle are considered. It is further suggested that the mass of recovered artifacts may permit their utilization in space tethers for momentum exchange. Other aspects and uses are considered. Author

A90-14726#
MOTION OF PARTICULATE MATERIAL EJECTED FROM A ROTATING SPACE PLATFORM
RHONALD M. JENKINS, JOHN E. COCHRAN, JR., and KENNETH A. PHELPS (Auburn University, AL) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 769, 770.
Copyright

The present investigation of the dynamics of particulate material ejected from a rotating space platform models a cloud of the material as a collection of discrete, finite-sized particles; the tracking problem thereby becomes solvable through a simulation of the motion of nonmutually interacting two-body systems. The coordinate system for the equations of motion is given with respect to a rotating space platform in earth orbit, and encompasses the effects of gravity and other external forces. The time-histories of particle positions and velocities obtained through numerical integration of the resulting nonlinear equations indicate that, for initial conditions corresponding to altitudes at which aerodynamic drag is significant, some of the ejected particulate material may recontact the platform. O.C.

A90-15094
ELECTRIC DIPOLE ANTENNAE USED AS MICROMETEOROID DETECTORS
J. M. LESCEUX, J. LEMAIRE (Institut d'Aeronomie Spatiale de Belgique, Brussels, Belgium), and N. MEYER-VERNET (Paris, Observatoire, Meudon, France) Planetary and Space Science (ISSN 0032-0633), vol. 37, Oct. 1989, p. 1291-1302. refs
Copyright

The possibility of using electric antennae made of two small spheres to study the velocity distribution of charged dust grains in space are examined in this paper. The electric potential difference between the two spheres is determined by solving the Poisson's equation in a dusty plasma. Several examples of waveforms are shown. Typical dust grains with radii of 100 microns and signals of the order of 500 micorvolts are produced. The limitations due to the antenna and the plasma are also examined. A table summarizes the results under different conditions. It is concluded that, with a system of antennae, it is possible to detect (especially near comets and planetary ionospheres) dusts and to determine their velocity characteristics. Author

A90-17817#
SOLAR CYCLE EFFECTS ON TRAPPED ENERGETIC PARTICLES
A. L. VAMPOLA (Aerospace Corp., Los Angeles, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Nov.-Dec. 1989, p. 416-427. refs
(Contract F04701-85-C-0086)
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The energetic particle populations in the earth's magnetosphere, which are the result of geomagnetic activity and, ultimately, are due to solar activity, have a major impact on the operation and survival of spacecraft. Departures from the nominal in solar activity produce requirements for changes from the nominal in the design and operation of spacecraft. If the approaching solar maximum is a robust one, as is indicated by preliminary solar data, the energetic particle population can be expected to be in excess of that predicted by particle models such as AE8 and AP8, since those models include solar-cycle effects based on nonimal solar activity. In the event of a robust solar cycle, accelerated degradation of electronics and power systems, increased sensor background effects, and more frequent operational anomalies may be expected on spacecraft that were designed for a nominal solar cycle. This paper discusses the relationships between solar activity and geomagnetic activity and provides a short tutorial on the mechanisms by which the energetic particle environment is produced and modified by magnetic activity. As an aid to spacecraft systems design and mission planning, the paper also indicates the types of changes from a nominal energetic particle population that could be expected based on a robust solar cycle 22. Author

A90-17818#
SOLAR CYCLE EFFECTS ON NEAR-EARTH PLASMAS AND SPACE SYSTEMS
D. J. GORNEY (Aerospace Corp., Los Angeles, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Nov.-Dec. 1989, p. 428-438. refs
(Contract F04701-86-C-0087)
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Recently, solar physicists have predicted with ever-increasing confidence that the upcoming maximum of solar activity, scheduled to occur near 1990, might be the most extreme ever recorded. Unfortunately, because of the complex and sometimes direct interactions between the sun and the plasma environment in near-earth space, very few firm quantitative predictions can be made regarding the expected effects of an extreme solar maximum on the near-earth environment or on the complex systems operating in that environment. However, a number of qualitative predictions can be made with high confidence. Satellite communications links in the vhf/uhf range will suffer signal fades more often and with greater severity. Short-wave and airline communications will be sporadically disrupted. Satellites will experience electrical charging of their surface and internal dielectric components, resulting in disruptive electrostatic discharges, and microelectronic devices on satellites will experience upsets more often. The purpose of this paper is to review the direct and indirect influences of solar activity on the near-earth plasma environment and on systems that operate within that environment. Author

A90-17819#
SOLAR CYCLE EFFECTS ON THE UPPER ATMOSPHERE - IMPLICATIONS FOR SATELLITE DRAG
R. L. WALTERSCHEID (Aerospace Corp., Los Angeles, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Nov.-Dec. 1989, p. 439-444. Research supported by the Aerospace Corp. refs
Copyright

High thermospheric temperatures are maintained against thermal diffusion primarily by the absorption of extreme ultraviolet (EUV) radiation by atmospheric constituents (mainly, atomic oxygen). Because the solar flux of EUV varies strongly over the 11-yr solar cycle, thermospheric temperatures likewise vary strongly over the solar cycle. In an average solar cycle, solar EUV and

thermospheric temperature increase by about a factor of two from solar cycle minimum to solar cycle maximum. Because density is mainly an integrated effect of temperature, the change in density over the solar cycle is amplified with respect to the temperature change. Changes in temperature cause changes in composition and these changes act to mitigate the direct thermal effects. The net effect of temperature and composition is to give order-of-magnitude changes in density over the solar cycle. The atmospheric drag on satellites is proportional to atmospheric density. The effects on satellite lifetimes are profound. A fairly typical satellite initially at 500 km would have a lifetime of about 30 years under typical solar cycle minimum conditions and only about 3 years under solar maximum conditions. Large increases in the rate of change of orbital period from solar minimum to solar maximum are possible. The fractional increase in the highly reactive species atomic oxygen can exceed two orders of magnitude. Author

A90-17822#
DETERMINING CHARACTERISTIC MASS FOR LOW-EARTH-ORBITING DEBRIS OBJECTS
MICHAEL R. DICKEY and ROBERT D. CULP (Colorado, University, Boulder) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Nov.-Dec. 1989, p. 460-464. Previously cited in issue 21, p. 3512, Accession no. A88-50436. refs

A90-18004* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ORBITAL DEBRIS FROM UPPER-STAGE BREAKUP
JOSEPH P. LOFTUS, JR., ED. (NASA, Johnson Space Center, Houston, TX) Washington, DC, American Institute of Aeronautics and Astronautics, Inc. (Progress in Astronautics and Aeronautics. Volume 121), 1989, 235 p. For individual items see A90-18005 to A90-18018.

The present conference on the effects of launch vehicle upper-stage breakup on the orbital debris scenario discusses an analysis of the SPOT 1 Ariane third stage, the explosive fragmentation of orbiting propellant tanks, albedo estimates for debris, Ariane-related debris in deep-space orbit, and the relationship of hypervelocity impacts to upper-stage breakups. Also discussed are the prospects for and the economics of the future removal of orbital debris, collision probabilities in GEO, current operational practices for Delta second stage breakup prevention, breakup-precluding modifications to the Ariane third stage, and the safing of the H-1 second stage after spacecraft separation. O.C.

A90-18005*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
CURRENT ORBITAL DEBRIS ENVIRONMENT
DONALD J. KESSLER (NASA, Johnson Space Center, Houston, TX) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 3-13. refs

NASA has instituted a plan for the definition of activities and resources required over the coming decade for the deepening of current understanding of anthropogenic orbital debris, and its effects on future mission operations. This understanding will be the basis of policy definition and policy implementation efforts. The most immediate requirement is the definition of the debris environment, with emphasis on data for debris sizes smaller than 4 cm. Systems-damage criteria and hypervelocity-impact theory will then be used to define the hazard to specific spacecraft. O.C.

A90-18006#
EVOLUTION OF THE ARTIFICIAL EARTH SATELLITE ENVIRONMENT
NICHOLAS L. JOHNSON (Teledyne Brown Engineering, Colorado Springs, CO) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 15-23.

Orbiting upper-stage breakup debris has come to reside in a small number of specific orbital regions defined by altitude and inclination. Unfortunately, the orbital planes in question are randomly distributed; the debris therefore poses a hazard to virtually all satellites, operational and nonoperational, currently in orbit. In November of 1986, the SPOT/Viking rocket fragmented into almost 500 detectable pieces. Some of this debris already traverses the altitudes frequented by manned spacecraft. The cause of fragmentation is under investigation. O.C.

A90-18007*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
HYPERVELOCITY IMPACTS AND UPPER-STAGE BREAKUPS
B. G. COUR-PALAIS and J. L. CREWS (NASA, Johnson Space Center, Houston, TX) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 25-38. refs

Preliminary analysis results have been obtained for tests conducted to ascertain whether a distinctive fragmentation 'signature' allows discrimination between launch vehicle upper stage destructions due to hypervelocity particle impacts and internal explosions. An account is presently given of factors controlling the damage pattern created by hypervelocity impacts, and an evaluation is made of the applicability of the simulation results obtained to actual upper stage destruction characterization. O.C.

A90-18008#
PRELIMINARY ANALYSIS OF THE FRAGMENTATION OF THE SPOT 1 ARIANE THIRD STAGE
NICHOLAS L. JOHNSON (Teledyne Brown Engineering, Colorado Springs, CO) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 41-106.

On November 13, 1986, the SPOT 1 Ariane third stage, unaccountably, explosively separated into 465 detectable fragments, the great majority of which are not expected to constitute a hazard to spacecraft operations for hundreds of years. Additional Ariane third stages may have broken up as a result of the mechanism suspected for the 1986 explosion, a residual liquid rocket propellant overpressurization of fuel tanks. The possibility that the SPOT 1 Ariane third stage was struck by an unseen hypervelocity object has not, however, been ruled out; an asymmetry in debris ejection pattern may help establish the more probable cause. O.C.

A90-18009*# National Aeronautics and Space Administration. White Sands Test Facility, NM.
EXPLOSIVE FRAGMENTATION OF ORBITING PROPELLANT TANKS
F. J. BENZ (NASA, White Sands Test Facility, Las Cruces, NM), R. L. KAYS (Lockheed Engineering and Sciences Co., Las Cruces, NM), C. V. BISHOP (McGean Rohco, Inc., Cleveland, OH), and M. B. ECK (Fairchild Space Co., Germantown, MD) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 107-129. refs

An examination is made of the in-orbit explosive characteristics of the Delta second stage and Ariane third stage, with a view to the vehicle breakups of the Ariane SPOT third-stage fuel tank in November, 1986, and of two Delta second stage tanks. Attention is given to the possible role of residual propellants in these breakups. After reviewing orbital data and comparing predicted fragment velocities with observed fragment velocities in debris patterns, a comparison has been made of total debris energy with total calculated explosion energy. Both physical and chemical explosions are deemed possible. O.C.

A90-18010*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ALBEDO ESTIMATES FOR DEBRIS
A. E. POTTER, KARL G. HENIZE (NASA, Johnson Space Center, Houston, TX), and D. L. TALENT (Lockheed Engineering and Sciences Co., Houston, TX) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 147-156.
Copyright

The albedo of upper-stage breakup debris is proposed as an accurate discriminator among the various possible causes of breakup, which encompass residual fuel explosions and hypervelocity particle impacts. The fragments from an impact are covered with a thin layer of soot deposited from the destruction of polymeric circuit boards, while pressure vessel explosion fragments can be expected to remain soot-free. Albedo also facilitates the interpretation of small-debris optical telescope measurements. O.C.

A90-18011*# Massachusetts Inst. of Tech., Lexington.
ARIANE-RELATED DEBRIS IN DEEP-SPACE ORBIT
L. G. TAFF (MIT, Lexington, MA) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 157-162. refs
(Contract NAS9-17138)

A group of data bases for deep-space artificial satellites has been analyzed for orbital element sets exhibiting mean motions within 1.5 rev/day of 2.2 rev/day, eccentricity within 0.3 of 0.73, and inclination within 3 deg of 6.2 deg, as would be expected of Ariane upper stage explosion debris. The rapid growth of objects in these Ariane-type orbits is consistent with the two recorded explosions of Ariane launch vehicle upper stage elements. About 250 objects are currently being tracked. O.C.

A90-18013*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
REMOVAL OF ORBITAL DEBRIS
ANDREW J. PETRO (NASA, Johnson Space Center, Houston, TX) and DAVID L. TALENT (Lockheed Engineering and Sciences Co., Houston, TX) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 169-182.
Copyright

The several methods presently identified for the reduction of orbital debris populations are broadly classifiable as either preventive or remedial, and fall within distinctive operational regimes. For all particles, (1) in the 250-2000-km altitude band, intelligent sweepers may be used; (2) for large objects, in the 80-250-km altitude band, orbital decay renders removal impractical; (3) for the 250-750-km altitude band, deorbit devices should be used; (4) for 750-2500-km altitude, OMV rendezvous for propulsive deorbit package attachment is foreseeable; and beyond 2500 km, (5) propulsive escape from earth orbit is required. O.C.

A90-18014*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
COST ESTIMATES FOR REMOVAL OF ORBITAL DEBRIS
ANDREW PETRO and HOWARD ASHLEY (NASA, Johnson Space Center, Houston, TX) IN: Orbital debris from upper-stage breakup. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 183-186.
Copyright

While there are currently no active measures for the removal of nonfunctional satellites or spent rocket stages from earth orbit, it has been deemed prudent to begin to identify and economically evaluate potential approaches for such orbital decluttering. The methods presently considered encompass retrieval with an OMV, forcible deorbiting via attached propulsive devices, and deorbiting via passive, drag-augmentation devices; the increases in payload-delivery costs they represent are respectively $15-20 million/object, $7.8 million/vehicle, and $5.5-15.5 million/unit. OMV removal appears the least economically feasible method. O.C.

A90-18744
EUROPEAN INVESTIGATIONS ON ORBITAL DEBRIS
D. REX (ESA, Space Debris Working Group, Brunswick, Federal Republic of Germany) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 347-358. refs
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The European Space Agency has put together a working group of European scientists in the space debris field with the objective to submit a report which is to appear by the end of 1988. The report will deal with the available data on space debris, the situation in low earth orbits and in the geostationary orbit and with the risks posed on ground by re-entering space objects. It will also cover preventive measures and legal aspects. Data and methods used by European investigators and the results obtained are reviewed in this paper. Author

A90-18745
REVIEW OF CURRENT ACTIVITIES TO MODEL AND MEASURE THE ORBITAL DEBRIS ENVIRONMENT IN LOW-EARTH ORBIT
R. C. REYNOLDS (Lockheed Engineering and Sciences Co., Houston, TX) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 359-371. refs
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A very active orbital debris program is currently being pursued at the NASA/Johnson Space Center (JSC), with projects designed to better define the current environment, to project future environments, to model the processes contributing to or constraining the growth of debris in the environment, and to gather supporting data needed to improve the understanding of the orbital debris problem and the hazard it presents to spacecraft. This paper is a review of the activity being conducted at JSC, by NASA, Lockheed Engineering and Sciences Company, and other support contractors, and presents a review of current activity, results of current research, and a discussion of directions for future development. Author

A90-18746
THE NEED FOR OPTICAL STUDY OF SPACE DEBRIS PARENTAGE
P. MALEY (Houston Museum of Natural Science, TX) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 373-376.
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Signature data from optical tracking of certain Cosmos satellite payloads has been found to produce useful data on their behavior. Satellites can be grouped not only by orbital element parameters, but by visible light signature. Intentional explosions have occurred on a continual basis since 1974 following mission completion of many Cosmos 699-type payloads. Other applications for optically derived data are discussed. Author

A90-18747* Arizona Univ., Tucson.
THERMAL MODELS APPLICABLE FOR VISUAL AND INFRARED STUDIES OF ORBITAL DEBRIS
LARRY A. LEBOFSKY (Arizona, University, Tucson) and FAITH VILAS (NASA, Johnson Space Center, Houston, TX) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 377-380. refs
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Over the past decade, thermal models have been developed for the determination of asteroid diameters and albedos. As a

first step to understanding the size/frequency distribution of the debris population in earth orbit, these thermal models have been modified to determine the sizes of orbiting debris. When possible, the model results have been compared to spherical satellites of known diameter. Author

A90-18748* Arizona Univ., Tucson.
THE DETECTION OF EARTH ORBITING OBJECTS BY IRAS
KIMBERLY L. DOW, MARK V. SYKES, FRANK J. LOW (Steward Observatory, Tucson, AZ), and FAITH VILAS (NASA, Johnson Space Flight Center, Houston, TX) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 381-384.
Copyright

A systematic examination of 1836 images of the sky constructed from scans made by the Infrared Astronomical Satellite has resulted in the detection of 466 objects which are shown to be in earth orbit. Analysis of the spatial and size distribution and thermal properties of these objets, which may include payloads, rocket bodies and debris particles, is being conducted as one step in a feasibility study for space-based debris detection technologies. Author

A90-18749
A PHASED APPROACH TO COLLISION HAZARD ANALYSIS
D. MCKNIGHT (U.S. Air Force Academy, Colorado Springs, CO) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 385-388.
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An analysis tool is proposed which evaluates the hazard to operational satellites from neighboring breakup events. The debris cloud from a satellite fragmentation is modeled as three concentric, overlapping clouds. The evolution of this debris cloud is represented in three distinct phases which in turn determine the resulting collision hazard to satellites at risk. This model, SCREEN, provides an efficient and robust method for quantifying the hazard to operational satellites from the fragmentation of other space systems. Use of SCREEN shows that a time independent hazard assessment is sufficient for many satellite systems. Author

A90-18750
THE VELOCITY DISTRIBUTION OF COLLISIONAL FRAGMENTS AND ITS EFFECT ON FUTURE SPACE DEBRIS ENVIRONMENT
S.-Y. SU (National Central University, Chung-Li, Republic of China) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 389-392. refs
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An empirical formula for the velocity versus size distribution of ejecta fragments obtained in a recent hypervelocity impact experiment has been scaled to include the projectile momentum and energy. The new velocity distribution of the ejecta is found to depend on the projectile energy, and the ejecta can now escape with a wide range of velocities for the same sized fragments when the target is impacted by projectiles with different sizes and energies. The effect of this new ejecta velocity distribution on the evolution of the future space debris environment is such that the newly generated ejecta fragments from collisions between orbiting objects can spread to various altitudes making other regions of space unsafe. Author

A90-18751* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
COLLISION PROBABILITY AT LOW ALTITUDES RESULTING FROM ELLIPTICAL ORBITS
DONALD J. KESSLER (NASA, Johnson Space Center, Houston, TX) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 393-396. refs
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The probability of collision between a spacecraft and another object is calculated for various altitude and orbit conditions, and factors affecting the probability are discussed. It is shown that a collision can only occur when the spacecraft is located at an altitude which is between the perigee and apogee altitudes of the object and that the probability per unit time is largest when the orbit of the object is nearly circular. However, at low altitudes, the atmospheric drag causes changes with time of the perigee and the apogee, such that circular orbits have a much shorter lifetime than many of the elliptical orbits. Thus, when the collision probability is integrated over the lifetime of the orbiting object, some elliptical orbits are found to have much higher total collision probability than circular orbits. Rocket bodies used to boost payloads from low earth orbit to geosynchronous orbit are an example of objects in these elliptical orbits. I.S.

A90-18752
ARAGATZ MISSION DUST COLLECTION EXPERIMENT
J. C. MANDEVILLE (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 397-401. refs
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Upon the next joint Soviet-French mision on the MIR space station, planned for the end of 1988, an experiment devoted to the collection and detection of cosmic dust and space debris will be deployed in space. A description of the proposed experimental device and anticipated results are given. Author

A90-18753
THE SPATIAL DISTRIBUTION OF SUBMICRON-SIZED DEBRIS IN THE TERRESTRIAL MAGNETOSPHERE
MIHALY HORANYI (Florida State University, Tallahassee) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 403-407. refs
(Contract DE-FC05-85ER-25000)
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The spatial distribution of submicron-sized debris in the terrestrial magnetosphere was studied using computer simulations to investigate the spatial distribution of 0.1-micron sized Al2O3 grains dumped into the magnetosphere during solid-rocket-propellant burns. The results on the evolution of a dust ring around a geosynchronous orbit, the variations of the electrostatic charge of a grain, and the effect of the geomagnetic activity are examined. It is shown that the lifetime of a 0.1-micron Al2O3 particle in the earth atmosphere is determiend by the solar radiation pressure and that the spatial distribution is also sensitive to the electrostatic charge of the grains. It is concluded that the Al2O3 grains may pose an environmental hazard in the geosynchronous environment as their electrostatic potential can vary from -2 to +11 volts, depending on the geomagnetic activity level. I.S.

A90-18754
MICRON AND SUBMICRON DEBRIS - LUNAR EJECTA CONCENTRATIONS BETWEEN L VALUES OF 1.7 AND 3.0 IN THE EARTH'S MAGNETOSPHERE
T. W. HYDE and W. M. ALEXANDER (Baylor University, Waco, TX) (COSPAR, IAA, IAU, and IUGG, Plenary Meeting, 27th, Symposium, Workshops, and Topical Meetings on Smaller Solar System Bodies and Orbits, Espoo, Finland, July 18-29, 1988)

Advances in Space Research (ISSN 0273-1177), vol. 10, no. 3-4, 1990, p. 409-412. Research supported by Baylor University. refs
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Recent investigations have discovered evidence of micron and submicron impacts on returned spacecraft surfaces which have been exposed in near earth space. These craters are generally assumed to be due to particles of near earth origin. The theoretical possibility that some of them could be due to impacts caused by lunar ejecta, as well as the possibility that lunar ejecta may exist in enhanced spatial density regions of the earth's magnetosphere between L values of 1.7 and 3.0, is discussed. A comparison of trapping dynamics is made between micron and submicron debris injected into the earth's magnetosphere during solid rocket propellent burns and ejecta in the earth's magnetosphere originating on the lunar surface. The possible effects of particle charging on trapping and quasi-trapping in this size range are discussed. Author

A90-18903
RETRIEVAL OF ATOMIC OXYGEN AND TEMPERATURE IN THE THERMOSPHERE. I - FEASIBILITY OF AN EXPERIMENT BASED ON THE SPECTRALLY RESOLVED 147 MICRON LIMB EMISSION
A. S. ZACHOR (Atmospheric Radiation Consultants, Inc., Acton, MA) and R. D. SHARMA (USAF, Geophysics Laboratory, Hanscom AFB, MA) Planetary and Space Science (ISSN 0032-0633), vol. 37, Nov. 1989, p. 1333-1346. refs
(Contract F19628-87-C-0053)
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Consideration is given to the possibility of recovering vertical profiles of the temperature and O-atom density from limb scan data obtained near 147 and/or 63 microns wavelength. It is shown that the two vertical profiles may be recovered by applying an onion-peeling method to synthetic data. The temperature and O-atom density are obtained simultaneously by a nonlinear least-squares spectrum fitting. It is found that spectral data in the 147-micron line from 300 km down to 130-90 km in altitude produces better results than the 63-micron data below 140 km. It is suggested that a confocal Fabry-Perot system operating near 147 microns could provide the S/N ratio and spectral resolution needed for successful retrievals. Retrievals down to 90 km from data obtained at orbital altitude would require cooled foreoptics with a diameter of about 1 meter. R.B.

A90-19677*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
EFFECTS ON THE ORBITAL DEBRIS ENVIRONMENT DUE TO SOLAR ACTIVITY
DONALD J. KESSLER (NASA, Johnson Space Center, Houston, TX) and PHILLIP D. ANZ-MEADOR (Lockheed Engineering and Sciences Co., Houston, TX) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 5 p. refs
(AIAA PAPER 90-0083) Copyright

The rate that earth-orbiting debris is removed from the environment is dependent on a number of factors which include orbital altitude and solar activity. It is generally believed that at lower altitudes and especially during periods of high solar activity, debris generated in the past will be eliminated from the environment. While some debris is eliminated, most is replaced by old debris from higher altitudes or new debris from recent launches. Some low altitude debris, which would reenter if the debris were in circular orbits, does not reenter because the debris is in higher-energy elliptical orbits. Author

A90-19678#
DEBRIS CREATION VIA HYPERVELOCITY IMPACT
DARREN S. MCKNIGHT and CHRISTOPHER B. BRECHIN (U.S. Air Force Academy, Colorado Springs, CO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 5 p. refs
(AIAA PAPER 90-0084)

Recent tests on the destruction of space structures via hypervelocity impact are analyzed by characterizing their mass distribution data and correlating impact parameters with breakup response. A variety of mathematical relationships are used to represent the experimental mass distributions. None of the curves work well as predictive tools despite high positive correlations between the terms and impact energy. The inability to generate a robust relationship between collision parameters and break response is addressed. C.D.

A90-19679#
DEBRIS EVOLUTION AND LIFETIME FOLLOWING AN ORBITAL BREAKUP
V. A. CHOBOTOV and D. B. SPENCER (Aerospace Corp., Los Angeles, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p. refs
(AIAA PAPER 90-0085) Copyright

The study of debris evolution and lifetime is important in assessing the collision hazard posed to other spacecraft by a debris-producing spacecraft breakup. This paper describes the theory and use of the Impact program, which models direct-impact and glancing-blow collisions and a low-intensity explosion scenario. The representation and evolution of an orbiting debris cloud as modeled in the Debris program, which determines the probability of collision when a resident space object enters the debris cloud, is also described. C.D.

A90-19680*# Science Applications International Corp., Huntsville, AL.
SPACECRAFT PROTECTIVE STRUCTURES DESIGN OPTIMIZATION
ROBERT A. MOG (Science Applications International Corp., Huntsville, AL) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. refs
(Contract NAS8-37378)
(AIAA PAPER 90-0087) Copyright

The optimization of spacecraft protective structures design to defeat hypervelocity impacts of meteoroids and space debris is presented. A space debris environment model is incorporated into an overall optimization methodology employing engineering models developed to predict protective structures design requirements for hypervelocity impact loads. Several nonlinear optimization techniques are used to generate design parametrics based on environment, mission, and configuration variables for the Space Station Core Module Configuration. Results indicate that careful consideration of the spacecraft structural configuration and materials can partially offset the design consequences of dramatic increases in the orbital space debris environment. Furthermore, the use of nonlinear optimization techniques coupled with hypervelocity impact engineering models can provide significant design tradeoff insight through the use of parametric analyses. Author

A90-19717*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
AN ONLINE SPACECRAFT ENVIRONMENT INTERACTIONS INFORMATION SYSTEM
MICHAEL LAURIENTE (NASA, Goddard Space Flight Center, Greenbelt, MD) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 8 p. Research supported by USAF. refs
(AIAA PAPER 90-0171) Copyright

This paper reviews the role that EnviroNET assumes as a contemporary system that scientists and engineers can use to share information on networks that are connected globally. Advantage is being taken to use this powerful communication tool for the space community to articulate the various anomalies that our space systems are experiencing. EnviroNET is being considered as a test bed for developing an expert system for diagnosing environmentally induced anomalies for spacecraft. The various offline activities in progress toward this objective are described. Author

A90-19719#
SPACECRAFT ENVIRONMENTAL ANOMALIES EXPERT SYSTEM
D. J. GORNEY and H. C. KOONS (Aerospace Corp., Space

Sciences Laboratory, Los Angeles, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 5 p. Research sponsored by Aerospace Corp.
(Contract F04701-86-C-0087)
(AIAA PAPER 90-0175) Copyright

A micro-computer-based expert system has been developed at the Aerospace Corporation Space Sceinces Laboratory for use in the diagnosis of satellite anomalies caused by the space environment. The expert system is designed to address anomalies caused by surface charging, bulk charging, single event effects, total radiation dose and other plasma effects. These effects depend on the orbit of the satellite, the local environment (which is highly variable), the satellite exposure time and the 'hardness' of the circuits and components of the satellite. The expert system is a rule-based system that uses the Texas Instruments Personal Consultant Plus expert system shell. The expert system knowledge base includes about 200 rules, as well as a spacecraft attributes database, an historical spacecraft anomalies database, and a space environment database which can be updated in near-real time.
Author

A90-19720*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ENVIRONMENT INDUCED ANOMALIES ON THE TDRS AND THE ROLE OF SPACECRAFT CHARGING
H. B. GARRETT, A. WHITTLESEY (JPL, Pasadena, CA), and S. DAUGHTRIDGE (Contel Corp., Contel Federal Systems Sector, Chantilly, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. refs
(AIAA PAPER 90-0178) Copyright

The NASA Tracking and Data Relay Satellites (TDRS) have experienced several classes of anomalies that appear to be related to the natural environment. The most serious of these have been anomalies in the Attitude Control System control processor electronics which resulted in check sum errors that were ultimately traced to high-energy, particle-induced single event upsets in the RAM memory. Three other types of anomalies on TDRS have also been correlated with environmental effects. This paper briefly documents the occurrences of these anomalies and describes the nature of each. These events are correlated with various environmental factors. For all cases, there appears to be a causal relationship between spacecraft charging events and the engineering anomalies.
C.D.

A90-19959*# Utah State Univ., Logan.
RECENT OBSERVATIONS OF HIGH VOLTAGE SPACECRAFT-ENVIRONMENT INTERACTION AT LEO ALTITUDES USING SOUNDING ROCKETS
W. J. RAITT, N. B. MYERS, J. A. ROBERTS, D. C. THOMPSON (Utah State University, Logan), B. E. GILCHRIST (Stanford University, CA) et al. AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 8 p. refs
(Contract NAG5-607; DNA001-87-C-0015)
(AIAA PAPER 90-0635) Copyright

The paper addresses the subject of the interaction of positively and negatively charged bodies with the terrestrial ionosphere at low earth orbit altitudes. Data from two recent sounding rocket flights are used to establish that the current collected by exposed conductors biassed positively at up to 45kV relative to the ionospheric plasma generally follow predictions which account for strong control of electron flow by the geomagnetic field. If the biased structure is in the vicinity of disturbing influences such as an emitted charged particle beam, or locally enhanced gas pressure, then large deviations from the space-charge-limited return currents occur.
Author

A90-19960*# Air Force Geophysics Lab., Hanscom AFB, MA.
SPACECRAFT CHARGING DURING ION BEAM EMISSIONS IN SUNLIGHT
S. T. LAI (USAF, Geophysics Laboratory, Hanscom AFB, MA), W. J. MCNEIL (Radex, Inc., Bedford, MA), and T. L. AGGSON (NASA, Goddard Space Flight Center, Greenbelt, MD) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 7 p. refs
(AIAA PAPER 90-0636; AD-A218201) Copyright

During ion beam emissions from the SCATHA satellite, the potential of the negatively charged satellite body shows a sinusoidal oscillation frequency of once-per-spin of the satellite. The minimum occurs when the ion beam is sunward. The processes that may be responsible for the voltage modulation are considered. Neutralization of ion beam space charge by photoelectrons is examined. The photoelectrons are accelerated by the negative potential of the satellite. Effects of electron impact ionization, excitation of metastable states, and photoionization of xenon neutral atoms in the ion beam are studied in detail. Critical ionization velocity interaction is unlikely under the condition considered.
Author

A90-19961#
A THREE-DIMENSIONAL MODEL FOR AN ARTIFICIAL PLASMA CLOUD ABOUT A SPACECRAFT IN LOW EARTH ORBIT
NIKOLAOS A. GATSONIS and DANIEL E. HASTINGS (MIT, Cambridge, MA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 18 p. refs
(AIAA PAPER 90-0638) Copyright

A fully three-dimensional model for an artificial plasma cloud in the ionosphere is developed. Such a cloud could result from deliberate release of neutrals or ions from a spacecraft or as a result of contamination around a spacecraft. All elastic collisions and finite temperature effects are taken into consideration along with variable densities for ambient neutrals and ions, altitude dependent ambient neutral winds, ambient electric fields, and gravity. An analytic solution to the system of momentum equations yields the velocities of the charged species in both the perpendicular and parallel plane. The generalized Einstein relations are found to hold between the mobility and diffusion transport coefficients. Simple relations hold between the diffusion and the rest of the transport coefficients.
C.D.

A90-20175* Lockheed Engineering and Sciences Co., Houston, TX.
OBSERVING ORBITAL DEBRIS USING SPACE-BASED TELESCOPES. I - MISSION ORBIT CONSIDERATIONS
ROBERT C. REYNOLDS, DAVID L. TALENT (Lockheed Engineering and Sciences Co., Houston, TX), and FAITH VILAS (NASA, Johnson Space Center, Houston, TX) Astronomical Society of the Pacific, Publications (ISSN 0004-6280), vol. 101, Nov. 1989, p. 1055-1060. refs
Copyright

In this paper, mission orbit considerations are addressed for using the Space Shuttle as a telescope platform for observing man-made orbital debris. Computer modeling of various electrooptical systems predicts that such a space-borne system will be able to detect particles as small as 1-mm diameter. The research is meant to support the development of debris- collision warning sensors through the acquisition of spatial distribution and spectral characteristics for debris and testing of detector combinations on a shuttle-borne telescopic experiment. The technique can also be applied to low-earth-orbit-debris environment monitoring systems. It is shown how the choice of mission orbit, season of launch, and time of day of launch may be employed to provide extended periods of favorable observing conditions.
Author

A90-20734* Alabama Univ., Huntsville.
THE BEHAVIOR OF THE ELECTRON DENSITY AND TEMPERATURE AT MILLSTONE HILL DURING THE EQUINOX TRANSITION STUDY SEPTEMBER 1984
P. G. RICHARDS, D. G. TORR (Alabama, University, Huntsville), M. J. BUONSANTO (Haystack Observatory, Westford, MA), and K. L. MILLER (Utah State University, Logan) Journal of Geophysical Research (ISSN 0148-0227), vol. 94, Dec. 1, 1989, p. 16969-16975. Previously announced in STAR as N89-20567. refs
(Contract NSF ATM-87-13693; NSF ATM-87-16036; NSF

ATM-87-14461; NSF ATM-88-08137; NSF ATM-87-15367; NAGW-996; NAGW-922)
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The ionospheric electron density and temperature variations is simulated during the equinox transition study in September 1984 and the results are compared with measurements made at Millstone Hill. The agreement between the modeled and measured electron density and temperature for the quiet day (18 September) is very good but there are large differences on the day of the storm (19 September). On the storm day, the measured electron density decreases by a factor of 1.7 over the previous day, while the model density actually increases slightly. The model failure is attributed to an inadequate increase in the ratio of atomic oxygen to molecular neutral densities in the MSIS neutral atmosphere model, for this particular storm. A factor of 3 to 5 increase in the molecular to atomic oxygen density ratio at 300 km is needed to explain the observed decrease in electron density. The effect of vibrationally excited N sub 2 on the electron density were studied and found to be small. Author

A90-22179#
NOAA'S SPACECRAFT ANOMALY DATA BASE
DANIEL C. WILKINSON (NOAA, National Geophysical Data Center, Boulder, CO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 6 p. refs
(AIAA PAPER 90-0173)

NOAA's National Geophysical Data Center maintains a data base of anomalous spacecraft behavior attributed to environmental interactions. This paper introduces the database and its capabilities. Examples from the data base are presented and their environmentally related trends are illustrated. Statistically verified anomaly trends provide an excellent reference point to begin analysis of a spacecraft's susceptibility to environmental conditions. Effects of recent solar activity, March - October 1989, on spacecraft systems are reviewed. Author

A90-22252*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE SPACE STATION PHOTOVOLTAIC PANELS PLASMA INTERACTION TEST PROGRAM - TEST PLAN AND RESULTS
HENRY K. NAHRA, MARIAN C. FELDER, BERNARD L. SATER, and JOHN V. STASKUS (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. Previously announced in STAR as N90-13581.
(AIAA PAPER 90-0722) Copyright

The plasma Interaction Test performed on two space station solar array panels is addressed. This includes a discussion of the test requirements, test plan, experimental set-up, and test results. It was found that parasitic current collection was insignificant (0.3 percent of the solar array delivered power). The measured arcing threshold ranged from -210 to -457 V with respect to the plasma potential. Furthermore, the dynamic response of the panels showed the panel time constant to range between 1 and 5 microsec, and the panel capacitance to be between .01 and .02 microF. Author

A90-22253*# Alabama Univ., Huntsville.
CURRENT COLLECTION MODEL ON TETHER SATELLITE SYSTEM
K. S. HWANG, S. T. WU (Alabama, University, Huntsville), N. STONE, and K. H. WRIGHT, JR. (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 7 p. refs
(Contract NAS8-36107)
(AIAA PAPER 90-0723) Copyright

Results are reported from numerical simulations of current collection by a tethered satellite moving in the earth magnetic field. The focus is on the instruments of the Research on Orbital Plasma Electrodynamics (ROPE) experiment planned for the TSS-1 mission (scheduled launch 1991). The derivation of the governing equations is outlined, and the results of simulations with and without the geomagnetic field are presented in graphs. It is predicted that beam-beam interaction will occur when no magnetic effect is present, especially when the instrument bias is lower than the local potential; with the magnetic effect, there should be complex multiple-stream interactions, magnetic-field shielding covering 30 percent or more of the satellite surface when the B field is greater than 0.35 G, and nearly complete collection of the electrons by the instrument arm. T.K.

A90-22254*# Systems Science and Software, La Jolla, CA.
HIGH-VOLTAGE PLASMA INTERACTIONS CALCULATIONS USING NASCAP/LEO
M. J. MANDELL and I. KATZ (Systems Science and Software, La Jolla, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 16 p. refs
(Contract NAS3-23881)
(AIAA PAPER 90-0725) Copyright

This paper reviews four previous simulations (two laboratory and two space-flight) of interactions of a high-voltage spacecraft with a plasma under low-earth orbit conditions, performed using a three-dimensional computer code NASCAP/LEO. Results show that NASCAP/LEO can perform meaningful simulations of high-voltage plasma interactions taking into account three-dimensional effects of geometry, spacecraft motion, and magnetic field. Two new calculations are presented: (1) for current collection by 1-mm pinholes in wires (showing that a pinhole in a wire can collect far more current than a similar pinhole in a flat plate); and (2) current collection by Charge-2 mother vehicle launched in December 1985. It is shown that the Charge-2 calculations predicted successfully ion collection at negative bias, the floating potential of a probe outside or inside the sheath under negative bias conditions, and magnetically limited electron collection under electron beam operation at high altitude. I.S.

A90-22255*# Systems Science and Software, La Jolla, CA.
PLASMA CONTACTOR MODELING WITH NASCAP/LEO - EXTENDING LABORATORY RESULTS TO SPACE SYSTEMS
V. A. DAVIS, I. KATZ, and M. J. MANDELL (Systems Science and Software, La Jolla, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 6 p. refs
(Contract NAS3-23881)
(AIAA PAPER 90-0726) Copyright

In the laboratory, hollow cathode-based plasma contactors have been observed to both emit and collect ampere-level electron currents with low impedance. The laboratory behavior of hollow cathode-based plasma contactors and the limited space experience with hollow cathodes suggest that, for many applications, a hollow cathode-based plasma contactor is the ideal device to provide electrical connection with the space plasma. In order to confidently extend the laboratory experience to the low-earth-orbit environment, a series of plasma contactor computer models has been developed. Calculations show that a hollow cathode plasma contactor that collects 0.5 A in the laboratory will only collect 2.4 mA in space. The simplest way to boost the collected current is to increase the gas flow. A mole of gas is enough to collect ampere level currents for 5-1/2 hours. Author

A90-23256*# Utah State Univ., Logan.
VEHICLE CHARGING EFFECTS DURING ELECTRON BEAM EMISSION FROM THE CHARGE-2 EXPERIMENT
NEIL B. MYERS, W. JOHN RAITT, A. BRENT WHITE (Utah State University, Logan), PETER M. BANKS, BRIAN E. GILCHRIST (Stanford University, CA) et al. Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 25-37. refs
(Contract NAG5-607; NAGW-1566; NGR-23-005-360)
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The CHARGE-2 sounding rocket payload has measured the transient and steady-state charging of a spacecraft in LEO during the emission of a low-power electron beam. The electron beam successfully escaped the emitting spacecraft above 240 km, rather than being degraded by the spacecraft's potentials. These potentials were limited to about half of the 1-kV beam accelerating potential at all latitudes, suggesting that the electron beam was able to escape at altitudes down to 160 km. Electrons created

from beam-plasma interactions become increasingly important in the return current below 240 km, and increased with decreasing altitude. O.C.

A90-23257*# Houston Univ., TX.
PARTICLE RADIATION NEAR THE ORBIT OF THE VACUUM WAKE SHIELD
EDGAR A. BERING, III and ALEX IGNATIEV (Houston, University, TX) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 38-42. refs
(Contract NAS5-28710; NAGW-977)
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The particle populations that are expected to inflict the most damage on thin film materials grown on the vacuum Wake Shield Facility (WSF) are ions and energetic neutral atoms with energies in the range of 100 eV to 20 keV. The production of films that have an order of magnitude fewer defects than are now available requires that the 1-keV particle flux be kept lower than 1000 particles/(sq cm s sr keV) (assuming a reasonable spectral shape). WSF will be flown on orbits with an inclination of 28 deg at altitudes of 300-700 km. Because of the background counting rate produced by the about 100 MeV trapped protons in the inner belt, obtaining accurate measurements of the particles of interest is very difficult. The quiet-time background fluxes of the relevant particles are not presently known. At times of magnetic activity, fluxes of 0.1-17 keV O(+) ions as great as 10 million ions/(sq cm s sr keV) have been observed flowing out of the ionosphere at these latitudes. It appears that instrumentation for detailed assessment is essential for the proof-of-concept flight(s) and that real-time monitoring of low-energy ion and energetic neutral radiation will be required for the production flights. Author

A90-23740
THE RADIATION ENVIRONMENT FOR EARTH-ORBITING ASTRONOMICAL SATELLITES
C. TRANQUILLE and E. J. DALY (ESA, Mathematics and Software Div., Noordwijk, Netherlands) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Feb. 1990, p. 51-56. Research supported by ESA. refs
Copyright

The near-earth radiation environment consists primarily of geomagnetically trapped and solar flare energetic electrons and protons, together with a component of galactic cosmic rays. These charged particles give rise to a variety of physical effects which can compromise the operation of the sensitive detectors and electronics currently used to make detailed astronomical observations from space. Data from astrophysical instruments flown on the Cos-B satellite and the Soviet space station, Mir, are used to illustrate how the terrestrial radiation environment can interfere with the study of distant celestial objects. Standard numerical radiation environment models are used to interpret the data, and limitations and improvements to the models are discussed.
Author

A90-24800#
SPACE DEBRIS - UNIVERSAL KILLER
EDWARD R. FINCH, JR. (National Space Society, Washington, DC) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 211-214.
Copyright

Recent studies on space debris are reviewed, including the Draft Principles on Nuclear Power Sources in Outer Space adopted by the Legal Subcommittee of the UN Committee on the Peaceful Uses of Outer Space in March, 1989. The current status of research concerning the environmental implications of space debris is discussed. The possibility of adopting an international space debris treaty is considered. R.B.

A90-24809#
THE NATURE OF SPACE DEBRIS AND HOW TO CLEAN IT UP
L. P. LEHMAN and G. E. CANOUGH (ExtraTerrestrial Materials, Inc., Endicott, NY) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 259-266. refs
Copyright

The problem of space debris has been looked at for some time, but to date no clean-up has been done. This article summarizes the debris problem and addresses the main problem: how to clean up the debris. There are approximately 7000 man-made trackable objects in orbit, 10 cm or larger. Most of these are known to be debris or nonfunctional spacecraft. In addition to trackable objects, there are 8-10 times as many untracked objects. The debris hazard now exceeds the meteor hazard by 5 orders of magnitude. In order to clean up the debris, the initial focus must be on removing larger objects from orbit. A garbage collector which is small, simple, and inexpensive is proposed; it is a drag device which can be attached to the debris and deployed to increase the drag on the junk by orders of magnitude, causing its orbit to decay rapidly. Author

A90-24847
DEBRIS-IMPACT PROTECTION OF SPACE STRUCTURES
A. M. RAJENDRAN (Dayton, University, OH) and N. ELFER (Martin Marietta Corp., New Orleans, LA) IN: Structural failure; International Symposium on Structural Crashworthiness, 2nd, Cambridge, MA, June 6-8, 1988, Invited Lectures. New York, Wiley-Interscience, 1989, p. 41-78. Research supported by Martin Marietta Corp. and University of Dayton. refs
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The response of space structures to debris impact is modeled using experimental results and analyses. In experiments with and without any intermediate layer of thermal insulation between the bumper shield and the rear wall, different failure modes in the rear wall were observed, with spallation being predominant without intermediate layers, and bulge and burst-type failure with the use of thermal blankets. The modeling of the debris cloud was found to require a careful interpretation of the cloud characteristics. The mass-filled and hollow-cloud models could model the spallation-type failure in experiments without any intermediate layers, whereas the impulse-velocity-based models were not suitable for predicting spall. The use of thermal blankets as intermediate layers led to the simple impulse-velocity-based models as more suitable for predicting bulging and necking-type failure modes. I.S.

A90-24933* Maxwell Labs., Inc., San Diego, CA.
COMPUTER MODELING OF CURRENT COLLECTION BY THE CHARGE-2 MOTHER PAYLOAD
M. J. MANDELL, J. R. LILLEY, JR., I. KATZ (Maxwell Laboratories, Inc., S-Cubed Div., San Diego, CA), T. NEUBERT (Stanford University, CA), and NEIL B. MYERS (Utah State University, Logan) Geophysical Research Letters (ISSN 0094-8276), vol. 17, Feb. 1990, p. 135-138. refs
(Contract NAS3-23881; F19628-86-C-0056)
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The three-dimensional computer codes NASCAP/LEO and POLAR have been used to calculate current collection by the mother payload of the CHARGE-2 rocket under conditions of positive and negative potential up to several hundred volts. For negative bias (ion collection), the calculations lie about 25 percent above the data, indicating that the ions were less dense, colder, or heavier than the input parameters. For positive bias (electron collection), NASCAP/LEO and POLAR calculations show similar agreement with the measurements at the highest altitudes. This agreement indicates that the current is classically magnetically limited, even during electron beam emission. However, the calculated values fall well below the data at lower altitudes. It is suggested that beam-plasma-neutral interactions are responsible for the high values of collected current at altitudes below 240 km.
Author

A90-25305* Florida Univ., Alachua.
HIGH-ENERGY RADIATION BACKGROUND IN SPACE
A. C. RESTER, JR., ED. (Florida, University, Alachua) and J. I. TROMBKA, ED. (NASA, Goddard Space Flight Center, Greenbelt, MD) New York, American Institute of Physics, 1989, 518 p. For individual items see A90-25306 to A90-25338.
Copyright

The radiation environment of near-earth space and its effects on biological and hardware systems are examined in reviews and reports. Sections are devoted to particle interactions and propagation, data bases, instrument background and dosimetry, detectors and experimental progress, biological effects, and future needs and strategies. Particular attention is given to angular distributions and spectra of geomagnetically trapped protons in LEO, bremsstrahlung production by electrons, nucleon-interaction data bases for background estimates, instrumental and atmospheric background lines observed by the SMM gamma-ray spectrometer, the GRAD high-altitude balloon flight over Antarctica, space protons and brain tumors, a new radioprotective antioxidative agent, LEO radiation measurements on the Space Station, and particle-background effects on the Hubble Space Telescope and the Lyman FUV Spectroscopic Explorer. T.K.

A90-25306* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
CHARGED PARTICLE RADIATION EXPOSURE OF GEOCENTRIC SATELLITES
E. G. STASSINOPOULOS (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 3-63. refs
Copyright

The near-earth radiation environment is characterized, summarizing published data on trapped and transient charged particles and their potential effects on hardware systems and the crews of manned missions. Topics examined include the role of the magnetosphere, the five radiation domains, cyclic and sporadic variations in the radiation environment, the potential effect of a high-altitude nuclear explosion, NASA empirical models for predicting trapped proton and electron fluxes, and the South Atlantic anomaly and the estimation of flux-free periods. Consideration is given to solar cosmic rays and heavy ions, Galactic cosmic rays, geomagnetic shielding, secondary radiation, the design of shielding systems, variables affecting dose evaluations, and ionizing-radiation doses. Extensive diagrams, graphs, and tables of numerical data are provided. T.K.

A90-25308* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
APPROXIMATE ANGULAR DISTRIBUTION AND SPECTRA FOR GEOMAGNETICALLY TRAPPED PROTONS IN LOW-EARTH ORBIT
J. W. WATTS, T. A. PARNELL (NASA, Marshall Space Flight Center, Huntsville, AL), and H. H. HECKMAN (California, University, Berkeley) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 75-85. refs
Copyright

The highly anisotropic nature of the radiation in the low-earth orbit has been ignored for most spacecraft shielding calculations made to date because the standard environmental models describe the omnidirectional flux only, because the varying attitude of the spacecraft in the environment is assumed to average out the effect and because of the added complexity of the calculation. The Space Station is planned to be stabilized with respect to the velocity vector and local vertical. Thus it will pass through the South Atlantic Anomaly where most of the radiation flux is encountered in much the same attitude on each pass. Any calculation including a complex shielding geometry should thus consider the angular distributuon of the incident radiation. An approximate trapped proton angular distribution is presented which includes both the 'pan caked' distribution relative to the magnetic field direction and the east-west effect which is energy dependent. This distribution is then used with a planar shielding geometry to obtain an estimate of the effect of the anisotropy on radiation dose rates in spacecraft. Author

A90-25313
HIGH-ENERGY RADIATION ENVIRONMENT DURING MANNED SPACE FLIGHTS
R. SILBERBERG, C. H. TSAO, J. H. ADAMS, JR. (U.S. Navy, E. O. Hulburt Center for Space Research, Washington, DC), and J. R. LETAW (Severn Communications Corp., Severna Park, MD) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 146-158. refs
Copyright

Results are reported from radiation-transport calculations for cosmic rays and solar-flare particles incident on shielded and unshielded spacecraft and crew on space missions. The principles and data bases underlying the computations are reviewed, and the results are presented in extensive graphs and discussed in detail. It is shown that the use of thicker shielding can reduce the doses of cosmic rays and particles to acceptable levels; with thicker shielding, radiation from neutron-generated nuclear recoils is more important than that from heavy nuclei. T.K.

A90-25314
HIGH-ENERGY OUTER RADIATION BELT DYNAMIC MODELING
Y. T. CHIU, R. W. NIGHTINGALE, and M. A. RINALDI (Lockheed Research Laboratories, Palo Alto, CA) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 159-174. refs
(Contract F19628-85-C-0073; N00014-76-C-0444)
Copyright

The numerical modeling techniques used to predict the exposure of spacecraft to high-energy particles from the earth's radiation belts are examined in an analytical review. Particular attention is given to factors affecting the transport, injection, and loss of trapped energetic electrons, represented in terms of diffusion in phase space. Results from analyses of data from SCATHA airborne measurements during a period of moderate belt activity (Reagan et al., 1981 and 1983; Davidson et al., 1988) are presented in extensive graphs and characterized in detail. The model predictions are shown to be in good agreement with available measurement data, and the applicability of the present techniques to the planned Combined Release and Radiation Effects Satellite project is indicated. T.K.

A90-25315* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NUCLEAR CROSS SECTIONS FOR ESTIMATING SECONDARY RADIATIONS PRODUCED IN SPACECRAFT
L. W. TOWNSEND and J. W. WILSON (NASA, Langley Research Center, Hampton, VA) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 177-191. refs
Copyright

The physical theory underlying calculations of nuclear absorption and fragmentation cross sections and EM dissociation cross sections is reviewed; typical results are presented in graphs; and the adequacy of the experimental data bases for each type of cross section are discussed. The emphasis is on computations applicable to the estimation of secondary radiation in shielded spacecraft. T.K.

A90-25317* Aerospace Corp., Los Angeles, CA.
ENVIRONET - AN INTERACTIVE SPACE-ENVIRONMENT INFORMATION RESOURCE
A. L. VAMPOLA (Aerospace Corp., Los Angeles, CA), WILLIAM N. HALL (USAF, Geophysics Laboratory, Hanscom AFB, MA), and MICHAEL LAURIENTE (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 210-215. Previously announced in STAR as N88-23812.
(Contract F04701-86-C-0087)
Copyright

EnviroNET is an interactive menu-driven system set up as an information resource for experimenters, program managers, and design and test engineers involved in space missions. Its basic use is as a fundamental single source of data for the environment encountered by Shuttle and Space Station payloads, but is also has wider applicability in that it includes information on environments encountered by other satellites in both low altitude and high altitude (including geosynchronous) orbits. It incorporates both a text-retrieval mode and an interactive modeling code mode. The system is maintained on the ENVET MicroVAX computer at NASA/Goddard Space Flight Center. Its services are available at no cost to any user who has access to a terminal and modem. It is a tail-node on SPAN, and so it is accessible either directly or through BITNET, ARPANET, and GTE/TELENET via NPSS.
Author

A90-25318
SEL MONITORING OF THE EARTH'S ENERGETIC PARTICLE RADIATION ENVIRONMENT
HERBERT H. SAUER (NOAA, Space Environment Laboratory, Boulder, CO) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 216-221.
Copyright

The Space Environment Laboratory (SEL) of the National Oceanic and Atmospheric Administration (NOAA) maintains instruments on board the GOES series of geostationary satellites, and aboard the NOAA/TIROS series of low-altitude, polar-orbiting satellites, which provide monitoring of the energetic particle radiation environment as well as monitoring the geostationary magnetic field and the solar X-ray flux. The data are used by the SEL Space Environment Services Center (SESC) to help provide real-time monitoring and forecasting of the state of the near earth environment and its disturbances, and to maintain a source of reliable information to research and operational activities of a variety of users. The data, data sources, and products relevant to the characterization of the near-earth radiation environment and its response to solar cosmic ray events are briefly described, as are the laboratory's archives and uses of these data. Author

A90-25326* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE HEAO 3 BACKGROUND - SPECTRUM OBSERVED BY A LARGE GERMANIUM SPECTROMETER IN LOW EARTH ORBIT
W. A. WHEATON, A. S. JACOBSON, J. C. LING, W. A. MAHONEY, and L. S. VARNELL (JPL, Pasadena, CA) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 304-322. refs
Copyright

Gamma-ray background spectra, obtained in the energy range from 45 keV to 10 MeV with the cooled high-resolution Ge spectrometer on the HEAO-3 satellite over a 50-day period in 1979-1980 are reported and analyzed. The instrument design and performance characteristics are reviewed; the data-analysis procedures are outlined; about 130 background lines are listed in a table with energies, count rates, and tentative identifications; and the spectra are presented graphically and discussed in detail.
T.K.

A90-25327
THE SPACE RADIATION ENVIRONMENT AT 840 KM
E. G. MULLEN, M. S. GUSSENHOVEN, and D. A. HARDY (USAF, Geophysics Laboratory, Hanscom AFB, MA) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 329-342. refs
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The Defense Meteorological Satellite Program (DMSP) F7 satellite, launched in November, 1983, carries a dosimeter provided by the Air Force Geophysics Laboratory. The dosimeter returns accurate, high-time-resolution dose measurements. Maps of the radiation dose (electron and proton) at 840 km are presented and compared to the NASA models. Maps of the very high energy deposits which can produce single event upsets in microelectronic components are also presented. Characteristics of energetic particles that enter the polar cap regions during solar particle events are discussed and compared to inner belt proton and cosmic ray background levels. Included is an analysis of two of the largest solar proton events since the launch of the satellite, those of 16 February, 1984 and 26 April, 1984. Author

A90-25335* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SPACE STATION - INFRASTRUCTURE FOR RADIATION MEASUREMENTS IN LOW EARTH ORBIT
B. D. MEREDITH (NASA, Langley Research Center, Hampton, VA) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 445-452.
Copyright

The general configuration, development schedule, and capabilities of the NASA International Space Station are reviewed, with an emphasis on the possibilities for long-term measurements of high-energy cosmic and secondary radiation from the main Station spacecraft, coorbiting or polar-orbit platforms, or Station-supported GEO satellites. Also outlined are the organizational structure and the application procedures to be followed by potential users of the Station facilities. Diagrams and drawings are provided. T.K.

A90-25338
RADIATION ENVIRONMENT EVALUATION FOR ESA PROJECTS
E. J. DALY (ESTEC, Noordwijk, Netherlands) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 483-499. refs
Copyright

The effects of the natural space radiation environment on ESA projects are discussed and methods and tools used by ESA for evaluating this environment and its effects are described. Various computer-based methods have been adopted, developed and applied to a variety of problems. Environment models are discussed, together with dose and upset-rate computation. Projects under consideration include astronomy and astrophysics missions, manned spacecraft, and polar platforms. In the light of these activities, areas of concern requiring further attention are identified. Author

A90-25510* Hughes Aircraft Co., Carlsbad, CA.
1989 IEEE ANNUAL CONFERENCE ON NUCLEAR AND SPACE RADIATION EFFECTS, 26TH, MARCO ISLAND, FL, JULY 25-29, 1989, PROCEEDINGS. PART 1
AGUSTIN OCHOA, JR., ED. (Hughes Aircraft Co., Carlsbad, CA) Conference sponsored by IEEE, DNA, Sandia National Laboratories, and JPL. IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 36, pt. 1 , Dec. 1989, 668 p. For individual items see A90-25511 to A90-25559.
Copyright

Various papers on nuclear science are presented. The general topics addressed include: basic mechanics of radiation effects, dosimetry and energy-dependent effects, hardness assurance and testing techniques, spacecraft charging and space radiation effects, EMP/SGEMP/IEMP phenomena, device radiation effects and hardening, radiation effects on isolation technologies, IC radiation effects and hardening, and single-event phenomena. C.D.

A90-25525
AN OVERVIEW OF ELECTRON AND ION BEAM EFFECTS IN CHARGING AND DISCHARGING OF SPACECRAFT
S. T. LAI (USAF, Geophysics Laboratory, Hanscom AFB, MA) (IEEE, DNA, Sandia National Laboratories, and JPL, Annual Conference on Nuclear and Space Radiation Effects, 26th, Marco Island, FL, July 25-29, 1989) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 36, pt. 1, Dec. 1989, p. 2027-2032. refs
(AD-A221890) Copyright

The charging and discharging of the SCATHA satellite by means of electron- and ion-beam emissions in the geosynchronous environment were investigated. It was found that during electron

beam emissions in sunlight the photoelectrons from nearby surfaces isolated from the satellite body tend to return to the body, thus affecting its potential. It was also found that attempts to discharge a spacecraft by means of electron-beam emission can result in differential charging between dielectric surfaces and spacecraft ground. At low ion-beam currents, the level of spacecraft charging increases as the current increases. Beyond a critical current, the level decreases with a nonmonotonic current-voltage behavior. Abundant neutrals are present in the ion beam. Low-energy ions generated by charge exchange return to the spacecraft and reduce the charging level. It was also shown that discharging by means of low-energy plasma-beam emission is more efficient than using an electron or ion beam alone. This conclusion is important for spacecraft engineers designing automatic discharge systems for future spacecraft. I.E.

A90-25526
SPACECRAFT-LEVEL CURRENT-INJECTION TESTING TO INVESTIGATE DISCHARGE COUPLING MODELS
C. BOWMAN, A. BOGORAD, P. SHIH (General Electric Co., Astro-Space Div., Princeton, NJ), D. TASCA, M. SHOMBERG et al. (IEEE, DNA, Sandia National Laboratories, and JPL, Annual Conference on Nuclear and Space Radiation Effects, 26th, Marco Island, FL, July 25-29, 1989) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 36, pt. 1, Dec. 1989, p. 2033-2040. Research sponsored by General Electric Co. refs
Copyright

The response of a spacecraft to a surface electrostatic discharge was predicted using lumped-element modeling. Current-injection testing on an actual satellite verified the predictions and characterized the transient pulses coupled into electronics boxes. These tests duplicated, very closely, an ESD (electrostatic discharge) stimulus on one of the solar panels. This work makes extensive use of STARSAT SGEMP methodology. Its ultimate objective is to develop a spacecraft-level test for engineering development of spacecraft systems and for qualification tests on fully assembled spacecraft. I.E.

A90-26855
NORWEGIAN STUDIES OF PLASMA MODIFICATIONS AROUND SPACECRAFT AND HOW THESE AFFECT THE VEHICLE POTENTIAL
BERNT N. MAEHLUM (Forsvarets Forskningsinstitutt, Kjeller, Norway) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, March 1990, p. 121-126. refs
Copyright

Studies conducted at the Norwegian Defence Research Establishment on vehicle-plasma interaction are discussed. Particular consideration is given to plasma modifications caused by the spacecraft; beam-plasma interaction processes; vehicle charging due to vehicle-plasma interaction and beams emitted from the vehicle; active neutralization of a charge vehicle by a charged particle emitter; and simulation studies of vehicle-plasma interaction and charging. Current research is concerned with the effects of plasma modifications on instruments on-board the spacecraft. I.F.

A90-26909#
SPACE DEBRIS - THE LEGAL REGIME, POLICY CONSIDERATIONS AND CURRENT INITIATIVES
KEVIN K. SPRADLING (USAF, Space Command, Peterson AFB, CO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. refs
(AIAA PAPER 90-0088)

A summary and analysis of relevant international and domestic law and policy is provided for the debris-conversant scientist/engineer. In less than a decade, the potential problems attending a steadily increasing orbital population of space debris have come to the fore. The focus of an increasingly concerned scientific community, inoperative satellites, payload shrouds, spent rocket stages, and other miscellaneous man-made pieces and particles of refuse pose an as yet incalculable, but very real economic and physical threat to future manned and unmanned space activities. It is concluded that existing international law is ill-suited to the meaningful regulation of space debris. It is noted that the AIAA interdisciplinary working group's methodology, at least in theory, brings the law into the process at the appropriate point, after an idea has been technically validated and a cost benefit analysis conducted. R.E.P.

A90-26932#
DEFINITION OF THE TRAPPED RADIATION IN EARTH ORBIT
A. L. VAMPOLA (Aerospace Corp., Los Angeles, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 16 p. refs
(Contract F04701-85-C-0086)
(AIAA PAPER 90-0290) Copyright

This paper is a tutorial covering the energetic charged particle environment in the earth's magnetosphere. It provides an overview of trapped particle morphology, the geometry of the trapping regions, the radiation environmental models, the current status of these models, and future modeling requirements. Author

A90-27722
EFFECTS OF THE SPACE ENVIRONMENT ON SPACE SCIENCE
JO ANN JOSELYN (NOAA, Space Environment Laboratory, Boulder, CO) and ELDEN C. WHIPPLE (California, University, San Diego) American Scientist (ISSN 0003-0996), vol. 78, Mar.-Apr. 1990, p. 126-133. refs
Copyright

A comprehensive account is given of the various threats posed to either the accuracy or the very physical existence of spacecraftborne instruments by various natural and anthropogenic phenomena. Natural phenomena encompass high energy cosmic radiation and micrometeorites, as well as upper-atmospheric ions and electrons. Human space activities have led to the accumulation of a virtual cloud of debris, including nonfunctional satellites, discarded rocket stages, and fragments from intentional and accidental explosions. Charged particles and plasmas in space may cause the electric potential of an entire spacecraft, or of its various exposed parts, to vary dramatically and generate EM noise pulses and electrostatic discharges. O.C.

A90-29073
MICROCRATERS ON TARGETS EXPOSED IN NEAR-EARTH ORBIT [MIKROKRATERY NA MISHENIAKH, EKSPONIROVANNYKH NA OKOLOZEMNOI ORBITE]
N. G. ZINOV'EVA, O. D. RODE, G. A. KUZIN, M. R. KONDRAT'EVA, and A. T. BAZILEVSKII Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, Jan.-Feb. 1990, p. 117-124. In Russian.
Copyright

The paper presents results of an electron-microscope study of micron-size impact craters formed on targets of various materials (Ti-coated glass, copper, and aluminum) flown in space. A morphological description of the craters is given and the chemical composition of the targets is analyzed. The crater sizd density distribution on different targets was determined, and the flux of particles causing the craters was evaluated. The microcraters were found to be due to two types of particles: cosmic dust and space debris. B.J.

A90-29699*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE SHUTTLE EXTERNALLY INDUCED ENVIRONMENT COMPARED WITH SKYLAB'S NATURAL ENVIRONMENT
MICHAEL SUSKO (NASA, Marshall Space Flight Center, Huntsville, AL) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Mar.-Apr. 1990, p. 222-224. refs
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Electret measurements obtained of the particulate contamination environment within the Space Shuttle Orbiter's cargo bay are presently compared with ground measurements of the particulates emitted by the Shuttle's SRBs, as well as with the expected natural particulate environment as measured by Skylab. Chemical analysis is shown to reveal the difference between natural

and anthropogenic space debris; the most probable primary source of the Space Shuttle's particulate environment is the SRB exhaust. O.C.

N90-10795*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ORBITAL DEBRIS RESEARCH AT NASA JOHNSON SPACE CENTER, 1986-1988
ROBERT C. REYNOLDS and ANDREW E. POTTER, JR. (Lockheed Engineering and Sciences Co., Houston, TX.) Sep. 1989 60 p (NASA-TM-102155; S-595; NAS 1.15:102155) Avail: NTIS HC A04/MF A01 CSCL 03/2

Research on orbital debris has intensified in recent years as the number of debris objects in orbit has grown. The population of small debris has now reached the level that orbital debris has become an important design factor for the Space Station. The most active center of research in this field has been the NASA Lyndon B. Johnson Space Center. Work is being done on the measurement of orbital debris, development of models of the debris population, and development of improved shielding against hypervelocity impacts. Significant advances have been made in these areas. The purpose of this document is to summarize these results and provide references for further study. Author

N90-11075# Engineering System International, Rungis (France).
NUMERICAL SIMULATION OF MICROMETEROIDS AND DEBRIS HYPERVELOCITY IMPACTS ON COLUMBUS PRESSURIZED MODULES
J. DUBOIS, F. VOGEL, A. DEROUVRAY, S. FALCONE, H. G. REIMERDES, and D. ALWES (Erno Raumfahrttechnik G.m.b.H. Bremen, Germany, F.R.) *In* ESA, Spacecraft Structures and Mechanical Testing p 685-692 Jan. 1989 Sponsored by ESA/ESTEC, Noordwijk, Netherlands
Copyright Avail: NTIS HC A99/MF E06

Numerical work performed to illustrate and improve the physical mechanisms and hardening concepts for micrometeoroids and debris hypervelocity impacts, on the pressurized module and viewports of Columbus is presented. Aluminum debris particles are typically spheres 6 to 20 mm in diameter travelling at 0 to 20 km/s. Micrometeoroids are 1.5 to 6 mm in diameter and travel at over 10 km/s. Three bumper perforation calculations are presented at 3.7 and 10 km/s. A backup calculation is performed to illustrate the damage: cratering on the front face, spallation on the rear face and plastification inside. The correlation between the numerical simulation, analytical formulae and tests results is discussed. The methodology for studying the backup shield in the second phase of the research is presented. ESA

N90-11770*# Arizona Univ., Tucson. Dept. of Aerospace and Mechanical Engineering.
AUTONOMOUS SPACE PROCESSOR FOR ORBITAL DEBRIS Final Report, 1988 - 1989
KUMAR RAMOHALLI, DAVID CAMPBELL, JEFF P. BROCKMAN, BRUCE CARTER, LESLIE DONELSON, LAWRENCE E. JOHN, MICKY C. MARINE, and DAN D. RODINA 1989 81 p Presented at the Universities Space Research Association Summer Conference, Huntsville, AL, 12-16 Jun. 1989 Prepared for Universities Space Research Association, Houston, TX
(Contract NASW-4435)
(NASA-CR-186043; NAS 1.26:186043) Avail: NTIS HC A05/MF A01 CSCL 22/1

This work continues to develop advanced designs toward the ultimate goal of a GETAWAY SPECIAL to demonstrate economical removal of orbital debris utilizing local resources in orbit. The fundamental technical feasibility was demonstrated last year through theoretical calculations, quantitative computer animation, a solar focal point cutter, a robotic arm design and a subscale model. During this reporting period, several improvements are made in the solar cutter, such as auto track capabilities, better quality reflectors and a more versatile framework. The major advance has been in the design, fabrication and working demonstration of a ROBOTIC ARM that has several degrees of freedom. The functions were specifically tailored for the orbital debris handling. These advances are discussed here. Also a small fraction of the resources were allocated towards research in flame augmentation in SCRAMJETS for the NASP. Here, the fundamental advance was the attainment of Mach numbers up to 0.6 in the flame zone and a vastly improved injection system; the current work is expected to achieve supersonic combustion in the laboratory and an advanced monitoring system. Author

N90-11772# Technische Univ., Brunswick (Germany, F.R.). Inst. fuer Raumflug- und Reaktortechnik.
THE TIME EVALUATION OF THE NUMBER OF SPACE PROBES AND DEBRIS AT DIFFERENT ORBIT HEIGHTS WITH A VIEW TO A FUTURE COLLISION RISK IN SPACE Final Report [DIE ZEITLICHE ENTWICKLUNG DER ANZAHL VON RAUMFLUGOBJEKTEN UND TRUEMMERN IN VERSCHIEDENEN BAHNHOEHEN IM HINBLICK AUF EIN ZUKUENFTIGES KOLLISIONSISIKO IM WELTRAUM]
P. EICHLER and D. REX 1987 86 p In GERMAN
(Contract BMFT-01-OV-86-810)
(R-8718; ETN-89-94626) Avail: NTIS HC A05/MF A01

A data base for the calculation of the collision in space probability for different possible scenarios is established. An extensive literature study is performed. A simplied assumption for tne determination of the collision probability is presented. The occupation density of the cataloged artificial objects is given, and that of noncataloged small artificial objects is estimated. The future evolution of the occupation density and collision probability is discussed. The orbit parameter data set of all objects with diameter larger than one cm in the earth orbit is presented. A computer program for the simulation of the time evolution of the number and the orbit parameter distribution of orbits in the earth orbit is developed. ESA

N90-12488*# New Mexico Univ., Albuquerque. Dept. of Physics and Astronomy.
THE ONSET OF THE SOLAR ACTIVE CYCLE 22
H. S. AHLUWALIA *In* NASA, Goddard Space Flight Center, Max '91 Workshop 2: Developments in Observations and Theory for Solar Cycle 22 p 320-323 1989
(Contract NAGW-1468)
Avail: NTIS HC A17/MF A03 CSCL 03/2

There is a great deal of interest in being able to predict the main characteristics of a solar activity cycle (SAC). One would like to know, for instance, how large the amplitude (R sub m) of a cycle is likely to be, i.e., the annual mean of the sunspot numbers at the maximum of SAC. Also, how long a cycle is likely to last, i.e., its period. It would also be interesting to be able to predict the details, like how steep the ascending phase of a cycle is likely to be. Questions like these are of practical importance to NASA in planning the launch schedule for the low altitude, expensive spacecrafts like the Hubble Space Telescope, the Space Station, etc. Also, one has to choose a proper orbit, so that once launched the threat of an atmospheric drag on the spacecraft is properly taken into account. Cosmic ray data seem to indicate that solar activity cycle 22 will surpass SAC 21 in activity. The value of R sub m for SAC 22 may approach that of SAC 19. It would be interesting to see whether this prediction is borne out. Researchers are greatly encouraged to proceed with the development of a comprehensive prediction model which includes information provided by cosmic ray data. Author

N90-12635*# National Aeronautics and Space Administration, Washington, DC.
REPORT ON ORBITAL DEBRIS
Feb. 1989 74 p Prepared in cooperation with Air Force Systems Command, Bolling AFB, Washington, DC Original contains color illustrations
(NASA-TM-101855; NAS 1.15:101855) Avail: NTIS HC A04/MF A01 CSCL 22/1

The success of space endeavors depends upon a space environment sufficiently free of debris to enable the safe and dependable operation of spacecraft. An environment overly cluttered with debris would threaten the ability to utilize space for

a wide variety of scientific, technological, military, and commercial purposes. Man made space debris (orbital debris) differs from natural meteoroids because it remains in earth orbit during its lifetime and is not transient through the space around the Earth. The orbital debris environment is considered. The space environment is described along with sources of orbital debris. The current national space policy is examined, along with ways to minimize debris generation and ways to survive the debris environment. International efforts, legal issues and commercial regulations are also examined. E.R.

N90-12647# Air Force Geophysics Lab., Hanscom AFB, MA.
OPTICAL DETECTION OF SPACE DEBRIS USING A LARGE ACHROMATIC CORONAGRAPH
S. KOUTCHMY and C. NITSCHELM (Centre National de la Recherche Scientifique, Paris, France) 1988 10 p Submitted for publication
(AD-A211362; AFGL-TR-89-0201) Avail: NTIS HC A02/MF A01 CSCL 17/5

The threat of space debris seems to increase steadily. Accordingly, new methods of detection are needed. We present a theoretical approach to this problem, assuming the use of a new generation large achromatic ground based coronagraph. Some interesting results are presented, including the estimation of the probability of being able to systematically observe small size space debris in a large range of altitudes. GRA

N90-12986# Atmospheric Radiation Consultants, Acton, MA.
RETRIEVAL OF ATOMIC OXYGEN AND TEMPERATURE IN THE THERMOSPHERE. PART 1: FEASIBILITY OF AN EXPERIMENT BASED ON THE SPECTRALLY RESOLVED 147 MICROMETER LIMB EMISSION Scientific Report No. 1, Feb. 1987 - Nov. 1988
A. S. ZACHOR, R. D. SHARMA, B. K. YAP, and J. P. RIEHL (Missouri Univ., Saint Louis.) 10 Apr. 1989 39 p
(Contract F19628-87-C-0053)
(AD-A211987; ARC-TR-89-011; GL-TR-89-0144) Avail: NTIS HC A03/MF A01 CSCL 04/1

The importance of atomic oxygen and translational temperature in mesospheric/thermospheric processes is the motivation to study the feasibility of recovering vertical profiles of the temperature and O-atom density from limb scan data obtained near 147 micrometer and/or 63 micrometer wavelength, corresponding to the oxygen atom ground electronic state (OI) transitions. The limb radiance data must be spectrally resolved to recover both temperature and atomic oxygen density if only one of the OI lines is used, which is the approach investigated in this report. We show how the two vertical profiles can be recovered by applying an onion-peeling method to synthetic data. The temperature and O-atom density in each peeled layer are obtained simultaneously by nonlinear least-squares spectrum fitting. Spectral data in the 147 micrometer line was found to yield reasonably accurate and stable profiles from 300 km down to an altitude between 130 and 90 km, depending on the noise level and spectral resolution, and gave better results than the stronger 63 micrometer data below 140 km. We estimate that the S/N and spectral resolution required for successful retrievals could be provided by a confocal Fabry-Perot system operating near 147 micrometer although retrievals down to 90 km from data obtained at orbital altitude would require cooled foreoptics roughly a meter in diameter. GRA

N90-13317# Royal Aerospace Establishment, Farnborough (England). Space Dept.
RADIOACTIVITY INDUCED IN GAMMA-RAY SPECTROMETERS
C. S. DYER, P. R. TRUSCOTT, N. D. A. HAMMOND, and C. COMBER (Scicon Consultancy International Ltd., London, England) 29 Feb. 1988 13 p
(RAE-TM-SPACE-363; BR107145; ETN-89-94997) Copyright Avail: NTIS HC A03/MF A01

The data and the methods used in the prediction of radioactivity, induced in spaceborne gamma ray spectrometers by the space radiation environment are reviewed. Due to large masses of current the application of particle transport codes are required. The results from such codes are given for scintillator detectors. Calculations and irradiation data are presented for germanium and bismuth germanate. ESA

N90-13318# Royal Aerospace Establishment, Farnborough (England). Space Dept.
THE COSMIC RADIATION EFFECTS AND ACTIVATION MONITOR
C. S. DYER, A. J. SIMS, R. J. HUTCHINGS, D. MAPPER, J. H. STEPHEN, and J. FARREN (Atomic Energy Research Establishment, Harwell, England) 29 Feb. 1988 13 p
(RAE-TM-SPACE-364; BR107144; ETN-89-94998) Copyright Avail: NTIS HC A03/MF A01

The cosmic radiation effects and activation monitor is described. It is designed to monitor real time linear energy transfer spectra together with mission integrated particle fluences and radioactivity. The aim of the work is to improve the predictive models used to define the aerospace environment. The experiment, together with the expected environments and ground calibration data, are presented. ESA

N90-15127# Air Force Geophysics Lab., Hanscom AFB, MA. Space Physics Div.
SCATHA (SPACECRAFT CHARGING AT HIGH ALTITUDES) ATLAS DATA BASE, VOLUME 1 Environmental Research Papers, 1 Jan. - 30 Jun. 1989
E. G. MULLEN, ed. and M. S. GUSSENHOVEN, ed. 1 Sep. 1989 201 p
(Contract AF PROJ. 7601)
(AD-A214204; GL-TR-89-0249(1)-VOL-1; GL-ERP-1037-VOL-1)
Avail: NTIS HC A10/MF A02 CSCL 22/5

A study of the plasma environment encountered by the P78-2 Spacecraft Charging At High Altitudes (SCATHA) satellite during its operation between March 1979 and June 1980 was conducted and reported in the SCATHA Environmental Atlas (AFGL-TR-83-0002). Summary plots of much of the data used in the Atlas are presented in two volumes. The first volume contains magnetic field data and spacecraft frame potential data. The second volume contains low and medium energy range electron and ion data, medium energy range ion composition data and high energy electron data. The data are presented in 24-hour plots. GRA

N90-15128# Air Force Geophysics Lab., Hanscom AFB, MA. Space Physics Div.
SCATHA (SPACECRAFT CHARGING AT HIGH ALTITUDES) ATLAS DATA BASE, VOLUME 2 Environmental Research Papers, 1 Jan. - 30 Jun. 1989
E. G. MULLEN, ed. and M. S. GUSSENHOVEN, ed. 1 Sep. 1989 285 p
(Contract AF PROJ. 7601)
(AD-A214205; GL-TR-89-0249(2)-VOL-2; GL-ERP-1038-VOL-2)
Avail: NTIS HC A13/MF A02 CSCL 22/5

A study of the plasma environment encountered by the P78-2 Spacecraft Charging At High Altitudes (SCATHA) satellite during its operation between March 1979 and June 1980 was conducted and reported in the SCATHA Environmental Atlas (AFGL-TR-83-0002). Summary plots of much of the data used in the Atlas are presented in two volumes. The first volume contains magnetic field data and spacecraft frame potential data. The second volume contains low and medium energy range electron and ion data, medium energy range ion composition data and high energy electron data. The data are presented in 24-hour plots. GRA

N90-15497# Photometrics, Inc., Woburn, MA.
MEASUREMENT OF OPTICAL RADIATIONS IN SPACECRAFT ENVIRONMENTS Scientific Report No. 1
I. L. KOFSKY, N. H. TRAN, M. A. MARIS, and C. A. TROWBRIDGE 15 Jun. 1989 52 p

(Contract F19628-88-C-0070)
(AD-A213814; PHM-P-06-89; GL-TR-89-0168; SR-1) Avail: NTIS HC A04/MF A01 CSCL 04/1

Three topics in remote sensing of the gaseous and particulate environment of spacecraft are reported and several further optical contamination and induced-glow phenomenology issues now under consideration are briefly reviewed. The transmission to ground stations of the near-ultraviolet radiation from OH* excited when high-kinetic energy water molecules in thruster rocket exhaust react with the ambient oxygen atoms is calculated from band and atmosphere models, and the measurement signal/noise is shown to depend on the concentrations of both (UV-absorbing) ozone molecules and (UV sky background-producing) O atoms along the view path as well as on the spatial distribution of radiance from the exoatmospheric collision volume. Vacuum-ultraviolet photolysis of water vapor off spacecraft with radiometry of the resulting electronically-excited, microsecond lifetime hydroxyl radicals is shown to be a feasible means for determining its rates of offgassing, and preliminary designs for such active probes are presented. An initial review of the potential for identification of spaceborne particulates from their chemical composition-dependent scattering and emission of visible and infrared quanta indicates these synthetic (instrument response-convolved) spectra of candidate contaminant particles are need to evaluate the concept. GRA

N90-15986# Consiglio Nazionale delle Ricerche, Frascati (Italy). Ist. di Fisica dello Spazio Interplanetario.
HOLLOW-CATHODE EXPERIMENTS TO SUPPORT ELECTRODYNAMIC TETHER APPLICATIONS
G. VANNARONI, U. GUIDONI, C. B. COSMOVICI, and F. DEVENUTO Mar. 1989 21 p Sponsored by Piano Spaziale Nazionale, Rome, Italy
(IFSI-89-5; ETN-90-96167) Avail: NTIS HC A03/MF A01

Interaction experiments between two hollow cathode plasma sources are carried out in a plasma chamber. The experiment is performed in order to simulate the electrodynamic phenomena of the tethered satellite system orbiting at ionospheric altitudes. The interaction region is investigated by means of Langmuir and emissive probes. Plasma parameter maps are carried out applying different voltage polarizations to the hollow cathode plasma contactor with respect to the ambient plasma. The results show the presence of two regions, the first where a double layer is formed, and the second presenting an electron heating effect. ESA

N90-16685# Oak Ridge National Lab., TN. Engineering Physics and Mathematics Div.
THE EFFECTS OF NATURAL AND ENHANCED VAN ALLEN BELT RADIATION ON A SPACE BASED WEAPON PLATFORM
R. T. SANTORO, J. M. BARNES, and J. O. JOHNSON 1990 5 p Presented at the HEART Conference, Monterey, CA, 12-16 Feb. 1990 Sponsored in part by AF
(Contract DE-AC05-84OR-21400)
(DE89-016219; CONF-900216-2) Avail: NTIS HC A01/MF A01

Monte Carlo radiation transport calculations have been performed to estimate the effects of natural (protons and electrons) and weapon enhanced (electron) Van Allen Belt (VAB) radiation on a space deployed weapon platform. (The satellite configuration adopted for this study represents the authors' concept of such a system.) The purpose of this study was to evaluate the long term and transient effects of these radiation modes on the components of a satellite deployed in a circular orbit at an altitude of 500 km and inclination angle of 0-deg. These kinds of satellites must survive long-term (up to 10 years) exposure to the natural radiation environment and the effects of enhanced radiation introduced when nuclear weapons are detonated in space. This paper describes the platform/weapon system and its components, the Van Allen Belt spectra, the methods of calculation, and summarizes the radiation damage to platform components from VAB protons and electrons and enhanced electron belt radiation. DOE

N90-16852*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACECRAFT ENVIRONMENTAL ANOMALIES HANDBOOK Final Report, Oct. 1987 - Aug. 1989
PAUL A. ROBINSON, JR. 1 Aug. 1989 282 p
(Contract NAS7-918; AF PROJ. 2822)
(NASA-CR-186331; NAS 1.26:186331; AD-A214603; GL-TR-89-0222) Avail: NTIS HC A13/MF A02 CSCL 22/2

Anomalies on spacecraft can be avoided by understanding their mechanisms and causes. This handbook discusses single event upsets (SEUs), surface charging and discharging, and internal or deep dielectric charging along with methods available for the reduction or elimination of the effects they can cause in spacecraft. GRA

N90-16856# Massachusetts Inst. of Tech., Cambridge. Center for Space Research.
RADIATION OF PLASMA WAVES FROM LARGE SPACE STRUCTURES IN LOW EARTH ORBIT Final Report, 30 Jun. 1986 - 31 Aug. 1988
D. E. HASTINGS, A. BARNETT, and S. OLBERT 5 Oct. 1988 39 p Repr. from Journal of Geophysical Research, v. 93, no. A3, 1 Mar. 1988 p 1945-1960
(Contract F19628-86-K-0027)
(AD-A215062; AFGL-TR-88-0276) Avail: NTIS HC A03/MF A01

There are many situations of interest in space and astrophysics which consist of a conducting body moving across a magnetized plasma. It is well known that large conducting objects which move slowly across mangetic field lines radiate low frequency (Alfven) waves. The interaction between a plasma and a moving conductor is studied to estimate the total power radiated at all frequencies. Toward this end, a formalism which permits the computation of the response of the plasma to an external current source was developed. An integral equation is derived which relates the source current to the electrical properties of the conducting body. Author

N90-17532# Aerospace Corp., El Segundo, CA. Space Sciences Lab.
SOLAR CYCLE EFFECTS ON TRAPPED ENERGETIC PARTICLES
ALFRED L. VAMPOLA 15 Oct. 1989 47 p
(Contract F04701-88-C-0089)
(AD-A215028; TR-0089(4940-05)-3; SD-TR-89-78) Avail: NTIS HC A03/MF A01 CSCL 22/1

The energetic particle populations in the earth's magnetosphere, which are the result of geomagnetic activity and, ultimately, are due to solar activity, have a major impact on the operation and survival of spacecraft. Departures from the nominal in solar activity produce requirements for changes from the nominal in the design and operation of spacecraft. If the approaching solar maximum is a robust one, as is indicated by preliminary solar data, the approaching solar maximum is a robust one, as is indicated by preliminary solar data, the energetic particle population can be expected to be in excess of that predicted by particle models such as AE8 and AP8, since those models include solar cycle effects based on nominal solar activity. In the event of a robust solar cycle, accelerated degradation of electronics and power systems, increased sensor background effects, and more frequent operational anomalies may be expected on spacecraft which were designed for a nominal energetic particle population that could be expected based on a robust solar Cycle 22. GRA

N90-17668# Naval Research Lab., Washington, DC.
CHEMICAL INTERACTIONS AND LIGHT EMISSIONS FROM VENTED SPECIES Final Report, Jun. 1988 - Mar. 1989
P. A. BERNHARDT and M. J. MULBRANDON 20 Oct. 1989 45 p
(AD-A214130; NRL-MR-6527) Avail: NTIS HC A03/MF A01 CSCL 04/1

Airglow emissions may be induced by the interaction of atmospheric constituents with vapors released from space vehicles. Such emissions can be produced by a number of chemical

mechanisms. This study considers neutral-plasma reactions as well as neutral-neutral reactions as the sources for excited species. The intensities of light emissions produced by the release of water and methyl alcohol into the upper atmosphere is estimated with a numerical mode. Chemical reactions between the injected neutrals, background ions, electrons, and neutrals, and artificially created ions and neutrals are considered. We find that OH is the primary excited species resulting from the water release. Vibrational and electronic states of OH will be excited to yield emission spectra between 240 and 4400 nm wavelengths. For the release of 10 to the 26th power molecules in the nighttime ionosphere with a density of 10 to the 6th power/cu cm, the intensities of the emissions will be greater than .0001 Rayleighs. The water release also produces vibrational states of H2O and electronic states of atomic oxygen. The addition of methyl alcohol to the release causes substantial production of vibrationally excited formaldehyde. It is concluded that the venting of reactive molecules into the upper atmosphere at 300 km altitude or above can produce excited species by neutral-neutral, ion-neutral, or electron-ion reactions. No one reaction process is dominant in the F-region. GRA

N90-19287# Technische Univ., Brunswick (Germany, F.R.). Abteilung fuer Raumflugtechnik.
PRESENT AND FUTURE RISK OF SATELLITE AND MANNED PLATFORMS COLLISIONS WITH OTHER SPACE OBJECTS AND PARTICLES ON EARTH ORBITS [KURZBERICHT UEBER KONSEQUENZEN UND ERFORDERLICHE MASSNAHMEN DER STUDIE: DAS GEGENWAERTIGE UND ZUKUENFTIGE RISIKO DER KOLLISION VON SATELLITEN UND BEMANNTEN PLATTFORMEN MIT ANDEREN RAUMFLUGOBJEKTEN UND SCHROTTEILEN AUF ERDNAHEN UMLAUFBAHNEN]
P. EICHLER and D. REX 1988 11 p In GERMAN
(Contract BMFT-01QV86810)
(R-8841; ETN-90-95896) Avail: NTIS HC A02/MF A01

The collision probability can reach a certain percentage for big structures and long missions. In view of the Hermes and Columbus projects, the Europeans examined the American approach to this problem, such as the foundation of the U.S. intergovernmental Working Group on Space Debris. The manned modules of the future International Space Station will be protected with enclosures, whose weight represents 25 percent of the total structure mass. Another problem arises with the extravehicular activities, for which NASA calculated a risk of collision for 700,000 hours. It is essential to produce new mathematic models of the simulation of production of debris by explosions and collisions in space, and of the dynamics of debris clouds. A better cooperation with NASA is advisable. Future explosions in space must be avoided, and objects must be moved away from the terrestrial orbit as quickly as possible in order to limit the creation of new debris. ESA

N90-19288# Technische Univ., Brunswick (Germany, F.R.). Abteilung fuer Raumflugtechnik.
PRESENT AND FUTURE RISK OF COLLISION OF SATELLITES AND MANNED PLATFORMS WITH OTHER SPACE OBJECTS AND PARTICLES IN TERRESTRIAL ORBIT Final Report [DAS GEGENWAERTIGE UND ZUKUENFTIGE RISIKO DER KOLLISION VON SATELLITEN UND BEMANNTEN PLATTFORMEN MIT ANDEREN RAUMFLUGOBJEKTEN UND SCHROTTEILEN AUF ERDNAHEN UMLAUFBAHNEN]
P. EICHLER and D. REX 1988 172 p In GERMAN
(Contract BMFT-01QV86810)
(R-8840; ETN-90-95897) Avail: NTIS HC A08/MF A01

For nonprotected satellites, an object with a diameter of 1 mm is dangerous. Others are jeopardized by objects with a diameter of 1 cm. There are few direct measurement data for objects between 1 to 10 cm. A simulation of the most important explosion facts can give information about debris number and orbit distribution. Since a lot of data about Russian or military satellites is missing, a second method is employed to estimate the surface charge using an iteration process. A broad dispersion is found, with a reducing frequency at the higher surface charges. The explosion intensity is evaluated by the mass of the exploding object, the typically produced mass spectrum, and the number of measurable debris. Another program allows calculation of the long term development of a debris cloud. All these methods give a representative set of data about 35,000 objects greater than 1 cm in earth orbit. To calculate the collision probability, a model based on the shock process that appear by the gas diffusion, according to the kinetic gas theory, is used. ESA

N90-19289# Technische Univ., Brunswick (Germany, F.R.). Abteilung fuer Raumflugtechnik.
SATELLITES AND DEBRIS IN EARTH REVOLUTION ORBITS AND FIRST ESTIMATION OF THE COLLISION PROBABILITY [BESETZUNG VON ERDUMLAUFBAHNEN MIT SATELLITEN UND TRUEMMERN UND ERSTE ABSCHAETZUNG DER KOLLISIONSWAHRSCHEINLICHKEIT]
P. EICHLER and D. REX 1987 92 p In GERMAN
(Contract BMFT-01-OO-8604)
(R-8709; ETN-90-95898) Avail: NTIS HC A05/MF A01

A model of the collision probability based on the shock processes of the gas diffusion is given. The special orbit mechanics of objects in the earth gravitational field is thereby disregarded. The debris distribution is examined. The maximal object flux and the maximal congestion ratio is between 600 and 1100 km orbit height. In this critical area, the object flux-particle size curve is proposed. The objects of a diameter lower than 1 cm are principally meteorites, but for greater diameters, artificial satellites are the most numerous. The evolution of the number of objects in orbit for the last thirty years is described. A data base was produced, that contained the orbit parameters for every considered object, such as incline, apogee and perigee height, eccentricity and great half axis. ESA

N90-19290# Bundesministerium fuer Forschung und Technologie, Bonn (Germany, F.R.).
PROJECT FOR THE EUROPEAN SPACE ORGANIZATION IN THE AREA OF SPACE DEBRIS [RAUMFAHRTRUECKSTAENDE]
25 Jul. 1989 44 p In GERMAN
(REPT-29/89; ETN-90-95903) Avail: NTIS HC A03/MF A01

A strong angle dependence of the object flow in terrestrial space is established by a deterministic calculation process, that takes into account the trajectory mechanics of every object in earth orbit. The object flow that is equivalent to the collision risk, seems to be in a plane vertical to the trajectory plane. A good orientation can then reduce the object flow and the necessary protection costs; for a cylinder, that corresponds to the free flyer of Columbus, the transverse position in the debris plane is the best. Another position can increase the object flow by 31 percent. The ultimate development of the space station might be as far as possible, inside the debris plane. Critical manned modules might be put inside towards the back, uncritical modules might be ouside towards the front. The uncritical parts would screen the critical parts, whose collision risk could be practically nil, without additional protection costs. To limit debris production, which will be greater than those of meteorites, the engineers decided to address unnecessary explosions. ESA

N90-19855# Northeastern Univ., Boston, MA.
ACTIVE PROBING OF SPACE PLASMAS Final Report, 25 Oct. 1985 - 30 Sep. 1989
CHANG CHAN, MICHAEL B. SILEVITCH, and ELENA VILLALON
1 Sep. 1989 110 p
(Contract F19628-85-K-0053)
(AD-A216867; GL-TR-89-0272) Avail: NTIS HC A06/MF A01
CSCL 04/1

During the course of the research period our efforts were focused on the following areas: (1) An examination of stochastic acceleration mechanisms in the ionosphere; (2) A study of nonequilibrium dynamics of the coupled magnetosphere - ionosphere system; and (3) Laboratory studies of active space experiments. Reprints include: Dynamics of charged particles in the near wake of a very negatively charged body -- Laboratory experiment and numerical simulation; Laboratory study of the electron temperature in the near wake of a conducting body; New

model for auroral breakup during substorms; Substorm breakup on closed field lines; New model for substorm on sets -- The pre-breakup and triggering regimes; Model of the westward traveling surge and the generation of Pi 2 pulsations; Ionospheric electron acceleration by electromagnetic waves near regions of plasma resonances; Relativistic particle acceleration by obliquely propagating electromagnetic fields; Some consequences of intense electromagnetic wave injection into space plasmas. GRA

05

MATERIALS

Descriptions and analyses of different structural materials, films, coatings or bonding materials. Mechanical properties of spacecraft construction materials. Descriptions of the effects of natural and induced space environments.

A90-11098#
PLASMA-DEPOSITED MULTI-PURPOSE PROTECTIVE COATINGS FOR SPACE APPLICATIONS
J. E. KLEMBERG-SAPIEHA, M. R. WERTHEIMER (Montreal, Ecole Polytechnique, Montreal Canada), and D. G. ZIMCIK (Canadian Space Agency, Ottawa, Canada) ESA Journal (ISSN 0379-2285), vol. 13, no. 2, 1989, p. 117-126. Research supported by NSERC and FCAR. refs
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The present paper reports results of investigations in which various thin-film protective layers have been applied to polymers used on spacecraft, in particular, Kapton polyimide and epoxy resin, that have been shown to be attacked by atomic oxygen. These protective films, derived from volatile compounds via microwave glow discharge, include amorphous hydrogenated silicon (a-Si:H) and the inorganic silicon compounds, silicon nitride (P-SiN) and oxide (P-SiO2). All these materials are shown to provide excellent protection against atomic oxygen attack. In addition, they have attractive electrical and optical properties which provide unique design opportunities that are useful in numerous other space applications and conditions. The electrical conductivity of a-Si:H (a semiconductor) can readily be controlled over many orders of magnitude by gas-phase doping. This allows one to prevent charge build-up, while assuring negligible reflection or attenuation of radio-frequency waves incident on the coated material. Finally, results of thermal radiative property measurements are presented for protective films both in the virgin state and after exposure to atomic-oxygen attack. Author

A90-11099#
ELECTRON BEAMS AND NONDESTRUCTIVE TESTING OF MATERIALS IN SPACE
J. L. FRANCESCHI (CNRS, Laboratoire d'Optique Electronique, Toulouse, France) and C. CHAPUIS (Toulouse, Institut National Polytechnique, France) ESA Journal (ISSN 0379-2285), vol. 13, no. 2, 1989, p. 127-134. refs
Copyright

A miniaturized electron-beam microscope is proposed for nondestructive testing of materials in space. The instrument, which was originally developed for the examination of cracks in aviation structures, is described and illustrated. An automated version of the electron beam generator has been developed for possible use in a space station. The accuracy of images obtained with the generator is evaluated. Consideration is given to three techniques for the analysis of the microscope data: backscattering imagery, X-rays, and elastic ultrasonic waves. R.B.

A90-11134
PHENOMENOLOGY OF E-IRRADIATED POLYMER BREAKDOWN
J. P. MARQUE (ONERA, Chatillon-sous-Bagneux, France) (Vacuum, vol. 39, no. 5, 1989, p. 443-452) ONERA, TP no. 1989-99, 1989, 11 p. refs
(ONERA, TP NO. 1989-99) Copyright

Electronic malfunctions may occur on geostationary satellites when they are immersed in a high-energy electron plasma during magnetic substorms. These events are thought to be induced by charges built-up on the various polymer insulators used for the thermal control of the spacecraft and subsequent electrostatic discharges. To understand these discharge mechanisms, laboratory experiments are carried out by irradiating thin FEP films in a vacuum vessel with an electron beam in the energy range 5 kev-50 keV. The discharges look like propagating surface discharges in gases at atmospheric pressure and are characterized by a strong electron emission out of the surface known as a 'blow-off emission'. This paper reviews the main characteristics of these surface discharges. A model is proposed for the initiation and propagation processes. The essential idea is that the discharge is the result of the ionization of a thin gas layer created by ionic stimulated desorption of the polymer ahead of the spark. The blow-off emission is then caused by the vacuum expansion of the plasma of the surface discharges. Author

A90-11430
THE IMPACT OF A PROPULSIVE JET ON THE WALL OF A SPACECRAFT [L'IMPACT D'UN JET PROPULSIF SUR LA PAROI D'UN ENGIN SPATIAL]
JEAN-CLAUDE LENGRAND (CNRS, Laboratoire d'Aerothermique, Meudon, France) AAAF, Colloque d'Aerodynamique Appliquee, 25th, Talence, France, Oct. 12-14, 1988. 21 p. In French. refs
(AAAF PAPER NT 88-10) Copyright

Previous theoretical and experimental studies on the effects of propulsive jets on spacecraft surfaces are reviewed. Emphasis is placed on the need to study the heat flux of the high-temperature gas ejected, the pressure and friction generated by the impact of the jet on the wall, and the contamination of optical surfaces and solar panels by the solid or liquid particles contained in the jets. Problems inherent in theoretical approaches to the modeling of the flow in the nozzle and in the jet are discussed. When adjusted for nozzle ejection Mach number, observational data obtained for the OTS-2 satellite are found to agree well with theoretical results. It is suggested that exact methods (solution of the laminar three-dimensional Navier-Stokes equations and Monte Carlo simulations) should be used to treat complex geometries and two-phase flows, and that approximate methods should be improved to include complex surfaces, vibrational energy, and the catalytic nature of the wall. R.R.

A90-12254#
HIGH-PERFORMANCE COMPOSITE MATERIALS WITH THERMOPLASTIC MATRIX MATERIALS FOR AIR AND SPACE TRAVEL [HOCHLEISTUNGSVERBUNDWERKSTOFFE MIT THERMOPLASTISCHEN MATRIX-WERKSTOFFEN FUER DIE LUFT- UND RAUMFAHRT]
J. BRANDT and H. RICHTER (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) Internationale Chemiefasertagung, 28th, Dornbirn, Austria, Sept. 20-22, 1989, Paper. 22 p. In German. refs
(MBB-Z-0273-89-PUB)

The development of new high-temperature thermoplastics has increased interest in the use of such materials in air and space travel. The most important characteristics that materials need to have to be used for these purposes are reviewed, and the processing of fiber-reinforced thermoplastics is described. Forming techniques applicable to such thermoplastics are briefly discussed, and the different kinds of semifabricated forms of fiber-reinforced thermoplastics are examined. C.D.

A90-13837#
ACCELERATED AGING OF THE THERMAL EXPANSION OF UNIDIRECTIONAL GRAPHITE/EPOXY COMPOSITES BY THERMAL FATIGUE
W. L. MORRIS, M. R. JAMES, and R. V. INMAN (Rockwell International Science Center, Thousand Oaks, CA) ASME,

Transactions, Journal of Engineering Materials and Technology (ISSN 0094-4289), vol. 111, Oct. 1989, p. 331-337. Research supported by Rockwell International Independent Research and Development Funds. refs
Copyright

The longitudinal coefficient of thermal expansion (alpha 1) of unidirectional T300/934 and AS/3501-5A graphite/epoxy composite changes within 1000 thermal cycles at ranges greater than 210 C. A phenomenological model is developed to extrapolate alpha 1 to a smaller thermal range (less than 100 C) and longer duration (200,000 cycles) typical of service in LEO. Factors affecting fiber/matrix interface cracking are considered, and the utility of calculating alpha 1 from an effective fiber volume fraction (which excludes from the volume fiber segments disbonded from the matrix) is demonstrated. This analysis is used to estimate the effect of fiber volume on alpha 1 of T300/934 during thermal fatigue. Author

A90-13849
PROPERTY PERFORMANCE OF THERMOPLASTIC COMPOSITES FOR SPACECRAFT SYSTEMS
E. M. SILVERMAN, R. A. GRIESE, and W. C. FORBES (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) SAMPE Journal (ISSN 0091-1062), vol. 25, Nov.-Dec. 1989, p. 38-47. refs
Copyright

Results are presented on evaluating several graphite/PEEK composites (including AS-4/PEEK, Pitch 75/PEEK, and Pitch 100/PEEK) and Kevlar-reinforced thermoplastic composites (Kevlar 49/Ultem, Kevlar 149/Ultem, Kevlar 49/PES, and Kevlar/PPS) with respect to requirements of spacecraft applications. The properties of these samples were compared with those of a typical baseline epoxy composite. Results showed that, compared to the T300/934 epoxy composite, the AS-4/PEEK composites exhibited equivalent mechanical properties and lower moisture uptake and outgassing, while damping was higher. The Pitch 75/PEEK and Pitch 100/PEEk composites exhibited equivalent mechanical properties and lower equilibrium moisture uptake at 95 percent relative humidity. Results also indicated that Kevlar-reinforced thermoplastics absorbed less water and exhibited superior dimensional stability compared to a Kevlar-reinforced epoxy composite. I.S.

A90-14027* Los Alamos National Lab., NM.
MOS2 INTERACTIONS WITH 1.5 EV ATOMIC OXYGEN
J. A. MARTIN, J. B. CROSS (Los Alamos National Laboratory, NM), and L. E. POPE (Sandia National Laboratories, Albuquerque, NM) IN: New materials approaches to tribology: Theory and applications; Proceedings of the Symposium, Boston, MA, Nov. 29-Dec. 2, 1988. Pittsburgh, PA, Materials Research Society, 1989, p. 271-276. Research supported by USAF and NASA. refs
(Contract DE-AC04-76DP-00789)
Copyright

Exposures of MoS2 to 1.5-eV atomic oxygen in an anhydrous environment reveal that the degree of oxidation is essentially independent of crystallite orientation, and that the surface-adsorbed reaction products are MoO3 and MoO2. A mixture of oxides and sulfide exists over a depth of about 90 A, and this layer has a low diffusion rate for oxygen. It is concluded that a protective oxide layer forms on MoS2 on exposure to the atomic-oxygen-rich environment of LEO. Author

A90-14657
MATERIAL APPLICATIONS OF THE SPACE STATION - KEY ISSUES AND THE APPROACH TO THEIR SOLUTION
D. F. THOMPSON and H. W. BABEL (McDonnell Douglas Space Systems Co., Huntington Beach, CA) SAMPE Quarterly (ISSN 0036-0821), vol. 21, Oct. 1989, p. 27-33. refs
Copyright

An evaluation is made of the low earth orbit environment factors that will affect the NASA Space Station over the course of its 30-year service life requirement. UV radiation and atomic oxygen are of primary concern due to their roles in the degradation of exposed organic and inorganic materials, especially solar-array substrates and thermal-control coatings; the temperature cycles encountered between sun-exposed and earth-shadowed portions of orbit, as well as space debris, are additional concerns. Attention is given to 'bumper' protective coating concepts and the choice of materials for structural truss tubes. O.C.

A90-14658
EXTENDED THERMAL CYCLE TESTING OF GRAPHITE/EPOXY COMPOSITE STRUTS FOR SPACE STATION APPLICATIONS
RANDY JONES, RUDY LUKEZ (Morton Thiokol, Inc., Aerospace Group, Brigham City, UT), BRYAN PETERSON, J. CLAIR BATTY, and FRANK J. REDD (Utah State University, Logan) SAMPE Quarterly (ISSN 0036-0821), vol. 21, Oct. 1989, p. 34-38. refs
Copyright

The thermal cycle tests to which the graphite fiber-reinforced/epoxy-matrix composite struts designed for the NASA Space Station have been subjected involved 10,000 cycles from 93 C to -101 C, in order to verify survival in the low earth orbit shadowed/insolated environment. Periodic microstructural inspections have identified no microcracking damage; coefficient of thermal expansion (CTE) and axial modulus tests of the sample struts indicated that they were not significantly affected by this level of thermal cycling severity. Classical lamination theory analysis indicates that CTE is far more sensitive to microcracking than axial modulus. O.C.

A90-14778
FRACTURE-RESISTANT ULTRALLOYS FOR SPACE-POWER SYSTEMS - NUCLEAR-THERMIONIC-CONVERSION IMPLICATIONS OF W,27RE
N. O. MORAGA, D. L. JACOBSON, and J. F. MORRIS (Arizona State University, Tempe) Engineering Fracture Mechanics (ISSN 0013-7944), vol. 34, no. 3, 1989, p. 553-565. Research supported by SDIO and DOE. refs
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The thermionic and thermal emissive characteristics of sintered tungsten-26.6 percent rhenium (W,27Re) alloy intended for use in space-nuclear-reactor systems were investigated using specially designed apparatus. Graphs are presented for variation of the effective work function of the W,27Re with temperature, heating time, and environmental conditions; variables cover thermionic emission at 1700 to 2200 K for 0 to 180 min and 10 to the -8th to 10 to the -6th torr total pressures comprising partial pressures of H2, N2 plus CO, H2O, CO2, and O2 between 10 to the -10th and 10 to the -6th torr. Results obtained emphasize the fallacy of characterizing ultralloys similar to the W,27Re alloy with single-valued thermophysicochemical properties, such as the work function. I.S.

A90-14779
FRACTURE-RESISTANT ULTRALLOYS FOR SPACE-POWER SYSTEMS - HIGH-TEMPERATURE TENSILE CHARACTERISTICS AND FRACTOGRAPHS FOR W,30RE AND W,30RE,1THO2
B. H. TSAO, D. L. JACOBSON, and J. F. MORRIS (Arizona State University, Tempe) Engineering Fracture Mechanics (ISSN 0013-7944), vol. 34, no. 3, 1989, p. 567-573, 575-577. Research supported by SDIO and DOE. refs
Copyright

Data on tensile properties are presented for sintered W,30Re and W,30Re,1Th for the 2000-2750 K range, along with fractographs taken at various temperatures in this range. It is shown that the inclusion of 1 wt pct ThO2 in the W,30Re alloy not only strengthens this ultralloy but also improves its ductility. Addition of ThO2 resulted also in fewer voids, higher twin densities, and smaller grain sizes. Metallographic observations also revealed that most of the ThO2 particles lie at grain boundaries along the tensile axes. SEM micrographs of the fracture surface demonstrated that the fracture mode of thoriated and unthoriated materials is intergranular. I.S.

A90-17400#
UP CLOSE - MATERIALS SCIENCES AT LOCKHEED PALO ALTO RESEARCH LABORATORY
ERNEST L. LITTAUER (Lockheed Missiles and Space Co., Inc., Palo Alto, CA) MRS Bulletin (ISSN 0883-7694), vol. 14, Nov. 1989, p. 79-83.

An overview on material science activities at Lockheed Palo Alto Research Laboratory is presented. Investigations have been conducted on a wide range of topics in metallurgy, chemistry, structures, and nondestructive test/evaluation. The laboratory's strong capability in performance analysis and problem identification/resolution for solid rocket propulsion systems contributed to the Polaris, Poseidon, and Trident I missiles. Efforts are also focused on materials for other aerospace applications, such as advanced aircraft, the Space Station Freedom, and the Strategic Defense Initiative. Examples of materials sciences achievements include the development of the Space Shuttle's heat shield tiles, the first use of lithium as an anode in batteries, a real-time X-ray inspection system for large rocket motors, and coated/uncoated refractory metal hot gas manifolds for ballistic missile propulsion. C.E.

A90-18409
EVALUATION OF A TOUGH TYPE MATRIX CFRP FOR USE IN SPACE STRUCTURE
T. KAMIYAMA, Y. NAGAO, N. SUGAHARA (Fuji Heavy Industries, Ltd., Utsunomiya, Japan), T. SEGUCHI, T. SASUGA (Takasaki Radiation Chemistry Research Establishment, Japan Atomic Energy Research Institute, Japan) et al. IN: Japan-U.S. Conference on Composite Materials, 4th, Washington, DC, June 27-29, 1988, Proceedings. Lancaster, PA, Technomic Publishing Co., Inc., 1989, p. 933-942. refs
Copyright

Two kinds of carbon fiber reinforced plastics, T-300/3601 (conventional) and IM-6/R6376 (tough), were evaluated as candidate materials for long-term missions in low-earth orbit. In particular, tests were conducted to evaluate the effects of electron irradiation, thermal cycling, and a combination of both on the mechanical properties of the composites. Both materials were stable under irradiation up to 10 MGy. However, microcracks were found in T-300/3601 after 3000 thermal cycles. Combined tests confirmed the superiority of the tough type composite, IM-6/R6376, for space structures in low-earth orbit. V.L.

A90-18410
CFRP STRUCTURE APPLICATION TO RECENT NASDA SPACECRAFT
HIDEHIKO MITSUMA (NASDA, Tsukuba Space Center, Japan) IN: Japan-U.S. Conference on Composite Materials, 4th, Washington, DC, June 27-29, 1988, Proceedings. Lancaster, PA, Technomic Publishing Co., Inc., 1989, p. 943-952. refs
Copyright

This paper presents some examples of CFRP application to spacecraft structures at NASDA, based on the results of R&D performed to obtain design data for the Japanese Earth Resources Satellite (ERS-1) and the Engineering Test Satellite ETS-VI. Recently developed CFRP structures include a truss-type structure and a panel-type structure. In this paper, the basic structures developed for ERS-1 and (ETS-VI) are introduced, and some characteristics of the structures are discussed. Author

A90-19992#
EFFECTS OF ATOMIC OXYGEN IRRADIATION ON SPACECRAFT MATERIALS - MATERIAL DEGRADATION STUDIES
MASASHI ARITA, TOSHIHIKO AIKAWA, YUSHI SHICHI, and MASAO AKIYAMA (Nissan Motor Co., Ltd., Yokosuka, Japan) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 7 p. refs
(AIAA PAPER 90-0727) Copyright

The material degradation of spacecraft materials was investigated using a ground-based atomic oxygen simulation facility utilizing a CO2 laser. The materials evaluated were polyimide film, graphite/epoxy composites and carbon/carbon composites. Similar effects of surface erosion and degradation were observed between the ground-based atomic oxygen simulation tests and the Space Shuttle flight tests. The surfaces of polyimide film and graphite/epoxy composites showed a 'rug-like' appearance after the simulation tests. X-ray photoelectron spectroscopy revealed that in the oxidation of the epoxy matrix a carboxyl peak and a carbonyl peak existed in the C1s spectra of the irradiated graphite/epoxy composite. Two kind of carbon/carbon composites were evaluated. The conventional carbon/carbon composite was affected by atomic oxygen, while the chemical vapor-deposited silicon carbide coating on the carbon/carbon composite was generally unaffected. The silicon carbide coating was thus confirmed to be useful in protecting carbon/carbon composite from erosion in low earth orbit applications. Author

A90-19993#
INFLUENCE OF 5 EV ATOMIC OXYGEN ON SURFACE PROPERTIES OF AG FILMS AND GRAPHITE
M. TAGAWA, M. UMENO, and N. OHMAE (Osaka University, Suita, Japan) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 8 p. refs
(AIAA PAPER 90-0728) Copyright

Deterioration in the surface properties of Ag films and carbon fibers due to irradiation by an energetic atomic oxygen beam has been studied. A nearly monoenergetic atomic oxygen beam at 5 eV with a flux of 10 to the 14th atoms/sq m sec was obtained by neutralizing an oxygen ion beam. Irradiation caused a remarkable change in the refraction coefficient of Ag film, and the formation of Ag2O shows good agreement with the exposure studies in LEO (STS-4). Author

A90-20021#
BIMETALLIC COMPATIBLE COUPLES
A. DE ROOIJ (ESA, Materials and Processes Div., Noordwijk, Netherlands) ESA Journal (ISSN 0379-2285), vol. 13, no. 3, 1989, p. 199-209. refs
Copyright

In the construction of a satellite, two metals that form a compatible couple may have to be placed in close proximity to one another. The static corrosion potential for a large number of metals and alloys has been established. These potentials were measured in a 3.5 pct NaCl solution representing a standard corroding atmosphere. The potentials measured have been compared against the data for similar materials to be found in the literature. Data for material combinations not tested in the present study have been compiled from the literature in order to make available one complete reference table. It is shown that, in the case of atmospheric galvanic corrosion, a simplified procedure can be used to estimate the compatibility of a bimetallic couple by taking into account the difference between the two static potentials of the materials involved. Author

A90-20070
DYNAMIC PROPERTIES OF AS4/3502 COMPOSITES UNDER HOSTILE ENVIRONMENTAL CONDITIONS
AJIT K. ROY and RAN Y. KIM (Dayton, University, OH) IN: International Congress on Experimental Mechanics, 6th, Portland, OR, June 6-10, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 937-941.
(Contract F33615-87-C-5239)
Copyright

Composite materials are increasingly being used in space structures to make the structure stronger and lighter. In this paper, the effects of temperature and moisture and stacking sequence on the dynamic properties of a group of multidirectional laminates of AS4/3502 are presented. Data on the storage moduli and loss factor of the composite are presented as a function of frequency and temperature. C.D.

A90-20890
MATERIALS FOR SPACE STATION

GEORGE MARSH Space (ISSN 0267-954X), vol. 5, Sept.-Oct. 1989, p. 6-8, 11.
Copyright

The requirements and materials needed for the Space Station truss network are examined. It is proposed that the Station's truss network be assembled in space and have a 30 year life expectancy in LEO. The effects of charged particle radiation, temperature cycling, space debris, UV radiation, and atomic oxygen on the truss structure are described. The use of materials, such as carbon-polyetheretherketone, Kevlar-polyetherimide, and thero-plastics for the Station's structure is investigated. The possibility of in space fabrication of the truss structure tubes is discussed. I.F.

A90-21905* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ESCA STUDY OF SEVERAL FLUOROCARBON POLYMERS EXPOSED TO ATOMIC OXYGEN IN LOW EARTH ORBIT OR WITHIN OR DOWNSTREAM FROM A RADIO-FREQUENCY OXYGEN PLASMA
MORTON A. GOLUB, THEODORE WYDEVEN (NASA, Ames Research Center, Moffett Field, CA), and ROBERT D. CORMIA (Surface Science Laboratories, Mountain View, CA) Polymer (ISSN 0032-3861), vol. 30, Sept. 1989, p. 1571-1575. refs
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The ESCA (*electron spectroscopy for chemical analysis*) spectra of films of Tedlar, tetrafluoroethylene- hexafluoropropylene copolymer (in the form of a Teflon FEP coating on Kapton H, i.e., Kapton F), and polytetrafluoroethylene (Teflon or Teflon TFE), exposed to atomic oxygen O(3P) either in LEO on the STS-8 Space Shuttle or within or downstream from a radio-frequency oxygen plasma, were compared. The major difference in surface chemistry of Tedlar induced by the various exposures to O(3P) was a much larger uptake of oxygen when etched either in or out of the glow of an O2 plasma than when etched in LEO. In contrast, Kapton F exhibited very little surface oxidation during any of the three different exposures to O(3P), while Teflon was scarcely oxidized. Author

A90-21927*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ETCHING OF PLASMA-POLYMERIZED TETRAFLUOROETHYLENE, POLYTETRAFLUOROETHYLENE, AND SPUTTERED POLYTETRAFLUOROETHYLENE INDUCED BY ATOMIC OXYGEN /O(3P)/
THEODORE WYDEVEN, MORTON A. GOLUB, and NARCINDA R. LERNER (NASA, Ames Research Center, Moffett Field, CA) Journal of Applied Polymer Science (ISSN 0021-8995), vol. 37, 1989, p. 3343-3355. refs

A90-22947
DESIGN OF THERMALLY STABLE GRAPHITE/ALUMINUM TUBULAR STRUCTURES FOR SPACE APPLICATIONS
D. G. ZIMCIK (Canadian Space Agency, Ottawa, Canada) and B. M. KOIKE (Composite Tecnologia, Sao Paulo, Brazil) SAMPE Quarterly (ISSN 0036-0821), vol. 21, Jan. 1990, p. 11-16. refs
Copyright

The thermal distortion of graphite reinforced aluminum space structures is evaluated and compared to the performance of graphite/epoxy. Both the coefficient of thermal expansion (CTE) and the thermal conductivity of the material (k) are considered in predicting the final distortion experienced in a typical hostile space environment. Metal matrix composite showed much better performance for tip distortion resistance for a wave-guide planar array than graphite/epoxy structures of equal mass. Author

A90-23267#
METHOD FOR ESTIMATING ATOMIC OXYGEN SURFACE EROSION IN SPACE ENVIRONMENTS
N. JOHN STEVENS (TRW, Inc., Redondo Beach, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 93-95. refs
(Contract F19627-84-C-0038)
Copyright

A technique has been developed which allows the computation of material losses due to the atomic oxygen erosion of surfaces on an inertially stabilized spacecraft in LEO, on the basis of ground-based test results. Excellent agreement is obtained between computation results and Space Shuttle test results for the cases of Kapton and Teflon. The technique is applicable to gravity-gradient stabilized spacecraft, and alleviates the current need for separate spaceflight testing of all materials and coatings. O.C.

A90-25609*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
APPLICATIONS OF HIGH THERMAL CONDUCTIVITY COMPOSITES TO ELECTRONICS AND SPACECRAFT THERMAL DESIGN
G. RICHARD SHARP (NASA, Lewis Research Center, Cleveland, OH) and TIMOTHY A. LOFTIN (DWA Composite Specialties, Inc., Chatsworth, CA) IN: AIAA International Communication Satellite Systems Conference and Exhibit, 13th, Los Angeles, CA, Mar. 11-15, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 59-64.
(AIAA PAPER 90-0783) Copyright

Recently, high thermal conductivity graphite fiber-reinforced metal matrix composites (MMCs) have become available that can save weight over present methods of heat conduction. Another significant advantage is that these materials can be used without the plumbing and testing complexities that accompany the use of liquid heat pipes. A spinoff of this research was the development of other MMCs as electronic device heat sinks. These use particulates rather than fibers and are formulated to match the coefficient of thermal expansion of electronic substrates in order to alleviate thermally induced stresses. The development of both types of these materials as viable weight-saving substitutes for the traditional methods of thermal control for electronics packaging and also for spacecraft thermal control applications are the subjects of this report. Author

A90-25858#
DIRECT MONTE CARLO SIMULATION OF HIGH ENERGETIC ATOMIC OXYGEN IMPINGING ON MATERIAL SURFACES
MASAHIRO ISHII (Ishikawajima-Harima Heavy Industries Co., Ltd., Yokohama, Japan) and TAKASHI ABE (Institute of Space and Astronautical Science, Sagamihara, Japan) IN: ISCFD Nagoya 1989 - International Symposium on Computational Fluid Dynamics, 3rd, Nagoya, Japan, Aug. 28-31, 1989, Technical Papers. Nagoya, Japan, Japan Society of Computational Fluid Dynamics, 1989, p. 971-976. refs

High kinetic energy oxgyen atoms impinging on satellites in LEO is a major cause of surface degradation of the satellites. The degree of degradation is lower in accelerated ground tests compared to degradation in LEO. Here, a simulation of the collision effect using an atomic oxygen flow facility operated under accelerated conditions is reported. It is found that, when the Knudsen number is decreased, the energy of impinging oxygen atoms is reduced by collisions with argon atoms or with other atomic oxygen atoms. Collisions with hydroxide reduce the number of impinging oxygen atoms. C.D.

A90-29226
AIAA/ASME/ASCE/AHS/ASC STRUCTURES, STRUCTURAL DYNAMICS AND MATERIALS CONFERENCE, 31ST, LONG BEACH, CA, APR. 2-4, 1990, TECHNICAL PAPERS. PART 1 - MATERIALS, ENGINEERING OPTIMIZATION AND DESIGN
Washington, DC, American Institute of Aeronautics and Astronautics, 1990, 586 p. For individual items see A90-29227 to A90-29282.
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This volume treats materials, engineering optimization, and design. Particular attention is given to materials behavior and characterization, aircraft design optimization, integrated control/structure optimization, optimization methods, component

and subsystem design, and space structures design. Twenty-one additional papers from this conference are published in NASA-CP-3064. B.J.

A90-30558
INFRARED EMISSION FROM THE REACTION OF HIGH-VELOCITY ATOMIC OXYGEN WITH GRAPHITE AND POLYETHYLENE
K. W. HOLTZCLAW, M. E. FRASER, and A. GELB (Physical Sciences, Inc., Andover, MA) Journal of Geophysical Research (ISSN 0148-0227), vol. 95, April 1, 1990, p. 4147-4153. refs (Contract DNA001-87-C-0114)
Copyright

A fast atomic oxygen source has been used to bombard samples of graphite and polyethylene. Infrared fluorescence is readily observed above both surfaces that is consistent with the expected primary combustion products CO, CO2, and OH. Emitter production efficiencies (defined as the ratio of emitters over incident O atoms) for both targets have been estimated from the observed radiation intensities. These are about 0.01 for CO and 0.001 for CO2 above both samples and about 0.01 for OH above polyethylene. Author

A90-31118#
MATERIAL REQUIREMENTS FOR THE SPACE STATION MOBILE SERVICING SYSTEM
D. G. ZIMCIK (Canadian Space Agency, Ottawa, Canada) and J. KAVANAGH (Astro Aerospace Corp., Carpinteria, CA) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 36, March 1990, p. 11-17. refs

The Canadian Mobile Servicing System (MSS) for the International Space Station must be designed for long life in a hostile environment. To meet functional requirements, the MSS must be designed to meet rigid requirements for pointing accuracy and stiffness. However, for space structures, environmental factors such as atomic oxygen, vacuum, radiation, thermal cycling, and space debris dominate design requirements. Strength will not be an overriding design consideration except for localized situations. New materials designed for enhanced performance are under development and evaluation. All of these must be thoroughly characterized and qualified to rigid NASA standards for manned space flight. The paper describes the details of the environmental and operational factors noted above to define the requirements to be considered in material selection for the MSS. Author

A90-31298#
THE OXIDATION OF SILVER BY ATOMIC OXYGEN
A. DE ROOIJ (ESTEC, Product Assurance and Safety Dept., Noordwijk, Netherlands) ESA Journal (ISSN 0379-2285), vol. 13, no. 4, 1989, p. 363-382. refs
Copyright

An improved model for the atomic oxygen oxidation of silver is presented. The transport of oxygen through the oxide layer is modeled using two transport mechanisms, namely gas flow through micropores and Fickian diffusion. Both processes exhibit parabolic growth. The interfacial reaction between oxygen and silver is taken as linear, resulting in a linear-parabolic oxidation with flux and time. The model results in a low-temperature oxidation by gas flow while at higher temperature the diffusion mechanism controls the kinetics of the oxidation. Flaking and spalling of the oxide layer is introduced in the model. This flaking behavior of the oxide results in a linear dependence between the thickness reduction of silver and the fluence of the atomic oxygen. Predictions of the thickness loss of silver are made as a function of orbital parameters, like time of the year, inclination angle, solar activity and altitude. These calculatios show that silver should not be used when exposed to atomic oxygen. Also so-called protection layers on silver are not always 100 percent protective. The amount of silver oxidized under the protective layer is usually much greater than the defects in the protection layers. Author

N90-10996# Technische Univ., Brunswick (Germany, F.R.). Inst. fuer Flugzeugbau und Leichtbau.
THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THIN-WALLED ALUMINUM PANELS UNDER CYCLIC SHEAR LOAD
P. HORST and H. KOSSIRA *In* ESA, Spacecraft Structures and Mechanical Testing p 79-84 Jan. 1989 Sponsored by the Deutsche Forschungsgemeinschaft, Bonn, Fed. Republic of Germany
Copyright Avail: NTIS HC A99/MF E06

Experimental and theoretical results for thin walled aluminum plates under cyclic shear load are presented. The theoretical results are obtained using a finite element code taking into account geometric as well as material nonlinearities. A slightly modified two-surface model is used in order to achieve the special characteristics of the cold worked aluminum alloy 2024 T3. Experimental investigations are performed on a special device that exhibits nearly pure shear. Good agreement of experimental and theoretical results is demonstrated. ESA

N90-10998# Politecnico di Torino (Italy). Dept. of Aerospace Engineering.
EQUILIBRIUM AND STABILITY IN COMPOSITE THIN SHELL
E. ANTONA and U. ICARDI (Fiat Research Center, Orbassano, Turin, Italy) *In* ESA, Spacecraft Structures and Mechanical Testing p 91-97 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A way of carrying out theoretical stability analyses on imperfect multilayered composite shells is proposed. The evolution of metric and curvature coefficients over the course of increasing external loads is measured. Elastic displacements involved in the process are also taken into consideration. The analysis of the geometric evolution of load increases could be useful in finite element analysis. In order to test the proposal on a practical application, shells made by orthotropic laminae are considered. They are modeled by the Kirchoff-Love hypothesis and by the Von Karman-Tzien strain tensor. The imperfections are shape defects of a general kind. The behavioral equations are obtained taking only the fundamental term displacements into consideration. ESA

N90-11013# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
NUMERICAL ANALYSIS OF NONLINEAR VISCOELASTIC STRUCTURES: APPLICATION TO ELASTOMERS AND RUBBER-LIKE MATERIALS
W. W. JARZAB, J. BAUER, and P. FOROS *In* ESA, Spacecraft Structures and Mechanical Testing p 201-206 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The finite element code ANVS (advanced numerical viscoelastodynamical simulation) which permits the investigation of complex elastomer structures is described. Different kinds of mounts and shock absorbers are analyzed. The dynamic stiffness and the loss factor are nonlinear functions of the static preloading, the displacement amplitude and the frequency. The stress strain hysteresis characterizes the nonlinearities, the damping behavior response energy dissipation and the dynamical stiffness of the elastomer structure. Structural modifications lead to a reduction of dynamic stiffness and an improvement of damping. ESA

N90-11029# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Structural Design Section.
REVIEW OF THE ESA FRACTURE CONTROL POLICY
T. K. HENRIKSEN *In its* Spacecraft Structures and Mechanical Testing p 319-324 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The efforts of ESA in developing a unified approach to damage tolerance and fracture control research are outlined. Based on experience gained with Spacelab and Eureca, the ESA Fracture Control Board has defined a set of fracture control requirements applicable to all ESA space systems. The reasoning behind the

fracture control requirements is discussed. Examples of applications of these requirements are given. The development of the second space telescope solar array is given as a specific example. ESA

N90-11030# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Inst. for Structures and Design.
LIQUID INFILTRATED C/SIC: AN ALTERNATIVE MATERIAL FOR HOT SPACE STRUCTURES
W. KRENKEL and H. HALD *In* ESA, Spacecraft Structures and Mechanical Testing p 325-330 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The technology involved in creating liquid infiltrated C/SiC (a carbon fiber reinforced silicon carbon ceramic matrix composite) is described. It is presented as a means of cost and fabrication time reduction in producing fiber reinforced composites. The mechanical properties of preliminary material samples were evaluated. Bending, tension and shear tests were carried out with specimens at room temperature. Extreme thermal tests in oxidative atmospheres with simulated reentry conditions were performed in an arc heated plasma channel at temperatures up to 1800 C. These tests are described and the results included. ESA

N90-11031# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. for Materials Research.
FATIGUE CRACK GROWTH RATES AS A FUNCTION OF DELTA K: VARIABILITY AND MATERIAL PROPERTY
G. MARCI, D. E. CASTRO, and V. BACHMANN *In* ESA, Spacecraft Structures and Mechanical Testing p 331-342 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

Fatigue crack propagation threshold measurements as influenced by closure phenomena are described. The way in which individual material properties determine crack propagation is outlined. A material property threshold beyond which crack propagation occurs is established. The microstructural differences of aluminum alloys are shown to influence primarily via the closure effects. The microstructural differences have a substantial influence on long cracks but very little influence on short crack growth behavior. ESA

N90-11032# Aeritalia S.p.A., Turin (Italy). Space Systems Group.
MATERIAL PROPERTIES OF 2219-T851 ALUMINUM ALLOY PLASMA WELDED COMPARED TO TIG WELDING
GIORGIO BANINO and EDOARDO TACCHINO *In* ESA, Spacecraft Structures and Mechanical Testing p 343-348 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The Variable Polarity Plasma Arc (VPPA) technique, using the aluminum alloy 2219-T851 was tested. The tests were performed with two primary objectives. The first was to optimize the welding process and microstructure of the joint versus tensile properties. The second was a complete mechanical characterization of the joints by means of experimental activities concerned with fatigue, fracture mechanics, stress corrosion cracking and residual stresses. All the results were compared with the TIG (Inert Gas Tungsten arc welding) process used in the Spacelab program. The 2219-T851 alloy is the basic material used in making the Columbus pressurized modules. ESA

N90-11034# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Strukturmechanik.
TRANSVERSE SHEAR STIFFNESS OF COMPOSITE AND SANDWICH FINITE ELEMENTS
K. ROHWER *In* ESA, Spacecraft Structures and Mechanical Testing p 363-368 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A technique for calculating transverse shear stiffness in composite and sandwich finite elements is proposed. Integrating the equilibrium conditions leads to shear stresses as functions of membrane force and bending moment derivatives, which can be replaced by transverse shear forces if cylindrical bending states are assumed. These functions are used in the complementary energy density estimation to determine improved stiffnesses. For homogeneous materials they correspond with Reissner's correction factor of 5/6 as applied to shear modulus times thickness. Isotropic layers show correction factors between 0.45 and 1.0 depending on the layer thickness and modulus ratios. The proposed formulation covers orthotropic material as well as sandwich constructions. This technique makes different versions of layered and sandwich elements obsolete. ESA

N90-11036# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Strukturmechanik.
ANALYSIS OF DELAMINATION GROWTH
H. EGGERS *In* ESA, Spacecraft Structures and Mechanical Testing p 377-381 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A simplified method is developed, in which a delaminated specimen is modeled by two layers of coupled beam lattices. The approximation is based on the known solution for buckled beams and can be used to analyze plane specimens with and without prebuckled imperfections. Close to the crack front an approximate modified plane strain state exists. Based on this assumption the Energy Release Rates (ERRs) for a layered structure are determined via forces and moments of the beam lattice. Buckling of a beam element, transformation of crack tips, and energy release rates, are studied. ESA

N90-11037# Katholieke Univ. te Leuven (Belgium). Dept. of Metallurgy and Materials Science.
INFLUENCE OF THE FIBER/MATRIX INTERFACE ON DAMAGE DEVELOPMENT IN CFRP
J. IVENS, M. WEVERS, I. VERPOEST, and P. DEMEESTER *In* ESA, Spacecraft Structures and Mechanical Testing p 383-386 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

Carbon fibers are surface treated in order to obtain the good interfacial properties needed for a good stress transfer between fiber and resin. A controlled oxidative surface treatment strongly improves the interfacial strength, depending on the treatment level. The influence of this surface treatment level on the damage development in a cross ply carbon epoxy laminate during monotonic tensile testing is investigated. The crack path is shown to be influenced by the interface strength. It is shown that the mechanical properties of a cross ply laminate improve by a low surface treatment level, while they decrease strongly for higher treatment levels. ESA

N90-11054# Centre National d'Etudes Spatiales, Toulouse (France).
DEVELOPMENT OF GRAPHITE-MAGNESIUM COMPOSITES FOR SPACE APPLICATIONS
PH. ROY and J. F. PATIN (Aerospatiale, Cannes, France) *In* ESA, Spacecraft Structures and Mechanical Testing p 521-527 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The work, technological approach, and logic involved in the development of metal matrix composites are described. Secondary structures of satellites, such as antenna reflectors and truss optical instrument supports, require a high structural stability to remain accurate. They must display low coefficients of thermal expansion, no sensitivity to radiation and moisture, no outgassing under vacuum environments, and better thermal and electrical conductivity. A magnesium matrix increases composite specific properties (stiffness and strength), due to its very low density. These characteristics make magnesium matrix composites very attractive for future spacecraft applications. ESA

N90-11056# Aerospatiale Aquitaine, Saint-Medard en Jalles (France).
SPACE ENVIRONMENT EFFECTS ON CARBON/EPOXY MATERIALS

P. PLOTARD and C. DURIN (Departement d'Etudes et de Recherches en Technologie Spatiale, Toulouse, France) *In* ESA, Spacecraft Structures and Mechanical Testing p 535-540 Jan. 1989 In FRENCH; ENGLISH summary

Tests carried out on structural composite materials in a space environment simulation facility are described. A carbon/epoxy filamentous composite and a carbon/epoxy laminated composite were tested. The space environment simulation facility and the simulation methods are described. Results of X-ray analysis, of micro fissure generation and of induced ageing of the composites are presented. It is concluded that such simulation tests are useful but do not take into account such parameters as ageing due to the presence of atomic oxygen in low orbit environments. ESA

N90-11060# Stuttgart Univ. (Germany, F.R.). Inst. for Aircraft Design.
WORKED-IN HOLES IN THREE-DIMENSIONAL REINFORCED COMPOSITES
F. J. ARENDTS and KLAUS DRECHSLER *In* ESA, Spacecraft Structures and Mechanical Testing p 573-578 Jan. 1989
Prepared in cooperation with MBB G.m.b.H., Munich, Germany, Fed. Republic of Germany and Vorwerk und Co., Kulmbach, Fed. Republic of Germany

To improve notched-strength of composites, holes and pins were worked into two- and three-dimensional reinforced fiber composites. To judge the mechanical properties many aspects were taken into consideration. Tension specimens with worked-in holes have greater strength than those with drilled holes, but demonstrate less resistance during fatigue tests and pin-joint bearing tests. This is a result of the higher shear stresses and the lack of forty five degree fibers in the three-dimensional weaves. They demonstrate however, lower notch sensitivity than laminates. Interesting properties obtainable by weaving in pins and rings during the textile process are described. ESA

N90-11061# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Strukturmechanik.
DELAMINATION TESTS UNDER STATIC COMPRESSION LOADING
M. GAEDKE *In* ESA, Spacecraft Structures and Mechanical Testing p 579-585 Jan. 1989

The strength and stiffness of arbitrarily stacked multidirectional laminates are predicted from well defined characteristic properties of unidirectional laminates established by tests dependent on temperature and moisture content. Elasticity, first-ply failures and ultimate strengths are verified by tests. Prestresses caused by temperature and moisture must be included in the calculations. Excellent correspondence was found for the moduli of elasticity while for the ultimate strength it is sufficient for practical estimates. In the experimental program on the response of carbon fiber reinforced epoxy laminates containing artificial delaminations, four defect diameters at four ply interfaces in three multidirectional laminates were investigated. The results of the delamination growth show the influence of the delamination size, the stacking sequence, the thickness and the stiffness of the separated sublaminates. In all cases buckling of the delaminated areas occurred prior to failure depending on the level of compression loading. ESA

N90-11062# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Strukturmechanik.
DELAMINATION TESTS UNDER COMPRESSION-COMPRESSION AND TENSION-COMPRESSION LOADING
H. C. GOETTING *In* ESA, Spacecraft Structures and Mechanical Testing p 587-592 Jan. 1989

The delamination behavior of multidirectional CFRP (carbon fiber reinforced plastics) was investigated under compression-compression and tension-compression fatigue loading by means of artificially introduced delaminations. A computer aided test procedure enabled observation of the relevant damage mechanisms during the last cycles prior to failure without destroying the test specimens. The influence of the depth of location as well as of the diameter of delaminations are discussed with special reference to failure critical damage. With tension-compression fatigue the matrix crack formation in off-axis plies seems to induce the compressive failure more than the artificial delamination. With respect to damage tolerance considerations some configurations of delamination states prove to be non-critical. ESA

N90-11063# Katholieke Univ. te Leuven (Belgium). Dept. of Metallurgy and Materials Science.
THE 2.5D- AND 3D-FABRICS FOR DELAMINATION RESISTANT COMPOSITE LAMINATES AND SANDWICH STRUCTURES
I. VERPOEST, M. WEVERS, and P. DEMEESTER *In* ESA, Spacecraft Structures and Mechanical Testing p 593-599 Jan. 1989

A technique for making two and a half dimensional fabrics from three-dimensional fabrics woven in one step is described. These two and a half dimensional fabrics show better peel strength and interlaminar fracture toughness. Stronger three-dimensional fabrics are formed by impregnation with polyurethane foam, creating a sandwich structure with interconnected skins. The results of peel tests, compression tests, and fracture toughness tests are given for these new materials. Preliminary results are encouraging. ESA

N90-11069# Ometron Ltd., London (England).
ADVANCES IN INSTRUMENTATION FOR EXPERIMENTAL STRESS AND VIBRATION ANALYSIS AND ITS APPLICATIONS
A. J. BARKER and D. J. BERRY *In* ESA, Spacecraft Structures and Mechanical Testing p 635-639 Jan. 1989

Instrumentation, utilizing the thermoelastic effect to provide full field stress data in a digitized form, that can be integrated with computer aided design methods for experimental optimization and validation of designs is described. The same full field data acquisition techniques have been applied to vibration measurements, and stress and vibration data can be obtained from the same experimental set up. Theoretical aspects of stress analysis using the thermoelastic effect are described. Laser Doppler interferometric methods are outlined. The combination of techniques for nondestructive testing of typical aerospace components, including composites, is illustrated. ESA

N90-11071# Engineering System International, Rungis (France).
INTRINSIC DAMAGE AND STRENGTH CRITERIA FOR ADVANCED COMPOSITE LAMINATES IN SPACE APPLICATIONS
A. DEROUVRAY, E. HAUG, P. DOWLATYARI, C. STAVRINIDIS, and A. KREIS (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Spacecraft Structures and Mechanical Testing p 649-664 Jan. 1989

Several classical strength criteria are evaluated on a large sample of test pieces with various stress concentrations and gradients loaded to ultimate failure. None of the strength criteria evaluated (K, G, Poe, Witney-Nuismer, etc) predicts satisfactorily the whole spectrum of test data. A new criterion is proposed, based on a damage mechanics concept, which fulfills the requirements of being intrinsic for both stress concentrations and stress gradients. Such a criterion is well suited for numerical simulations of composite damage and strength. Its effectiveness is demonstrated in the prediction of the scale effect on the ultimate tensile strength of center notched tensile test pieces of a cross ply laminate. It also allows to predict approximately, with the help of a simple analytical formula, the notch sensitivity effects in

composite plates with cut-outs, and suggests thresholds for the applicability of low strain criteria in the analysis of the damage tolerance of composite components. ESA

N90-11076# IKO Software Service G.m.b.H., Stuttgart (Germany, F.R.).
STSA-SPACE TELESCOPE SOLAR ARRAY INTERCONNECTORS: FROM SIMPLE APPROACHES TO COMPLEX MODELING. A CASE STUDY OF THE NECESSITY OF COMPLEX ANALYSIS
PH. DELOO, M. KLEIN, and U. WIELAND (AEG-Telefunken, Wedel, Germany, F.R.) *In* ESA, Spacecraft Structures and Mechanical Testing p 693-701 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The analysis of weld points in the interconnections between cells in the solar array of the Hubble space telescope is described. These welds, subjected to about 30,000 thermal cycles in the long duration low earth orbit mission, were first investigated using only locally focused two-dimensional models. The need to consider the spatial extension of the interconnectors between two cells, the layered nature of the cells, and the layered nature of the cell substrate result in large three-dimensional mathematical models. It is also shown that general effects that result from the non-linear material properties need to be considered in the low temperature range. ESA

N90-11139# Massachusetts Inst. of Tech., Cambridge. Ceramics Processing Research Lab.
BASIC RESEARCH ON PROCESSING OF CERAMICS FOR SPACE STRUCTURES Final Report, 1 Aug. 1984 - 15 Feb. 1988
H. KENT BOWEN, WENDELL E. RHINE, ANNE BAGLEY HARDY, CHRISTOPHE ZING, MARI-ANN EINARSRUD, WILLIAM C. MOFFATT, SUMIO KAMIYA, HYYUN M. JANG (Pohang Inst. of Science and Technology, Republic of Korea), BRUCE BISHOP, and MARK SPOTZ 31 Jan. 1989 305 p Submitted for publication
(Contract F49620-84-C-0097)
(AD-A205954; AFOSR-89-0289TR) Avail: NTIS HC A14/MF A02 CSCL 11/2

The hydrolysis of alkoxide emulsion droplets was investigated for preparing un-agglomerated, submicrometer oxide ceramic particles with a homogeneous composition. This technique was used to prepare single- and mixed-oxide powders whose overall cation composition corresponded to the initial alkoxide cation composition. Uncalcined powders were amorphous, with high surface areas and low densities; upon calcination, powders densified and became crystalline. In other studies, a water-in-oil emulsion technique was investigated for preparing SrTiO3 and BaTiO3. Two AlN precursors were synthesized from dimethylaminoalane and NH3 . Both AlN precursors gave fine, high purity AlN powders after heat-treatment; a colloidally pressed sample densified to 95 percent of theoretical density at 1750 C. GRA

N90-13461*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCED COMPOSITE MATERIALS FOR PRECISION SEGMENTED REFLECTORS
BLAND A. STEIN and DAVID E. BOWLES *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 72-73 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 11/4

The objective in the NASA Precision Segmented Reflector (PSR) project is to develop new composite material concepts for highly stable and durable reflectors with precision surfaces. The project focuses on alternate material concepts such as the development of new low coefficient of thermal expansion resins as matrices for graphite fiber reinforced composites, quartz fiber reinforced epoxies, and graphite reinforced glass. Low residual stress fabrication methods will be developed. When coupon specimens of these new material concepts have demonstrated the required surface accuracies and resistance to thermal distortion and microcracking, reflector panels will be fabricated and tested in simulated space environments. An important part of the program is the analytical modeling of environmental stability of these new composite materials concepts through constitutive equation development, modeling of microdamage in the composite matrix, and prediction of long term stability (including viscoelasticity). These analyses include both closed form and finite element solutions at the micro and macro levels. Author

N90-13462*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
LIGHTWEIGHT COMPOSITE REFLECTOR PANELS
R. E. FREELAND and P. M. MCELROY *In its* Report of the Asilomar 3 LDR Workshop p 74-75 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 11/4

The Hexel Corp. has produced additional composite panels, based on JPL designs, that: (1) have increased the panel size from 0.15 to 0.40 meters, (2) have improved the as-manufactured surface precision 3.0 to approx. 1.0 micron RMS, (3) have utilized different numbers of face sheet plys, (4) have improved face sheet fiber orientation, (5) have variations of aluminum honeycomb core cell size, (6) have combined graphite/epoxy (Gr/Ep) face sheets with E-glass honeycomb cores, and (7) have used standard aluminum core with face sheets composed of combinations of glass, Kevlar, and carbon fibers. Additionally, JPL has identified candidate alternate materials for the facesheets and core, modified the baseline polymer panel matrix material, and developed new concepts for panel composite cores. Dornier designed and fabricated three 0.6 meter Gr/Ep panels, that were evaluated by JPL. Results of both the Hexel and Dornier panel work were used to characterize the state-of-the-art for Gr/Ep mirrors. Author

N90-14092*# Cockerham (John M.) and Associates, Inc., Huntsville, AL.
OPTICAL PROPERTIES MONITOR: EXPERIMENT DEFINITION PHASE Final Report, 16 Sep. 1988 - 29 Sep. 1989
DONALD R. WILKES, JEAN M. BENNETT, LEIGH L. HUMMER, RUSSELL A. CHIPMAN, JAMES B. HADAWAY, and LARRY PEZZANITI Sep. 1989 147 p Prepared in cooperation with Alabama Univ., Huntsville
(Contract NAS8-37755)
(NASA-CR-183836; NAS 1.26:183836) Avail: NTIS HC A07/MF A01 CSCL 20/6

The stability of materials used in the space environment will continue to be a limiting technology for space missions. The Optical Properties Monitor (OPM) Experiment provides a comprehensive space research program to study the effects of the space environment-both natural and induced-on optical, thermal and space power materials. The OPM Experiment was selected for definition under the NASA/OAST In-Space Technology Experiment Program. The results of the OPM Definition Phase are presented. The OPM Experiment will expose selected materials to the space environment and measure the effects with in-space optical measurements. In-space measurements include total hemispherical reflectance total integrated scatter and VUV reflectance/transmittance. The in-space measurements will be augmented with extensive pre- and post-flight sample measurements to determine other optical, mechanical, electrical, chemical or surface effects of space exposure. Environmental monitors will provide the amount and time history of the sample exposure to solar irradiation, atomic oxygen and molecular contamination. Author

N90-15987# Consiglio Nazionale delle Ricerche, Frascati (Italy). Ist. di Fisica dello Spazio Interplanetario.
ELECTRICAL CHARACTERISTICS MEASUREMENTS FOR THE TSS-1 SATELLITE PAINTING
G. VANNARONI and U. GUIDONI Apr. 1989 22 p
(IFSI-89-7; ETN-90-96169) Avail: NTIS HC A03/MF A01

The measurements performed in order to determine the electrical characteristics of some space paints are presented. These paints are going to be used as thermal coating of the external surface of the Tethered Satellite System number one

(TSS-1) satellite. Painted samples used as Langmuir probes are tested in a plasma chamber, under plasma conditions close to ionospheric ones. The classical current-voltage technique is used to measure the volume resistivity of the paints. The results pointed out that all the painted samples behave as poor conductors compared with naked aluminum. For the NS43C paint, a quasi linear decrease of resistivity is found when the voltage applied across the layer is increased above 100V. ESA

N90-16925*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
POLYCARBONATE ARTICLE WITH CHEMICAL RESISTANT COATING Patent Application
JOSEPH J. KOSMO, inventor (to NASA) and FREDERIC S. DAWN, inventor (to NASA) 30 Nov. 1989 10 p
(NASA-CASE-MSC-21503-1; NAS 1.71:MSC-21503-1; US-PATENT-APPL-SN-443414) Avail: NTIS HC A02/MF A01 CSCL 11/3

An article of laminate construction is disclosed which is comprised of an underlayer of polycarbonate polymer material to which is applied a chemically resistant outer layer of polysulfone. The layers which are joined by compression-heat molding, are molded to form the shape of a body protective shell such as a space helmet comprising a shell of polycarbonate, polysulfone laminate construction attached at its open end to a sealing ring adapted for connection to a space suit. The front portion of the shell provides a transparent visor for the helmet. An outer visor of polycarbonate polysulfone laminate construction is pivotally mounted to the sealing ring for covering the transparent visor portion of the shell during extravehicular activities. The polycarbonate under layer of the outer visor is coated on its inner surface with a vacuum deposit of gold to provide additional thermal radiation resistance. NASA

N90-17888# Air Force Astronautics Lab., Edwards AFB, CA.
HEATING RATES IN A HIGH ENERGY PROPULSION SYSTEM (HEPS) ORBITAL TRANSFER VEHICLE (OTV) Final Report, Jun. - Aug. 1989
RODNEY L. MILLER Oct. 1989 27 p
(AD-A214354; AL-TR-89-056) Avail: NTIS HC A03/MF A01 CSCL 21/6

Rocket propulsion systems which use nuclear energy sources present unique challenges to the design, safety, and reliability of the concept. Since the vehicle and its components must operate in high radiation fields, nuclear heating and radiation effects must be determined and factored into the system design. The nuclear heating in a High Energy Propulsion System (HEPS) Orbital Transfer Vehicle (OTV) nozzle was analyzed. Using the FEMP2D (Finite Element, Multigroup, Pn, 2-Dimensional) code for an aluminum and carbon-carbon nozzle, it was determined that the heating contribution was found to be the significant source of heating for both materials. The overall heating rate in the aluminum nozzle (approx. 12 W/cc) was significantly higher than that found in the carbon-carbon nozzle (approx. 8 W/cc). GRA

N90-18459# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Structures and Mechanisms Div.
COMPOSITES DESIGN HANDBOOK FOR SPACE STRUCTURE APPLICATIONS
Apr. 1989 271 p Revised
(ESA-PSS-03-1101-ISSUE-1-REV-1; ETN-90-96297) Copyright Avail: NTIS HC A12/MF A02

The handbook is divided into several sections and detailed subsections which are fully described in a table of contents. The main section titles relate to: material properties and applications, calculation methods of laminates, general design aspects, load transfer and design of joints, design of structures, integrity control, verification guidelines and manufacturing aspects. Issue status and control sheets are included as a reference to new and revised pages. A glossary of terms is presented to ensure precision of meaning and consistency of usage in relation to composites. All references are detailed. ESA

N90-18461# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Product Assurance and Safety Dept.
THE DETERMINATION OF OFFGASSING PRODUCTS FROM MATERIALS AND ASSEMBLED ARTICLES TO BE USED IN A MANNED SPACE VEHICLE CREW COMPARTMENT
Feb. 1989 18 p
(ESA-PSS-01-729-ISSUE-1; ISSN-0379-4059; ETN-90-96303) Copyright Avail: NTIS HC A03/MF A01

A specification describing a test to provide data for aid in the evaluation of the suitability of assembled articles and materials for use in a space vehicle crew compartment is presented. The data obtained concern the nature and quantity of organic and inorganic volatile contaminants evolved when the articles and materials are subjected to the crew compartment environment. Preparatory conditions, test performance, accpetance limits and quality assurance are covered. ESA

06

STRUCTURAL MEMBERS & MECHANISMS

Design, analysis and description of structures. Includes their manufacture, arrangement, testing, weight analysis and fatigue. Also includes the design of joints, control mechanisms, springs, latches, or docking hardware.

A90-10413
CLOSED-FORM SOLUTIONS IN OPTIMAL DESIGN OF STRUCTURES WITH NONLINEAR BEHAVIOR
MARCO ROVATI and *CARLO CINQUINI* (Pavia, Universita, Italy) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 16, no. 4, 1988-1989, p. 407-422. refs
Copyright

Optimal design problems for flexural systems with a nonlinear constitutive law are considered, in the presence of constraints on displacements. A general nonlinear holonomic moment-curvature relationship is assumed and a direact variational method is applied in order to obtain optimality criteria. Accordingly, a general method of solution is proposed and some examples are solved. Author

A90-11204* Virginia Polytechnic Inst. and State Univ., Blacksburg.
SMART STRUCTURES RESEARCH PROGRAM AT VIRGINIA TECH
R. O. CLAUS, A. SAFAAI-JAZI, K. D. BENNETT, R. G. MAY, B. D. DUNCAN (Virginia Polytechnic Institute and State University, Blacksburg) et al. IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 12-18. Research supported by NASA, Hercules Aerospace Co., Virginia Center for Innovative Technology, et al. refs
Copyright

A review of the smart structures and avionics research and teaching program that started in 1979 at Virginia Tech is described. Current smart structures research include major efforts in the development of embedded and attached optical fiber and acoustic fiber sensors for cure monitoring, in-service lifetime structural testing, nondestructive evaluation, and impact and damage detection and analysis; of gradual material degradation; sensor signal multiplexing, processing and data handling to achieve near real-time distributed structural analysis; and the integration of embedded sensors, actuators and control electronics to achieve controlled structural response. Special campus facilities used for this work include an optical fiber fabrication facility, an autoclave for composite structure fabrication and curing, and laboratories for optical fiber sensor development, materials response and nondestructive evaluation, structural control testing and computer engineering. C.E.

A90-11208
FIBER OPTIC SENSOR SYSTEMS FOR SMART AEROSPACE STRUCTURES
P. D. DEAN, R. O. CLAUS, D. A. MARTIN, and D. TRITES (Lockheed Aeronautical Systems Co., Burbank, CA) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 55-61. refs
Copyright

The paper discusses the possibilities of adding smarts to structural components, noting the impact of optical fiber sensors and associated system requirements and related issues. From a systems point of view, a smart structure has a number of specific elements whose functions are critically dependent on the end use of the sensor information. The basic system consists of a sensor subsystem, a signal conditioning subsystem, a communications subsystem, and a decision-making subsystem. The use of optical fibers in the sensor system is explicitly discussed, especially in connection with high performance military aircraft as well as vehicles travelling at sustained hypersonic speeds (above Mach 5). C.E.

A90-11210
OPTICAL FIBER SENSING CONSIDERATIONS FOR A SMART AEROSPACE STRUCTURE
DAVID W. JENSEN (Pennsylvania State University, University Park) and RICHARD W. GRIFFITHS (G2 Corp., Pacific Palisades, CA) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 70-76. Research supported by USAF. refs
Copyright

In this paper, many of the critical issues which affect the application of embedded fiber-optic sensors for smart structures applications are identified, discussed, and - to a limited extent - experimentally verified. In particular, fabrication, durability, and characterization issues are addressed. The fabrication procedures for embedding these sensors into advanced composite components have been refined. This has been demonstrated with the successful fabrication of a 1.5 inch diameter by 58 inch long composite tube with an embedded fiber-optic pressure sensor. Preliminary characterization results using an optical time-domain reflectometer are presented. Author

A90-11211
DYNAMIC POLARIMETRIC STRAIN GAUGE CHARACTERIZATION STUDY
BRIAN W. BRENNAN (Hercules Aerospace Co., Norwich, NY) IN: Fiber optic smart structures and skins; Proceedings of the Meeting, Boston, MA, Sept. 8, 9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 77-84.
Copyright

Dynamic loading conditions have been used to characterize a polarimetric fiber optic strain gage developed for integration into structural control systems. The gage can be used to provide sensor feedback for dynamic structural control needs in large composite space structures. The optical sensing technique measures changes in polarization state due to strain induced birefringence in an optical fiber. Dynamic strain measurements were made on a vibrating cantilevered beam with the gage and compared to measurements made on the same system using resistive strain gages that were co-located. Results over the frequency range of 40-500 Hz show excellent agreement between the two gages. The experimental data also compared favorably with standard vibrating beam theory. Author

A90-11667
A STANDARD FIBER OPTIC SENSOR INTERFACE FOR AEROSPACE APPLICATIONS - TIME DOMAIN INTENSITY NORMALIZATION (TDIN)
BRUCE JOHNSON, TOM LINDSAY, MARK MARION, and RANDY MORTON (Eldec Corp., Bothell, WA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 57-67. refs
(Contract DAAJ02-85-C-0050)
Copyright

This paper describes an attractive approach for referencing fiber optic intensity sensors in mobile platforms where variations of source, fiber path, or receiver parameters can severely compromise measurement of the desired parameter. The approach, named Time Domain Intensity Normalization (TDIN), operates with a wide variety of intensity-based sensors and also provides a means for sensor multiplexing. It therefore can serve as the basis for a standard fiber optic sensor system interface. Various schemes for intensity sensors are compared, followed by discussion of optical and electronic design implementation of TDIN, including system multiplexing. Theoretical analyses of key performance issues and test results (using a position sensor mechanism) are discussed. Author

A90-11995
INFLATABLE CONCENTRATORS FOR SOLAR PROPULSION AND DYNAMIC SPACE POWER
G. GROSSMAN and G. WILLIAMS (L'Garde, Inc., Tustin, CA) IN: Solar engineering - 1989; Proceedings of the Eleventh Annual ASME Solar Energy Conference, San Diego, CA, Apr. 2-5, 1989. New York, American Society of Mechanical Engineers, 1989, p. 39-45. refs
(Contract F04611-86-C-0112)
Copyright

The development of an inflatable concentrator for solar propulsion to provide heat to a hydrogen engine aboard the Solar Thermal Rocket is discussed. The concentrator system is described, including the reflector membrane, the outer rim support or torus, and the structural truss. The determination of the gore shapes, the development of the inflated reflector, and the effects of the space environment on inflatable structures are examined. R.B.

A90-13306*# *Lockheed Engineering and Sciences Co., Houston, TX.*
USING COMPUTER GRAPHICS TO DESIGN SPACE STATION FREEDOM VIEWING
B. S. GOLDSBERRY, B. O. LIPPERT, S. D. MCKEE (Lockheed Engineering and Sciences Co., Houston, TX), J. L. LEWIS, JR., and F. E. MOUNT (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p.
(IAF PAPER 89-093)

An important aspect of planning for Space Station Freedom at the United States National Aeronautics and Space Administration (NASA) is the placement of the viewing windows and cameras for optimum crewmember use. Researchers and analysts are evaluating the placement options using a three-dimensional graphics program called PLAID. This program, developed at the NASA Johnson Space Center (JSC), is being used to determine the extent to which the viewing requirements for assembly and operations are being met. A variety of window placement options in specific modules are assessed for accessibility. In addition, window and camera placements are analyzed to insure that viewing areas are not obstructed by the truss assemblies, externally-mounted payloads, or any other station element. Other factors being examined include anthropometric design considerations, workstation interfaces, structural issues, and mechanical elements. Author

A90-13466#
INFLATABLE, SPACE-RIGIDIZED SUPPORT STRUCTURES FOR LARGE SPACEBORNE OPTICAL INTERFEROMETER SYSTEMS
M. C. BERNASCONI (Contraves AG, Zurich, Switzerland) and W. J. RITS (ESTEC, Noordwijk, Netherlands) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs

(Contract ESA-6975/86/NL/PH)
(IAF PAPER 89-338) Copyright

The realization of structural supports for kilometric optical arrays requires innovative approaches to comply with both the transportation and installation requirements and the operational needs for such a delicate application. Inflatable, space-rigidized structure technology has been used to define a number of configurations of 100 m nominal extension. Evaluation of a number of system aspects, basing on current-technology parameter values, has shown that such structures are not only of low mass (0.8-1.8 kg/m baseline) and efficient packaging (all can be launched by an Ariane 5) but also provide a thermally stable backbone, with sufficient stiffness to make attitude control easily manageable and offering the promise of good separation between the equipment and the sensors at the critical high frequencies, where backbone stability is mandatory to make astronomical observations possible. Author

A90-13467#
APPLICATION OF HIGH-FIDELITY STRUCTURAL DEPLOYMENT ANALYSIS TO THE DEVELOPMENT OF LARGE DEPLOYABLE TRUSSES
JOHN M. HEDGEPETH (Astro Aerospace Corp., Carpinteria, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 17 p.
(IAF PAPER 89-339) Copyright

This paper describes the application of ASTRAN, an efficient tool for analyzing the deployment behavior of large truss structures, to the preliminary design and development of several examples of space structures. A general review of the truss structure and its modeling is given along with a summary of the ASTRAN computer program. The example applications considered are: (1) the analysis of the deployment and stowage of an articulated Astromast test specimen, (2) the evaluation of the deployment and stowage of a derivative concept called the Z-beam, and (3) an examination of whether Pactruss-deployable structures intended to support doubly-curved reflector surfaces can be deployed successfully. C.D.

A90-13471#
RESEARCH AND DEVELOPMENT OF A REFLECTOR STRUCTURE EMPLOYING INFLATABLE ELEMENTS
SUMIO KATO, YOSHINORI SAKAI (Kawasaki Heavy Industries, Ltd., Aircraft Engineering Div., Kakamigahara, Japan), OSAMU MURAGISHI (Kawasaki Heavy Industries, Ltd., Technical Institute, Akashi, Japan), YUZO SHIBAYAMA (NEC Corp., Space Development Div., Yokohama, Japan), and MICHIHIRO NATORI (Institute of Space and Astronautical Science, Sagamihara, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(IAF PAPER 89-343) Copyright

This paper presents the recent results of research and development of a modularized inflatable structure for high precision reflector missions in relatively near future. The structure consists of inflatable elements and a back-up structure. An appropriate reflector system including inflatable elements and a back-up structure is investigated in detail. Surface accuracy of inflatable elements are studied. Thermal analysis and thermal deflection analysis are conducted to estimate the membrane temperature during rigidization and the surface deviation caused by thermal input. Results of rigidization tests of inflatable elements, and interface test of inflatable element and truss etc., are described. An appropriate modularized inflatable antenna structure for space VLBI application is also proposed. Author

A90-13553#
CONCEPT OF A LARGE SPACE RADIO-TELESCOPE
C. MARCHAL (ONERA, Chatillon-sous-Bagneux, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-464) Copyright

The characteristics of existing large ground radio telescopes are examined together with limitations of a ground telescope. A concept of a large spaceborne radio telescope is presented with special attention given to the choice of the orbit and the aspects of mass, shape, and size, deployment, rigidification, and resistance to deformation and degradation. It is concluded that, for a price much lower than that of a large ground radio telescope, it is possible to build and launch a large space telescope that will be excellent for metric and decametric waves. I.S.

A90-13554#
OPTICAL INTERFEROMETER SYSTEMS IN SPACE - CONFIGURATION AND STRUCTURE CONCEPTS USING SPACE RIGIDIZED ELEMENTS
M. C. BERNASCONI, S. KOESE (Contraves AG, Zurich, Switzerland), and W. J. RITS (ESTEC, Noordwijk, Netherlands) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(Contract ESA-6975/86/NL/PH)
(IAF PAPER 89-465) Copyright

Inflatable space rigidized structures have been studied to assess their ability to provide 100-m long supporting elements for such orbital optical interferometers. It has been found that such systems could be built and packaged for launch to geostationary orbit by Ariane 5, with specific masses of 0.8-1.8 kg/m. They could be stiff enough to be controllable, but also provide interfaces to the observing telescopes sufficiently clear of vibration at the sensors scanning frequencies. Author

A90-13771
SHAPE OPTIMIZATION OF SATELLITE TANKS FOR MINIMUM WEIGHT AND MAXIMUM STORAGE CAPACITY
H.-A. ESCHENAUER (Siegen, Universitaet-Gesamthochschule, Federal Republic of Germany) Structural Optimization (ISSN 0934-4373), vol. 1, Sept. 1989, p. 171-180. Research supported by MBB-ERNO Raumfahrttechnik GmbH. refs
Copyright

The aim of structural design is to determine the dimensions and the shape of a system that fulfills certain requirements in an optimal way. Although this problem is not at all new, the application of mathematical algorithms together with multicriteria and shape optimization techniques as strategies for achieving an optimum are still very rarely used in practice. The efficiency of the optimization procedure SAPOP is demonstrated through the shape optimization of ultra light shell structures (e.g. satellite tanks) for which bending effects as well as the influence of large deformations in the shell theory are taken into account. After estabishing a corresponding transfer matrix method for analysis, the meridional shape can be determined by using special shape functions (modified ellipsoids) and a 'direct' shape optimization strategy. In addition, simultaneous optimization of shape and wall thickness distribution is introduced. Author

A90-13777
INTERACTION HYPERSURFACES APPLIED TO ESTIMATE THE LOAD-CARRYING CAPACITY OF SPACE TRUSSES
J. A. KONIG, J. A. KARCZEWSKI, and J. CZERNECKI (Polska Akademia Nauk, Instytut Podstawowykh Problemow Techniki; Warszawa, Politechnika, Warsaw, Poland) Rozprawy Inzynierskie (ISSN 0035-9408), vol. 36, no. 2, 1988, p. 207-215. refs
Copyright

When determining the load-carrying capacity of a space truss, it has been assumed that the result depends exclusively on properties of elements (struts); i.e., that the strength of joints is sufficiently high. Since joints constitute up to 30 percent of the total truss weight, such an approach seems inefficient. This paper presents another approach to the design of joints, based on analysis of their strength by means of interaction hypersurfaces of forces acting upon them. The general concept is outlined, and possible simplifications are shown in the case of joint and load symmetries. The theoretical considerations are illustrated by the numerical example of a truss plate. Author

A90-14928
RETRACTABLE ADVANCED RIGID ARRAY

J. DE KAM (Fokker Space and Systems, Amsterdam, Netherlands) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 860-867.
Copyright

The design and development of a retractable, retrievable, and reusable advanced rigid array solar array is presented. The first application will be for EURECA in a 5-kW version. The array is designed for ten years in LEO and five shuttle launch-landing cycles. The design of new mechanisms to incorporate the retraction and relatching requirements is presented. The setup of a monitoring and electronic control system for the functional requirements is shown. A selection of materials and processes suitable for LEO missions regarding atomic oxygen erosion and thermal cycling is also shown. Rigorous fracture control measures to satisfy the reusability requirements, in view of shuttle safety regulations, are presented. I.E.

A90-15882
DYNAMIC COMPRESSION MEMBERS
PAUL BIRCH British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Nov. 1989, p. 501-508. refs
Copyright

The application of momentum support techniques to high-strength struts and energy storage systems for use with solar sails, MHD wings, and interstellar vehicles is discussed. It is suggested that structures utilizing momentum support could have any strength up to the relativistic limit without breaking or buckling. R.B.

A90-15884
THE HOLLOW BODY SOLAR SAIL
JORG STROBL British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Nov. 1989, p. 515-520. refs
Copyright

A possible solution ot the problem of transfering force to a payload from a highly-stressed solar sail operating near the sun is proposed. Models of hollow body solar sails are evaluated for payloads between 1000 and 50,000 kg and terminal speeds of ca. 430 km/s and 320 km/s, respectively. R.B.

A90-16189* European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
UNFURLABLE SATELLITE ANTENNAS - A REVIEW
ANTOINE G. ROEDERER (ESTEC, Noordwijk, Netherlands) and YAHIA RAHMAT-SAMII (JPL, Pasadena, CA) (Journees Internationales sur les Antennes, Nice, France, Nov. 8-10, 1988) Annales des Telecommunications (ISSN 0003-4347), vol. 44, Sept.-Oct. 1989, p. 475-488. Research supported by NASA and ESA. refs
Copyright

A review of unfurlable satellite antennas is presented. Typical application requirements for future space missions are first outlined. Then, U.S. and European mesh and inflatable antenna concepts are described. Precision deployables using rigid panels or petals are not included in the survey. RF modeling and performance analysis of gored or faceted mesh reflector antennas are then reviewed. Finally, both on-ground and in-orbit RF test techniques for large unfurlable antennas are discussed. Author

A90-16997* Lockheed Missiles and Space Co., Sunnyvale, CA.
HUBBLE SPACE TELESCOPE-SPACE SHUTTLE INTERFACE DYNAMIC VERIFICATION TEST
MARK A. BLAIR and NAGARJUNA VADLAMUDI (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 1. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 657-663.
(Contract NAS8-32697)
Copyright

A test program has been developed for the interface between the Space Shuttle Orbiter and the Hubble Space Telescope which couples a standard modal test for a simple suspended structure with a novel, 'interface verification' test. While the free-free modal test is used to verify the high loads generating structural modes due to the interaction of internal components of the structure with the rest of the structure, the interface verification test verifies the character of the high-loading generating modes in which the structure reacts against the booster interface. The novel method excites the structure at a single payload-booster interface DOF, while all other interfaces are left free to move. O.C.

A90-17671
ANALYSIS, DESIGNS, AND BEHAVIOR OF DISSIPATIVE JOINTS FOR COUPLED BEAMS
G. CHEN (Texas A & M University, College Station), S. G. KRANTZ (Washington University, Saint Louis, MO), D. L. RUSSELL (Wisconsin, University, Madison), C. E. WAYNE, H. H. WEST (Pennsylvania State University, University Park) et al. SIAM Journal on Applied Mathematics (ISSN 0036-1399), vol. 49, Dec. 1989, p. 1665-1693. refs
(Contract AF-AFOSR-85-0253; AF-AFOSR-87-0334; AF-AFOSR-85-0283; NSF DMS-85-01306; NSF DMS-86-02001)
Copyright

The function and properties of the dissipative joints used in large flexible space structures are investigated analytically. The joints are grouped in four classes on the basis of the parameters displacement, rotation, bending moment, and shear, and mechanical designs are developed for linear passive dissipative joints. It is shown that two families of eigenvalues exist in the spectrum of two identical coupled beams with a linear dissipative joint. These findings are found to be in good agreement with the results of numerical simulations using the Legendre spectral method. T.K.

A90-17995#
EFFECTS OF A PIEZO-ACTUATOR ON A FINITELY DEFORMED BEAM SUBJECTED TO GENERAL LOADING
SEYOUNG IM (Korea Advanced Institute of Science and Technology, Seoul, Republic of Korea) and S. N. ATLURI (Georgia Institute of Technology, Atlanta) AIAA Journal (ISSN 0001-1452), vol. 27, Dec. 1989, p. 1801-1807. Research supported by USAF. refs
Copyright

The deformation of a beam-column, the upper and lower surfaces of which are bonded in segments with piezo-ceramic liners, is studied for the purpose of obtaining appropriate expressions for the force transferred to the structural member by the piezo-actuator. This concept may be employed for the control of large dynamic deformations of a lattice-type flexible space-structure. The presented model, which is based upon a static analysis, accounts for the effects of transverse shear and axial forces in addition to a bending moment on the beam in formulating the governing equilibrium equations. The present model provides more complete expressions for the force transmitted to the structural member than a model reported earlier in literature, in which the shear and axial forces are neglected. Author

A90-18157*#
APPROXIMATION METHOD FOR CONFIGURATION OPTIMIZATION OF TRUSSES
SCOTT R. HANSEN and GARRET N. VANDERPLAATS (VMA Engineering, Goleta, CA) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3, p. 1667-1676) AIAA Journal (ISSN 0001-1452), vol. 28, Jan. 1990, p. 161-168. Research supported by Cray Research, Inc. Previously cited in issue 12, p. 1910, Accession no. A88-32351. refs
(Contract NAG1-567)
Copyright

A90-20022#
LARGE-SCALE PRODUCTION OF LIGHTWEIGHT MIRRORS
A. CONNOLLY (ESA, Instrument Technology Div., Noordwijk, Netherlands) and W. EGLE (Carl Zeiss, Oberkochen, Federal

Republic of Germany) ESA Journal (ISSN 0379-2285), vol. 13, no. 3, 1989, p. 211-228. refs
Copyright

The production of lightweight mirrors for the ESA X-ray telescope is discussed. The basic requirements and optical layout for the telescope are presented. The telescope design has 58 mirrors of almost cylindrical form supported in a mirror module with their cylinder axes aligned. The use of a CFRP mirror carrier and epoxy replication techniques are examined. The feasability of X-ray spectroscopy mission mirror production is evaluated experimentally. It is observed that the lightweight X-ray mirrors, consisting of thin-walled CFRP carriers replicated from a high-quality mandrel using a epoxy replica technique, are applicable for producing mirror modules for the X-ray spectroscopy mission X-ray telescope. I.F.

A90-20386
SPACEHAB MODULE DEVELOPMENT
PAOLO MARCHESE, LAZZARO COSTAMAGNA, ANTONINO SFERLAZZO, and ENRICO ANGELINO (Aeritalia S.p.A., Settore Spazio, Turin, Italy) Huntsville Association of Technical Societies, Annual Technical and Business Exhibition and Symposium, 5th, Huntsville, AL, May 16, 17, 1989. 12 p.
(TABES PAPER 89-903) Copyright

The Spacehab module is designed to be carried in the Orbiter Cargo Bay together with another commercial or scientific payloads without interfering with the normal operation of the Shuttle. The manufacturing of three units is foreseen: two flight units, FU1, FU2, and a structural test article, STA. An overall description of the Spacehab module is presented, along with an analysis of the Spacehab Primary Structure and Passive Thermal Control. The preliminary design review was successfully completed in 1988. The analytical activity is now in progress to allow the submission of the manufacturing drawings. C.E.

A90-21448#
COMPUTER SIMULATION OF SPACE MECHANISMS
N. CABLE (ESTEC, Mechanical Systems Dept., Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 60, Nov. 1989, p. 46-53.
Copyright

Computer simulations of mechanisms in space and the impact of simulations on the approach to mechanism design are discussed. Various types of simulations and modeling software are considered and the Automatic Dynamic Analysis of Mechanical Systems software package is evaluated. Example simulations are described and the engineering, financial, and social implications of developments in computer modeling are examined. R.B.

A90-23007
COMPOUND STAYED COLUMN FOR USE IN SPACE
A. K. JEMAH and F. W. WILLIAMS (University College, Cardiff, Wales) Computers and Structures (ISSN 0045-7949), vol. 34, no. 1, 1990, p. 171-178. refs
Copyright

Previous work on ultralight compact deployable stayed columns for use in space has concentrated on a type of stayed column tested by NASA and on developments of it. These columns all consisted of a core with three identical stay frames equally spaced around it, with each stay frame consisting of a central compressed spoke which pretensions the stays which radiate from its end to the core. The compound stayed column of the present paper consists of two such internal stayed columns, which are placed end to end to form the core of a simple external stayed column, for which each stay frame consists of a central spoke and two stays. Possible mechanisms for deploying this compound stayed column are discussed, and theoretical studies show that it could lead to reductions of about 56 percent for the packaged volume and 34 percent for the mass. Author

A90-23114*# California Univ., Santa Barbara.
SEQUENTIAL LINEARIZATION METHOD FOR MULTILEVEL OPTIMIZATION
G. N. VANDERPLAATS (VMA Engineering, Goleta, CA), Y. J. YANG, and D. S. KIM (California, University, Santa Barbara) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1, p. 125-132) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 290-295. Previously cited in issue 12, p. 1940, Accession no. A88-32190. refs
(Contract NAG1-567)
Copyright

A90-23115#
SIMULTANEOUS MATERIAL/LOAD/SHAPE VARIATIONS OF THERMOELASTIC STRUCTURES
R. A. MERIC (Istanbul Technical University, Turkey) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 296-302. refs
Copyright

Simultaneous variations of material properties, load functions, and shape configurations of dynamic thermoelastic structures are considered. A continuous approach is adopted in order to find the total variation of a general performance criterion. The present analysis may find important physical applications in the simultaneous shape optimization and control of large space structures in time by applied thermal and/or mechanical loads. The adjoint variable method and the material derivative concept are used to find the sensitivity expressions, which are checked by a simple one-dimensional example problem. Author

A90-23118#
SHAPE CONTROL OF THE TENSION TRUSS ANTENNA
JIN MITSUGI, TETSUO YASAKA (NTT, Radio Communications Systems Laboratories, Yokosuka, Japan), and KORYO MIURA (Institute of Space and Astronautical Science, Sagamihara, Japan) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 316-322.
Copyright

The tension truss antenna is a deployable mesh surface antenna featuring a cable network, called a tension truss, that gives a parabolic shape to the reflective mesh. Cables in the tension truss are rigid enough to prevent their elongation due to the tension, and the number of nodes and cables satisfies the statically determinant condition. In this paper, surface sensitivity to magnitude and direction errors of the applied force, which gives the tensile force to the tension truss, is evaluated by Monte Carlo simulation. Results show that the surface deformation of a tension truss antenna is smaller than that of an antenna whose cable network is made of flexible cables. A surface control algorithm is derived using the perturbation method, and numerical simulations and experimental verifications of the algorithm are carried out. Results show that the surface shape of a tension truss antenna can be controlled by charging cable lengths, and local surface deformations can be improved without affecting the shape of the other parts of the surface. It is concluded that the tension truss antenna is promising candidate for a large space antenna.
Author

A90-23240#
ISOGRID SHELL IN AEROSPACE STRUCTURES
A. K. MUKHERJEE Institution of Engineers (India), Journal, Aerospace Engineering Division (ISSN 0257-3423), vol. 69, Sept. 1988-Mar. 1989, p. 6-9. Research supported by ISRO. refs

This paper presents the application of higher-order finite element on isogrid structural components of satellite launch vehicles. Isogrid is a method to stiffen cylindrical shells of boosters or the heat shields for satellites. The isogrid form is achieved by integrally machining ribs in a repititive equilateral triangular pattern. For such structural forms both static and dynamic analysis have been described through a general analysis of a ribbed shell of zero or non-zero Gaussian curvature with ribs in any direction. Thus the formulation is general in nature and can be applied for other cases of stiffened shells. Relative merits of the method is apparent from the accuracy of results achieved and relative case of formulation procedure in comparison to other methodologies as applied to shells and arch ribs as shown. Author

A90-24305
SHAPE DISTORTION OF SPACE STRUCTURES - POSTULATES AND CONTROVERSY
MENAHEM BARUCH (Virginia Polytechnic Institute and State University, Blacksburg) Zeitschrift fuer angewandte Mathematik und Physik (ISSN 0044-2275), vol. 41, Jan. 1990, p. 51-60. refs
Copyright

The space-structure shape-control robustness criterion derived using purely geometrical means by Baruch (1988) is considered analytically. Alternative formulations such as the mixed approach of Haftka (1984) are examined, and the geometric criterion is generalized to account for the discrepancies identified. The generalized method is applied to a simple 5-DOF free-beam structure with lumped masses, and the results are presented in tables. It is found that the shape controls are independent of the mass of the structure, and that their most efficient positions can be determined by maximizing the robustness parameter mu(rb). T.K.

A90-24846
STRUCTURAL FAILURE; INTERNATIONAL SYMPOSIUM ON STRUCTURAL CRASHWORTHINESS, 2ND, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, JUNE 6-8, 1988, INVITED LECTURES
TOMASZ WIERZBICKI, ED. (MIT, Cambridge, MA) and NORMAN JONES, ED. (Liverpool, University, England) New York, Wiley-Interscience, 1989, 571 p. For individual items see A90-24847 to A90-24851.
Copyright

The book discusses the fragmentation of solids under dynamic loading, the debris-impact protection of space structures, the controlled fracturing of structures by shock-wave interaction and focusing, the tearing of thin metal sheets, and the dynamic inelastic failure of beams, and dynamic rupture of shells. Consideration is also given to investigations of the failure of brittle and composite materials by numerical methods, the energy absorption of polymer matrix composite structures (frictional effects), the mechanics of deep plastic collapse of thin-walled structures, the denting and bending of tubular beams under local loads, the dynamic bending collapse of strain-softening cantilever beams, and the failure of bar structures under repeated loading. Other topics discussed are on the behavior of composite and metallic superstructures under blast loading, the catastrophic failure modes of marine structures, and industrial experience with structural failure. I.S.

A90-25984#
SENSOR AND ACTUATOR SELECTION FOR LARGE SPACE STRUCTURE CONTROL
M. L. DELORENZO (USAF, Air Command and Staff College, Maxwell AFB, AL) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 249-257. Research supported by USAF. refs

This paper presents an algorithm that aids the controls engineer in specifying a sensor and actuator configuration for regulation of large-scale, linear, stochastic systems such as a large space structure model. The algorithm uses a linear quadratic Gaussian controller, an efficient weight-selection technique based on successive approximation, and a measure of sensor and actuator effectiveness to specify a final sensor and actuator configuration. This configuration enables the closed-loop system to meet output specifications with minimal input power. The algorithm involves no complex gradient calculations and is numerically tractable for large linear models, as demonstrated by the solar optical telescope example in this paper. Additionally, the algorithm provides the controls engineer with information on the important design issues of actuator sizing, reliability, redundancy, and optimal number. Author

A90-26810*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYSIS AND APPLICATION OF A VELOCITY COMMAND MOTOR AS A REACTION MASS ACTUATOR
JEFFREY L. SULLA, JER-NAN JUANG, and LUCAS G. HORTA (NASA, Langley Research Center, Hampton, VA) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 360-370. refs
(AIAA PAPER 90-1227)

A commercially available linear stepper motor is applied as a reaction mass (RM) actuator. With the actuator operating in the (RM) relative-velocity command mode, open-loop and closed-loop testing is performed to determine operational limits. With the actuator mounted on a simple beam structure, root strain, RM acceleration, or beam acceleration is used in the feedback loop to augment the structural damping. The RM relative position is also used as feedback to ensure that the RM remains centered. Author

A90-27490* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION FREEDOM CUPOLA DEFINITION
LAURIE A. WEAVER (NASA, Johnson Space Center, Houston, TX) and JOHN LAUGER (McDonnell Douglas Space Systems Co., Space Station Div., Huntington Beach, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 11 p.
(SAE PAPER 891525) Copyright

Following the realization that adequate Space Station Freedom viewing could not be achieved without breaking the plane of the modules, a conceptual design phase for the development of a cupola progressed from the idea of a small, bubble-type canopy to a much larger, two crewmember cupola. The evolving cupola conceptual designs were each evaluated against the requirements for providing a large field-of-view, a complete proximity control workstation with flexible and relocatable restraints, and sufficient volume for two, 95th percentile crewmembers to operate while still maintaining reasonable weight and size restrictions. As the SS Freedom program Preliminary Design Review draws closer, the cupola development phase shifts toward evaluation of viewing and operational capability. The appropriate balance of viewing, structures and operations must be achieved before the program can place confidence in a cupola design providing SS Freedom with a direct viewing workstation capable of supporting the great variety of tasks projected for the life of the station. Author

A90-27710* Rockwell International Corp., Canoga Park, CA.
STRUCTURAL CONFIGURATION OPTIONS FOR THE SPACE STATION FREEDOM SOLAR DYNAMIC RADIATOR
ADRIAN TYLIM (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0883-6272), vol. 8, no. 4, 1989, p. 459-468.
(Contract NAS3-25082)
(IAF PAPER ICOSP89-4-5) Copyright

In order to meet the growing power demands of the Space Station, the electrical power system design includes an option to provide additional power capability in increments of 50 kWe of power. Each increment consists of a pair of two solar dynamic power modules (SDPMs), each of which containing a closed Brayton Cycle (CBC) thermodynamic engine. A solar dynamic radiator (SDR) enables the CBC to reject the waste heat to the surrounding space environment. This paper analyzes three alternatives to the baseline configuration of the Space Station Freedom solar dynamic radiator and discusses their merits based on Space Shuttle cargo capabilities, location with respect to the SDPM supporting structure, thermal performance, drag, concentrator shading, mass, and other issues of concenrn. Results indicating the advantages and disadvantages of each option are presented along with diagrams of the alternative configurations. I.S.

A90-27796
A RECONFIGURABLE MESH REFLECTOR ANTENNA
P. J. B. CLARRICOATS, Z. HAI, R. C. BROWN (London, University, England), G. T. POULTON (CSIRO, Canberra, Australia), and G. E. CRONE (ESA, Noordwijk, Netherlands) IN: International

Conference on Antennas and Propagation (ICAP 89), 6th, Coventry, England, Apr. 4-7, 1989, Proceedings. Part 1. London, England and Piscataway, NJ, Institution of Electrical Engineers, 1989, p. 112-116.
Copyright

The paper describes a novel method for controlling the coverage pattern of a spacecraft antenna. An offset mesh reflector is proposed with reconfiguration achieved by means of adjustment to forces applied at control points on the reflector surface. Synthesis software has been developed and this is demonstrated for typical regional coverage patterns. A model of the mesh based on a network of springs is used and this has been successfully verified following precision mechanical measurements using an 85 cm diameter reflector. Gold-plated molybdenum mesh has been chosen so that the antenna can be tested electrically at a frequency of 10 GHz. Author

A90-27951
SMART STRUCTURES WITH NERVES OF GLASS
R. M. MEASURES (Toronto, University, Downsview, Canada) Progress in Aerospace Sciences (ISSN 0376-0421), vol. 26, no. 4, 1989, p. 289-351. Research supported by NSERC, Ontario Laser and Lightwave Research Centre, Institute for Space and Terrestrial Science, et al. refs
Copyright

A comprehensive presentation is made of the development status and prospective applications of fiber-optic sensor-incorporating 'smart structures', which will be capable of collecting component-integrity information through a 'nervous system' over the course of their service lives. During fabrication and assembly, the integral sensor networks would check for structural flaws or handling damage, thereby enhacing a manufacturer's quality control efforts. In service within aircraft structures, integral fiber-optic sensors could provide strain, displacement, and deformation data required for many control situations, allowing actuators to respond to gusts almost instantaneously. O.C.

A90-29252*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTEGRATED CONTROLS-STRUCTURES OPTIMIZATION OF A LARGE SPACE STRUCTURE
SHARON L. PADULA, JOANNE L. WALSH (NASA, Langley Research Center, Hampton, VA), CHRIS A. SANDRIDGE, and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 258-267. refs
(Contract NAG1-603)
(AIAA PAPER 90-1058) Copyright

A technique for the simultaneous optimization of structural and control elements of a large space structure is developed and demonstrated for a test problem, the NASA COFS-I Mast Flight System. General-purpose control and structural-analysis codes are applied directly to a large detailed model, with realistic objective and constraint functions. The steps in the process (structural optimization, control optimization, and system coordination) are described and illustrated with diagrams; the numerical implementation (using different computers for different steps) is discussed; and results showing significant design improvements in three COFS-I configurations are presented in graphs. When the weights of both structure and power-generating equipment are taken into account, a 40-bay truss design is found to be better than designs with 42 or 44 bays. T.K.

A90-29257#
OPTIMAL ADAPTIVE GEOMETRY OF AN INTELLIGENT TRUSS STRUCTURE
YOSHISADA MUROTSU (Osaka Prefecture, University, Sakai, Japan) and SHAOWEN SHAO IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 308-317. refs
(AIAA PAPER 90-1093) Copyright

This paper is concerned with the optimal adaptive geometry of an intelligent truss structure subjected to either deterministic or probabilistic external loading. The optimal geometry is attained by changing the lengths of some active members to obtain the maximum structural strength. The proposed approach is applied to a planar intelligent truss structure. The numerical results show that the structural strength is greatly increased by optimizing the geometry of the structure and that uncertainty in the load and the strengths can not be ignored in the shape optimization. Author

A90-29258*# College of William and Mary, Williamsburg, VA.
MINIMIZING DISTORTION AND INTERNAL FORCES IN TRUSS STRUCTURES BY SIMULATED ANNEALING
REX K. KINCAID (College of William and Mary, Williamsburg, VA) and SHARON L. PADULA (NASA, Langley Research Center, Hampton, VA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 327-333. refs
(AIAA PAPER 90-1095) Copyright

Inaccuracies in the length of members and the diameters of joints of large space structures may produce unacceptable levels of surface distortion and internal forces. Here, two discrete optimization problems are formulated, one to minimize surface distortion (DSQRMS) and the other to minimize internal forces (FSQRMS). Both of these problems are based on the influence matrices generated by a small-deformation linear analysis. Good solutions are obtained for DSQRMS and FSQRMS through the use of a simulated annealing heuristic. Author

A90-29271*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DESIGN AND FABRICATION OF AN ERECTABLE TRUSS FOR PRECISION SEGMENTED REFLECTOR APPLICATION
HAROLD G. BUSH, CATHERINE L. HERSTROM, WALTER L. HEARD, JR., TIMOTHY J. COLLINS, W. B. FICHTER (NASA, Langley Research Center, Hampton, VA) et al. IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 454-462. refs
(AIAA PAPER 90-0999) Copyright

The design of a first generation, 4-meter-diameter, doubly-curved, tetrahedral support truss for precision parabolic reflector panels, incorporating joints specifically designed for on-orbit astronaut assembly, is presented. Operational and design features of the erectable joint are detailed. Methods used to achieve very accurate strut lengths are described. Initial static and dynamic truss test results are presented which demonstrate linear structural response and predictability. Truss surface accuracy, determined photogrammetrically, is shown to be within 0.003 inch (RMS) of design. Author

A90-29272*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PRELIMINARY DESIGN CONSIDERATIONS FOR 10 TO 40 METER-DIAMETER PRECISION TRUSS REFLECTORS
MARTIN M. MIKULAS, JR., TIMOTHY J. COLLINS (NASA, Langley Research Center, Hampton, VA), and JOHN M. HEDGEPETH (Astro Aerospace Corp., Carpinteria, CA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990. Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 463-475. refs
(AIAA PAPER 90-1000) Copyright

A simplified preliminary design capability for erectable precision segmented reflectors is presented. This design capability permits a rapid assessment of a wide range of reflector parameters as

well as new structural concepts and materials. The preliminary design approach was applied to a range of precision reflectors from 10 meters to 100 meters in diameter while considering standard design drivers. The design drivers considered were: weight, fundamental frequency, launch packaging volume, part count, and on-orbit assembly time. For the range of parameters considered, on-orbit assembly time was identified as the major design driver. A family of modular panels is introduced which can significantly reduce the number of reflector parts and the on-orbit assembly time. Author

A90-29278*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PRELIMINARY DESIGN OF A LARGE TETRAHEDRAL TRUSS/HEXAGONAL PANEL AEROBRAKE STRUCTURAL SYSTEM
JOHN T. DORSEY and MARTIN M. MIKULAS, JR. (NASA, Langley Research Center, Hampton, VA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 533-546. refs
(AIAA PAPER 90-1050) Copyright

This paper introduces an aerobrake structural concept consisting of two primary components: (1) a lightweight erectable tetrahedral support truss, and (2) a heatshield composed of individual sandwich hexagonal panels which, when attached to the truss, function as a continuous aerobraking surface. A general preliminary analysis procedure to design the aerobrake components is developed, and values of the aerobrake design parameters which minimize the mass and packaging volume for a 120-foot-diameter aerobrake are determined. Sensitivity of the aerobrake design to variations in design parameters is also assessed. Author

A90-29281*# Rockwell International Corp., Canoga Park, CA.
SPACE STATION FREEDOM ELECTRIC POWER SYSTEM PHOTOVOLTAIC POWER MODULE INTEGRATED LAUNCH PACKAGE
THEODORE H. NATHANSON, DONALD D. CLEMENS, RAYMOND R. SPATZ (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), and LUKE A. KIRCH (NASA, Lewis Research Center, Cleveland, OH) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 568-571.
(AIAA PAPER 90-1053) Copyright

The launch of the Space Station Freedom solar power module requires a weight efficient structure that will include large components within the limited load capacity of the Space Shuttle cargo bay. The design iterations to meet these requirements have evolved from a proposal concept featuring a separate cradle and integrated equipment assembly (IEA), to a package that interfaces directly with the Shuttle. Size, weight, and cost have been reduced as a result. Author

A90-29282#
DEVELOPMENT OF A HIGH STIFFNESS EXTENDIBLE AND RETRACTABLE MAST 'HIMAT' FOR SPACE APPLICATIONS
TAKAYUKI KITAMURA, KOICHI YAMASHIRO, AKIRA OBATA (Japan Aircraft Manufacturing Co., Ltd., Yokohama, Japan), and MICHIHIRO NATORI (Institute of Space and Astronautical Science, Sagamihara, Japan) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 572-577. refs
(AIAA PAPER 90-1054) Copyright

The concept of a folding longeron extendible mast with high stiffness and strength when extended is introduced, and its development for space applications is presented in detail. In size and stiffness, this mast positions between the continuous longeron extendible mast and the manned-assembly truss-beam structures. An engineering model with deployer and the results of its tests are also presented. Author

A90-29409
AIAA/ASME/ASCE/AHS/ASC STRUCTURES, STRUCTURAL DYNAMICS AND MATERIALS CONFERENCE, 31ST, LONG BEACH, CA, APR. 2-4, 1990, TECHNICAL PAPERS. PART 4 - STRUCTURAL DYNAMICS II
Washington, DC, American Institute of Aeronautics and Astronautics, 1990, 552 p. For individual items see A90-29410 to A90-29465.
Copyright

Theoretical and applications topics in structural dynamics are examined in reviews and reports. Sections are devoted to dynamic modeling, dynamic analysis, spacecraft dynamics, launch-system dynamics, and adaptive structures. Particular attention is given to the assumed-modes method with static constraint modes, the nonlinear dynamics of a spherical joint and a jointed truss-cell structure, bounds on the eigenvalues of finite-element systems, an articulated-truss space-crane concept, and active control of torsional vibration using piezoceramic sensors and actuators. Also discussed are the representation of HF Space Shuttle data by algorithms and random response spectra, vibration suppression by variable-stiffness members, the chaotic motion of beams due to finite deformations, and self-tuning algorithms for uniform damping control of spacecraft. T.K.

A90-29416#
NONLINEAR DYNAMICS OF A SPHERICAL JOINT AND A JOINTED TRUSS-CELL UNIT STRUCTURE - THEORY AND ARMA ANALYSIS
H. S. TZOU, Y. RONG, and J. P. SADLER (Kentucky, University, Lexington) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1956-1964. Research supported by the University of Kentucky. refs
(AIAA PAPER 90-0939) Copyright

This paper presents a mathematical modeling and stochastic simulation study of a three-dimensional (3-D) spherical joint, a design feature of importance to a class of deployable space structures. An analytical model of the joint including friction and clearance effects is studied; and a system equation with time-variant coefficient matrices is then derived. A parametric study, including joint clearance size, joint rigidity/damping, and link elasticity/damping, of a jointed truss-cell model is investigated. The friction is assumed to be a normally distributed random variable and the external excitation is also treated random in a stochastic simulation study using auto-regresive moving average (ARMA) model. This study shows that the joint dynamic contacts are affected by joint surface condition (stiffness/damping), joint clearance, link stiffness/damping, excitation, etc. Friction contacts dominate the system dynamics when the clearance is small and normal contacts dominate when the clearance is large. Author

A90-29432*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN ARTICULATED-TRUSS SPACE CRANE CONCEPT
THOMAS R. SUTTER, HAROLD G. BUSH (NASA, Langley Research Center, Hampton, VA), and RICHARD E. WALLSOM (Lockheed Engineering and Sciences Co., Hampton, VA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2117-2125. refs
(AIAA PAPER 90-0994) Copyright

An articulated-truss space-crane concept is described, and four articulating-joint (AJ) concepts are evaluated. The space-crane concept uses the same truss structure hardware as Space Station Freedom. The joint concepts are compared according to their actuator stroke ratio, actuator authority, and part count. One AJ

concept is selected as a candidate space-crane joint because of its better performance and lower part count. The space-crane reach envelope is determined as a function of the number of AJs and the number of fixed-length booms. A space crane with three booms, three AJs, and one rotary joint provides an adequate reach envelope for an expected work area. The space-crane tip velocity, because of an allowable truss strut compressive load, is limited to approximately 1.0 in./sec for a 300,000-lbm payload. The displacement response is also shown for an emergency stop scenario as a function of the payload mass. The space-crane tip deflection is on the order of 12 in. for a 300,000-lbm payload.
Author

A90-29436#
DESIGN AND DEVELOPMENT OF A MODULARIZED INFLATABLE REFLECTOR
MICHIHIRO NATORI (Institute of Space and Astronautical Science, Sagamihara, Japan), SUMIO KATO (Kawasaki Heavy Industries, Ltd., Aerospace Engineering Div., Kakamigahara, Japan), OSAMU MURAGISHI, and TOKIO OHNISHI (Kawasaki Heavy Industries, Ltd., Technical Institute, Akashi, Japan) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2164-2172. refs
(AIAA PAPER 90-0998) Copyright
A reflector structure consisted of modularized inflatable rigidized elements and a back-up deployable planar truss is a powerful candidate for solar reflectors and space antennas. Various aspects of its design and development including accuracy analysis, manufacturing process and back-up structure are presented. Design of a reflector system with seven cell modules is also introduced.
Author

A90-29450#
A CONSTRUCTION CONCEPT OF LARGE SPACE STRUCTURES USING INTELLIGENT/ADAPTIVE STRUCTURES
KORYO MIURA, MICHIHIRO NATORI (Institute of Space and Astronautical Science, Sagamihara, Japan), and SABURO MATUNAGA IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2298-2305. refs
(AIAA PAPER 90-1128) Copyright
The objective of this paper is to introduce new construction concept of large space structure assemblies using intelligent/adaptive structures. Some structural modules are introduced in this construction concept; they are classified into main structures, docking structures, integrated docking structures, and intelligent/adaptive integrated structures. For the main frame construction of a desired large space structure, a recursive assembling method using the above structural modules and space robots is proposed. A two-dimensional truss beam model is introduced as an analytical and experimental model to demonstrate the proposed concept.
Author

A90-30886* Space Telescope Science Inst., Baltimore, MD.
EXTREMELY LIGHTWEIGHT SPACE TELESCOPE MIRRORS WITH INTEGRATED ACTIVE FIGURE CONTROL
PIERRE Y. BELY (Space Telescope Science Institute, Baltimore, MD) and JOHN F. BOLTON (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Active telescope systems; Proceedings of the Meeting, Orlando, FL, Mar. 28-31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 365-371. refs
Copyright
A concept for an extremely lightweight primary mirror for a large space telescope is proposed. The mirror uses a sandwich structure composed of aluminum faceplates with an aluminum foam core. Modal analysis indicates that a fundamental frequency of 100 Hz can be obtained for a 6 meter diameter mirror with a tapered back and having a total mass of about 3500 kg. An array of thermal actuators embedded in the mirror corrects for figure errors. Such an active thermal figure control system does not have a quick response, but is well suited to space applications where disturbances have relatively long time constants. The advantage of thermal actuators is very high reliability, a primary concern in any space system requiring a large number of actuators.
Author

A90-30888* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SEGMENTED MIRROR, MANUFACTURING AND ALIGNMENT TOLERANCES (SMMAT)
P. K. MANHART (JPL, Pasadena, CA) and J. MICHAEL RODGERS (Optical Research Associates, Pasadena, CA) IN: Active telescope systems; Proceedings of the Meeting, Orlando, FL, Mar. 28-31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 387-405.
Copyright
An attempt is made to define surface errors, and hence wavelength aberrations or optical path differences, due to fabrication and alignment errors of mirror segments. A FORTRAN routine is written to help to understand the relationship between system performance (Strehl ratio, etc.) and manufacturing and alignment errors for Precision Segmented Reflectors and Large Deployable Reflector. The power of having compensation parameters such as piston and tilt responding to errors in position or figure is demonstrated. Compensation can improve performance by two orders of magnitude.
V.T.

A90-30889* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ACTIVE WAVEFRONT CONTROL CHALLENGES OF THE NASA LARGE DEPLOYABLE REFLECTOR (LDR)
ADEN B. MEINEL, MARJORIE P. MEINEL, PAUL K. MANHART, and ERIC B. HOCHBERG (JPL, Pasadena, CA) IN: Active telescope systems; Proceedings of the Meeting, Orlando, FL, Mar. 28-31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 406-409.
Copyright
The 20-m Large Deployable Reflector will have a segmented primary mirror. Achieving diffraction-limited performance at 50 microns requires correction for the errors of tilt and piston of the primary mirror. This correction can be obtained in two ways, the use of an active primary or a correction at a demagnified pupil of the primary. A critical requirement is the means for measurement of the wavefront error and maintaining phasing during the observation of objects that may be too faint for determining the error. Absolute phasing can only be determined using a cooperative source. Maintenance of phasing can be done with an on-board source. A number of options are being explored as discussed below. The many issues concerning the assessment and control of an active segmented mirror will be addressed with an early construction of the Precision Segmented Reflector testbed.
Author

A90-30893* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUPPORT TRUSSES FOR LARGE PRECISION SEGMENTED REFLECTORS - PRELIMINARY DESIGN AND ANALYSIS
TIMOTHY J. COLLINS and W. B. FICHTER (NASA, Langley Research Center, Hampton, VA) IN: Active telescope systems; Proceedings of the Meeting, Orlando, FL, Mar. 28-31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 453-468. refs
Copyright
The Precision Segmented Reflector (PSR) primary structures plan is outlined. Geometries and design considerations for erectable and deployable reflector support structures are discussed. Support truss requirements and goals for the PSR are given, and the results of static and dynamic analyses of a prototype four meter diameter structure are presented. In addition, similar results are presented for two 20-meter diameter support trusses. Implications of the analyses for the PSR program are considered and the

formulation and limitations of current PSR finite element models are discussed. It is shown that if the secondary optical system is supported by a simple tripod design, the first six vibration modes are likely to be dominated by the secondary system. The 20-meter diameter support trusses are found to be quite stiff for structures of such large size. V.T.

A90-30894* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
STRUCTURES TECHNOLOGIES FOR THE PRECISION SEGMENTED REFLECTOR (PSR)
C. M. SATTER and M. C. LOU (JPL, Pasadena, CA) IN: Active telescope systems; Proceedings of the Meeting, Orlando, FL, Mar. 28-31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 470-482. refs
Copyright

The PSR program is a first step in the development and validation of increasingly more precise and larger size lightweight segmented reflector technology that might ultimately be used in space on projects such as the Large Deployable Reflector (LDR). The LDR is described, and objectives of the PSR are discussed. Requirements for the PSR, including structure dimensions and geometric constraints, mass characteristics, erectable and deployable concepts, truss surface precision, and thermal and dynamic characteristics are discussed along with gravity deflections, secondary support characteristics, and removable members. Analytical development and system- and component-level tests are outlined. V.T.

A90-31250#
SOLAR PANELS FOR COLUMBUS [ZONNEPANELEN VOOR COLUMBUS]
H. J. CRUIJSSEN and H. VAN DEN BRINK (Fokker Space and Systems, Amsterdam, Netherlands) Ruimtevaart, vol. 39, Feb. 1990, p. 11-20. In Dutch.

Solar-panel R&D efforts undertaken for the ESA Columbus program in 1989 are surveyed. The primary Columbus components (Columbus Attached Laboratory, Free-Flying Laboratory, and Polar Platform) are briefly described; their solar-panel requirements are discussed; and the proposed flat-pack, telescopic mast, and matrix solar-panel configurations are characterized in detail and illustrated with drawings. It is pointed out that only the flat-pack configuration is applicable to all three Columbus components, making it the most feasibile economically (unless the component designs are changed significantly as the program evolves). Also included is a brief examination of the role of the Netherlands space industry in Columbus projects; the small number of contracts granted to Dutch companies is attributed to the low percentage (1.3 percent) of Dutch financial participation in Columbus. T.K.

A90-31300#
MODELLING OF DEPLOYMENT MECHANISMS FOR LATCH-UP SHOCKS
B. S. NATARAJU, R. CHINNASAMY, T. S. KRISHNAMURTHY, and D. H. BONDE (ISRO, Satellite Centre, Bangalore, India) ESA Journal (ISSN 0379-2285), vol. 13, no. 4, 1989, p. 393-400.
Copyright

The use of deployment mechanisms on satellites is becoming a necessity. Design of such mechanisms is complex because a wide range of environmental conditions has to be taken into account. The systems are stowed during launch and deployed in orbit. At the end of the deployment, the hinges are subjected to shock. A quick and simple method is required for predicting the shock within reasonable and conservative values. Moreover, the method must predict well within the engineering limits. In the work reported here, various methods have been used for estimating the loads experienced by the hinges. Theoretical estimates have been compared with measured values. Author

N90-10022# Charles River Analytics, Inc., Cambridge, MA.
HIERARCHICAL DAMAGE TOLERANT CONTROLLERS FOR SMART STRUCTURES Final Report, Jun. - Dec. 1988
A. K. CAGLAYAN, S. M. ALLEN, and S. J. EDWARDS Mar. 1989 68 p
(Contract F33615-88-C-3212)
(AD-A209422; AFWAL-TR-89-3009) Avail: NTIS HC A04/MF A01 CSCL 13/12

The research and development results are presented of the Hierarchical Damage Tolerant Controllers for Smart Structures. The major aim is the investigation and definition of a baseline architecture for a smart aerospace structure which can detect and isolate structural damage in real time and provide on-line reconfiguration of the structure's control system under the detected impairment conditions. In particular, how a smart aerospace structure can be implemented as a real-time knowledge based expert system was investigated by addressing issues involved with structural knowledge representation, structural damage detection and isolation strategies and real time performance in an embedded environment. GRA

N90-10072# Selenia S.p.A., Rome (Italy). Missile System Div.
EXPERIENCE GAINED IN THE IMPROVEMENT OF THE ASPIDE AERODYNAMIC CONFIGURATION FOR THE SURFACE TO AIR ROLE
S. MAZZUCA *In* AGARD, Stability and Control of Tactical Missile Systems 10 p Mar. 1989
Copyright Avail: NTIS HC A15/MF A02

From the beginning to the end, the development process of the new aerodynamic version of the Aspide in the surface to air roles is described. The aims, constraints and main activities of the project are reported. The entire decision process is also analyzed in great detail. The successful completion of the above process, with the new configuration in full production constitutes the solid background for further improvements or new designs. Author

N90-10120*# Ottawa Univ. (Ontario).
MODELING AND STABILIZATION OF LARGE FLEXIBLE SPACE STATIONS
S. S. LIM and N. U. AHMED *In* NASA. Langley Research Center, *Proceedings of the Workshop on Computational Aspects in the* Control of Flexible Systems, Part 2 p 943-956 May 1989
Avail: NTIS HC A21/MF A03 CSCL 01/3

A preliminary formulation of a large space structure is presented. The system consists of a (rigid) massive body, which may play the role of experimental modules located at the center of the space station and a flexible configuration, consisting of several beams, which is rigidly attached to the main body. The equations that govern the motion of the complete system consist of several partial differential equations with boundary conditions describing the vibration of flexible components coupled with six ordinary differential equations that describe the rotational and translational motion of the central body. The problem of (feedback) stabilization of the system is discussed. This study is expected to provide an insight into the complexity of design and stabilization of actual space stations. Author

N90-10126 Texas Univ., Austin.
SYSTEM IDENTIFICATION FOR LARGE SPACE STRUCTURES Ph.D. Thesis
HYOUNG MAN KIM 1988 156 p
Avail: Univ. Microfilms Order No. DA8909689

A system identification procedure for large space structures is presented. A large space structure has a very large number of degrees of freedom - due to complexity as well as large size, and it is highly flexible and very lightly damped. Such structures should be tested and identified on orbit, and this may require a combination of on-line and off-line algorithms. System identification not only involves the selection of model, data, hardware, etc., but also requires those selected items to be properly combined. Therefore, the system identification method must be evaluated as a whole. An analytical model, as a mathematical model for simulation and as a base model for identification, is introduced. Model order-reduction techniques are considered to reduce the order of analytical models to a sufficiently small size. Among those, an unsymmetric block Lanczos method is outlined in detail. Some of

the important signal processing techniques involved in system identification are introduced. The number of sampled data is first reduced in the frequency domain by using regression analysis or principal component analysis. Based on a reduced set of sampled data, an experimental model is found by using a least-squares algorithm. The order of the experimental model is reduced by a Lanczos method, and the Lanczos vectors are identified. Several examples are presented to illustrate various aspects of the proposed system identification procedure. They include an 8-degree of freedom beam-rotor assembly and a 474-degree of freedom Space Station model which are employed to evaluate an unsymmetric block Lanczos algorithm, an 8-degree of freedom cantilever beam which is employed to evaluate the whole system identification procedure, and a 60-degree of freedom Space Station model which is employed to apply the proposed system identification procedure to a large structure. It is found that the proposed system identification method works well with large space structures, which have very low frequency and very closely-spaced modes. Dissert. Abstr.

N90-10127*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PRELIMINARY DESIGN OF A LARGE TETRAHEDRAL TRUSS/HEXAGONAL HEATSHIELD PANEL AEROBRAKE
JOHN T. DORSEY and MARTIN M. MIKULAS, JR. Sep. 1989 46 p
(NASA-TM-101612; NAS 1.15:101612) Avail: NTIS HC A03/MF A01 CSCL 22/2

An aerobrake structural concept is introduced which consists of two primary components: (1) a lightweight erectable tetrahedral support truss; and (2) sandwich hexagonal heatshield panels which, when attached to the truss, form a continuous impermeable aerobraking surface. Generic finite element models and a general analysis procedure to design tetrahedral truss/hexagonal heatshield panel aerobrakes is developed, and values of the aerobrake design parameters which minimize mass and packaging volume for a 120-foot-diameter aerobrake are determined. Sensitivity of the aerobrake design to variations in design parameters is also assessed. The results show that a 120-foot-diameter aerobrake is viable using the concept presented (i.e., the aerobrake mass is less than or equal to 15 percent of the payload spacecraft mass). Minimizing the aerobrake mass (by increasing the number of rings in the support truss) however, leads to aerobrakes with the highest part count. Author

N90-10128*# DWA Composite Specialities, Inc., Chatsworth, CA.
SPACE STRUCTURES CONCEPTS AND MATERIALS Final Report
A. M. NOWITZKY and E. C. SUPAN 25 Jun. 1988 126 p
(Contract NAS8-37257)
(NASA-CR-183727; NAS 1.26:183727) Avail: NTIS HC A07/MF A01 CSCL 22/2

An extension is preseted of the evaluation of graphite/aluminum metal matrix composites (MMC) for space structures application. A tubular DWG graphite/aluminum truss assembly was fabricated having the structural integrity and thermal stability needed for space application. DWG is a proprietary thin ply continuous graphite reinforced aluminum composite. The truss end fittings were constructed using the discontinuous ceramic particulate reinforced MMC DWAI 20 (trademark). Thermal stability was incorporated in the truss by utilizing high stiffness, negative coefficient of thermal expansion (CTE) P100 graphite fibers in a 6061 aluminum matrix, crossplied to provide minimized CTE in the assembled truss. Tube CTE was designed to be slightly negative to offset the effects of the end fitting and sleeve, CTE values of which are approx. 1/2 that of aluminum. In the design of the truss configuration, the CTE contribution of each component was evaluated to establish the component dimension and layup configuration required to provide a net zero CTE in the subassemblies which would then translate to a zero CTE for the entire truss bay produced. E.R.

N90-10153*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STRUCTURAL CONCEPTS FOR VERY LARGE (400-METER-DIAMETER) SOLAR CONCENTRATORS
MARTIN M. MIKULAS, JR. and JOHN M. HEDGEPETH (Astro Aerospace Corp., Carpinteria, CA.) *In its* Second Beamed Space-Power Workshop p 239-257 Jul. 1989
Avail: NTIS HC A19/MF A03 CSCL 10/1

A general discussion of various types of large space structures is presented. A brief overview of the history of space structures is presented to provide insight into the current state-of-the art. Finally, the results of a structural study to assess the viability of very large solar concentrators are presented. These results include weight, stiffness, part count, and in-space construction time. Author

N90-10986# European Space Agency, Paris (France).
SPACECRAFT STRUCTURES AND MECHANICAL TESTING
W. R. BURKE, comp. Jan. 1989 753 p In ENGLISH and FRENCH International conference held in Noordwijk, Netherlands, 19-21 Oct. 1988; sponsored by ESA, CNES, and DFVLR
(ESA-SP-289; ISSN-0379-6546; ETN-89-95384) Copyright
Avail: NTIS HC A99/MF E06

Diverse aspects of spacecraft structure design and testing are discussed. Special attention is given to dynamic control, structural analysis tools, vibroacoustics, hardware development, thin walled structures, solar arrays, and composite materials. Structural technology issues for Ariane, Columbus, Hermes and the International Space Station are discussed. ESA

N90-10987# *Aerospatiale, Cannes (France).*
EVALUATION OF TESTS AND DESIGN FACTORS
C. VIDAL, T. DEMOLLERAT, and M. KLEIN (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Spacecraft Structures and Mechanical Testing p 3-14 Jan. 1989 Previously announced as N89-23889
Copyright Avail: NTIS HC A99/MF E06

A method for the definition of the safety factors ensuring structural reliability is presented. The proposed procedure encompasses both theoretical reliability and practical aspects, combining design requirements, qualification, and acceptance tests. Design criteria in terms of reliability were defined based on previous spacecraft projects and then translated into structural design requirements that can be met in a practical design process. This was performed using a rational approach in terms of statistical variation coefficients of both strength and loads. A set of safety factors is proposed which is valid for unmanned spacecrafts up to 2000 kg. The methodology can easily be extended to larger masses. Complementary factors are defined for manned spacecraft applications. A computer implementation was developed in order to make the application of this methodology simpler and more efficient. ESA

N90-10988# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Space Communications and Propulsion Systems Div.
ENVIRONMENTAL TESTING: AN APPROACH TO MORE COST EFFICIENCY
E. D. SACH *In* ESA, Spacecraft Structures and Mechanical Testing p 15-19 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

An environmental testing philosophy in which cost considerations play an important role is developed. Various environmental requirements are given different levels of importance depending on the type of structural part concerned. The need for verification of the basic analytical model and verification of the structure or its essential parts to the decisive design constraint in the structure considered is stressed. It is proposed that the reliability of analytical models, well substantiated by tests, allows one to avoid complicated load simulations thus decreasing testing costs. ESA

N90-10990# Fokker B.V., Amsterdam (Netherlands). Space and Systems Div.
QUALIFICATION BY SIMULATION: DREAM OR REALITY
M. P. NIEUWENHUIZEN *In* ESA, Spacecraft Structures and Mechanical Testing p 27-35 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The possibility of eliminating a number of development tests to be replaced by computerized simulations is presented. The cost reductions involved in using generic designs are discussed. The use of identical or similar hardware elements in subsequent programs is presented as another cost reduction technique. The need to test the validity of computerized simulations is stressed. It is concluded that qualification by simulation alone is still a dream even for a generic product. A Fokker solar array generic design effort is presented as an example of how certain development tests can be eliminated. ESA

N90-10994# Besancon Univ. (France). Lab. de Mecanique Appliquee.
PARAMETRIC IDENTIFICATION OF CONSERVATIVE SELF ADJOINT STRUCTURES
G. LALLEMENT, J. PIRANDA, and R. FILLOD *In* ESA, Spacecraft Structures and Mechanical Testing p 63-68 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The parametric correction of the symmetric mass and stiffness matrices representing the linear elastodynamic behavior of the associated conservative structure to a real dissipative structure are examined. The initial estimations of these matrices are considered to have been constructed by a finite element discretization. Their parametric correction is based on the minimization of the distance between the eigensolutions of the model to be corrected and the identified eigensolutions of the physical structure. ESA

N90-10995# Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).
OVERVIEW OF ACTUAL BUCKLING CALCULATION METHODS FOR SPACE VEHICLE STRUCTURES
W. HUESSLER and H. OERY (Technische Hochschule, Aachen, Germany, F.R.) *In* ESA, Spacecraft Structures and Mechanical Testing p 71-78 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The complexities involved in the buckling analysis of cylindrical shells is presented. The deficiencies of present methods of buckling calculations and of the design codes and specifications based on these calculations are described. The need for updating these methods and for the systematization and synthesis of available results is stressed. The so called lower bound design curves which do not differentiate between badly or well manufactured shells need to be revised in order to reach maximum cost and mass effectiveness in lightweight spacecraft structures. The need for design guidelines for some practical load combinations is stressed. ESA

N90-11008# Construcciones Aeronauticas S.A., Madrid (Spain). Space Div.
EXPERIENCES USING A MAJOR FEM PACKAGE INTERACTIVELY FOR SPACECRAFT APPLICATIONS
J. SANCHEZCERCOS and V. GOMEZMOLINERO *In* ESA, Spacecraft Structures and Mechanical Testing p 167-172 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The advantages and disadvantages of the interactive execution mode compared with the batch mode in using an FEM (finite element models) package are described. These two approaches are compared for a variety of environments determined by the type of user and the class of calculation carried out. Results based on experiments in spacecraft structural design are presented. Present and future applications of the ASKAIN (ASKA Interactive) software program are discussed. These include using the interactive program to train inexperienced engineers as well as create new analytical procedures not directly related to the mother program. ESA

N90-11017# Centre National d'Etudes Spatiales, Toulouse (France).
THE THIRD GENERATION RIGID SOLAR ARRAY GSR3
A. MAMODE, D. GANGLOFF, J. L. BASTARD, and PH. AUFFRAY (Aerospatiale, Cannes, France) *In* ESA, Spacecraft Structures and Mechanical Testing p 227-232 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The design of a prototype solar array model featuring a new deployment mechanism is presented. The solar array is pre-flight tested using prediction tools. The structure of the solar panels and the hinge mechanism between panels is described. The GSR3 panels are concluded to be suitable for orbiting stations and retractable solar arrays. The GSR3 panels, which cover a wide range of specifications and have a modular design, can be used in a variety, of missions, thus lowering the costs of the individual missions. ESA

N90-11018# International Telecommunications Satellite Organization, Washington, DC.
ADVANCES IN DESIGN AND TESTING OF SPACECRAFT STRUCTURES
BRIJ N. AGRAWAL *In* ESA, Spacecraft Structures and Mechanical Testing p 233-237 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The results of Intelsat research and development projects in the area of spacecraft structural analysis, design and testing are summarized. These research projects show advances in the determination of the accuracy of predicted dynamic launch loads by coupled analysis, simpler methods to update launch loads, composite material analysis, prediction of acoustic response, improvements of design verification tests, and development of deployable offset reflectors. Further development work is required in some of these areas. ESA

N90-11020# National Space Development Agency, Tokyo (Japan).
DEVELOPMENT OF THE LARGE SPACECRAFT STRUCTURE
K. NAKAMURA, H. MITSUMA, A. TSUJIHATA, T. KATOH, T. TSUKASHIMA, and F. KUWAO (Toshiba Corp., Kawasaki, Japan) *In* ESA, Spacecraft Structures and Mechanical Testing p 247-252 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The development work involved in designing the ETS-6 (engineering test satellite-6) satellite is described. The ETS-6 satellite is a two ton class geostationary spacecraft to be launched in the summer of 1992. Structural tests were carried out on a full-scale model. The results of these tests of structural design, analysis and construction technique are included. The feasibility of a large scale lightweight structure which meets the requirements of ETS-6 is confirmed. ESA

N90-11021# Construcciones Aeronauticas S.A., Madrid (Spain). Space Div.
THE SERVICE MODULE STRUCTURE OF THE IOS SPACECRAFT DEVELOPMENT AND QUALIFICATION PROGRAM
FRANCISCO GONZALES *In* ESA, Spacecraft Structures and Mechanical Testing p 253-260 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The work carried out in establishing the structure of the ISO (infrared space observatory service module) is described. The contraints involved in designing the module are outlined including the necessity for low conductance with the payload module. This calls for the use of glass fiber in making the main structure struts near to the cryostat. The rest of the struts are made of carbon fiber composites. Analytical models used and the results obtained are presented. ESA

N90-11035# Veritas Research A.S., Hovik (Norway).
NONLINEAR COLLAPSE SIMULATION OF ANISOTROPIC PLATES AND CORRUGATED PANELS
P. G. BERGAN, R. O. BJOERUM, and M. K. NYGARD *In* ESA,

Spacecraft Structures and Mechanical Testing p 369-376 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

Advances in nonlinear finite element analysis of anisotropic and corrugated plates and shells are described. Free formulation plate and shell elements with six freedoms per node are developed for this purpose. Efficient ways of establishing the ultimate carrying capacity of structures are discussed. The combined use of nonlinear simulation and linearized eigenvalue analysis is given particular attention. Two examples are presented: a buckling analysis of an anisotropic cylindrical panel with a circular hole and a collapse analysis of a corrugated panel. ESA

N90-11044# Rome Univ. (Italy). Dipt. Aerospaziale.
STRUCTURAL PROBLEMS OF ACCURATE INFLATABLE SURFACES
C. ARDUINI and U. PONZI *In* ESA, Spacecraft Structures and Mechanical Testing p 439-445 Jan. 1989 Sponsored by Contraves Italiana, Rome
Copyright Avail: NTIS HC A99/MF E06

A toroidal ring used as a stiffner in a large inflatable antenna is analyzed. Analytical and numerical methods are used in the analysis of the ring and numerical results are given. Particular attention is given to the pressure-induced shape modifications which may affect the surface accuracy of the structure. A perfect toroidal membrane is considered and possible practical approximations of the same shape proposed. ESA

N90-11046# IKO Software Service G.m.b.H., Stuttgart (Germany, F.R.).
A NEW ASPECT FOR THE USE OF THIN WALLED BEAMS AS SHELL STIFFENERS OF SPACECRAFT STRUCTURES
FERENC KISS *In* ESA, Spacecraft Structures and Mechanical Testing p 455-460 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A consistent and compatible transformation for seven parameter Timoshenko beams is introduced. This transformation is applied to the new beam elements of the ASKA software program system. The comparison of the results obtained by different methods shows the validity of the solution and points to specific problems, where the effect in question plays an important role. One such problem is the modeling of a shell-like spacecraft structure by thin-walled beams eccentrically connected to the covering surface modeled by the shell. ESA

N90-11050# Mitsubishi Electric Corp., Tokyo (Japan).
TEST RESULTS ON CONCEPTUAL MODELS OF THE LARGE DEPLOYABLE ANTENNA FOR MOBILE COMMUNICATIONS SATELLITES
YUICHIRO BABA, YUJI TSUTSUMI, AKIO ISO, and KAZUO YAMAMOTO *In* ESA, Spacecraft Structures and Mechanical Testing p 491-496 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A preliminary study of a large antenna reflector for mobile communications, functioning on a Geostationary Platform (GPF) is described. The use of the 800/900 MHz band and an aperture diameter of about 30 m are assumed. The partial and scale models of three new truss configurations are introduced. They are fabricated and tested to confirm the soundness of their structural concept and to study their practicality more concretely. The results of the tests are outlined. ESA

N90-11051# IKO Software Service G.m.b.H., Stuttgart (Germany, F.R.).
SPACE TELESCOPE SOLAR ARRAY: NONLINEAR TEST AND ANALYSIS EFFECTS
PH. DELOO and M. KLEIN (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Spacecraft Structures and Mechanical Testing p 497-504 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A geometrical and material nonlinear model of a solar array boom of the space telescope is developed and its static behavior fitted to experimental data. The model is used to perform a nonlinear dynamic assessment of the real boom response to in-orbit loads. Allowable in-orbit loads are derived based on allowable bending moments computed from static test results. An accurate correlation of the model with the fully nonlinear system is achieved. ESA

N90-11052# Aerospatiale, Cannes (France).
ESA-D: AN INTEGRATED SOFTWARE FOR ANTENNA DESIGN AND ANALYSIS
L. MARRO, J. P. BOISSET, and K. PONTOPPIDAN (TICRA A/S, Copenhagen, Denmark) *In* ESA, Spacecraft Structures and Mechanical Testing p 505-510 Jan. 1989 Previously announced as N89-23784
(Contract ESTEC-6659/86/NL/PH)
Copyright Avail: NTIS HC A99/MF E06

The functional and architectural characteristics of the ESA-D software are described. This software allows full evaluation of the dimensional characteristics of satellite antenna reflectors in an integrated and interactive way. Such reflector profile requirements are fundamental design drivers for reflector design and manufacturing, and as such have to be thoroughly evaluated early in the design phase. Either rigid, unfurlable or inflatable types of reflectors can be processed using this software. ESA

N90-11053# Virginia Polytechnic Inst. and State Univ., Blacksburg. Materials Response Group.
THE USE OF DAMAGE CHARACTERIZATION FOR LIFE PREDICTION METHODOLOGIES
KENNETH L. REIFSNIDER *In* ESA, Spacecraft Structures and Mechanical Testing p 513-519 Jan. 1989
(Contract N62269-85-C-2345; AF-AFOSR-0087-85)
Copyright Avail: NTIS HC A99/MF E06

An attempt to construct a life prediction methodology which can be used for space structures on the basis of the analysis of damage development in composite components is described. Special attention is given to the use of damage characterization methods and test techniques which provide the data necessary to construct a mechanistic representation which can be used to anticipate performance under combinations of conditions that are unfamiliar or difficult to reproduce in the laboratory. These modeling concepts have been successfully applied to the prediction of remaining tensile and compressive strength of laminates constructed from two different composite material systems. ESA

N90-11055# Katholieke Univ. te Leuven (Belgium). Dept. of Metallurgy and Materials Engineering.
HYGROTHERMAL DEFORMATIONS OF COMPOSITE SHELLS
LAWRENCE E. DOXSEE, JR. *In* ESA, Spacecraft Structures and Mechanical Testing p 529-534 Jan. 1989 Sponsored in part by the Hughes Space and Communications Group and General Motors Research Labs.
Copyright Avail: NTIS HC A99/MF E06

A method developed for determining the deformations of laminated fiber-reinforced composite plates and shells subjected to changes in temperature and moisture concentration is described. The method consists of two parts: a two-dimensional shell theory which includes the effects of transverse shear and normal strains, and a displacement based finite element program for shells of revolution with axisymmetric temperature and moisture distributions. The shell theory and the finite element program were verified by obtaining solutions to a wide variety of problems using the finite element program and comparing these solutions to existing analytical solutions. Numerical examples demonstrate the importance of including transverse normal strains in the shell theory. ESA

N90-11078# Engineering System International, Rungis (France).
EXPLOITATION OF DATA MANAGEMENT FACILITIES FOR FINITE ELEMENT ANALYSIS IN AEROSPACE STRUCTURAL ENGINEERING APPLICATIONS
J. DUBOIS, R. VALENT, J. L. GREGIS, P. CARLIER, M. KLEIN, and A. KREIS (European Space Agency. European Space

Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Spacecraft Structures and Mechanical Testing p 721-728 Jan. 1989 Sponsored by ESA/ESTEC, Noordwijk, Netherlands
Copyright Avail: NTIS HC A99/MF E06

The ESA-CAR software system designed to reduce bottlenecks involved in the numerical analysis of spacecraft structures is described. The goals of this system are to reduce manpower and delays for such key activities as configuration and calculation control, increase quality, increase reutilization use for result replication, and facilitate heuristic knowledge transfer to individuals and organizations. ESA

N90-11771*# Auburn Univ., AL.
DESIGN OF A SOLAR SAIL MISSION TO MARS Final Report
RICHARD EASTRIDGE, KERRY FUNSTON, AMINAT OKIA, JOAN WALDROP, and CHRISTOPHER ZIMMERMAN 5 May 1989 61 p
(Contract NASW-4435)
(NASA-CR-186045; NAS 1.26:186045) Avail: NTIS HC A04/MF A01 CSCL 22/1

An evaluation of the design of the solar sail includes key areas such as structures, sail deployment, space environmental effects, materials, power systems, telemetry, communications, attitude control, thermal control, and trajectory analysis. Deployment and material constraints determine the basic structure of the sail, while the trajectory of the sail influences the choice of telemetry, communications, and attitude control systems. The thermal control system of the sail for the structures and electronics takes into account the effects of the space environment. Included also are a cost and weight estimate for the sail. Author

N90-13451*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A FIGURE CONTROL SENSOR FOR THE LARGE DEPLOYABLE REFLECTOR (LDR)
R. BARTMAN and S. DUBOVITSKY *In its* Report of the Asilomar 3 LDR Workshop p 50-51 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

A sensing and control system is required to maintain high optical figure quality in a segmented reflector. Upon detecting a deviation of the segmented surface from its ideal form, the system drives segment mounted actuators to realign the individual segments and thereby return the surface to its intended figure. When the reflector is in use, a set of figure sensors will determine positions of a number of points on the back surface of each of the reflector's segments, each sensor being assigned to a single point. By measuring the positional deviations of these points from previously established nominal values, the figure sensors provide the control system with the information required to maintain the reflector's optical figure. The optical lever, multiple wavelength interferometer, and electronic capacitive sensor, the most promising technologies for the development of the figure sensor, are illustrated. It is concluded that to select a particular implementation of the figure sensors, performance requirement will be refined and relevant technologies investigated further. Author

N90-13482*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INITIAL TEST RESULTS FOR THE MINI-MAST
L. HORTA and G. HORNER *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 122-123 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

The objectives of the 20-meter Mini-Mast were: (1) to learn how to efficiently test this type of large truss structure, (2) to relate component testing to the overall behavior of the structure, and (3) to update the associated analytical model based upon the experimental data. The Mini-Mast represents structural characteristics similar to the COFS beam which is planned to be flown on Shuttle to perform on-orbit structures and controls experiments. The information is of interest to LDR because it represents analysis and test information on a truss-type structure which may be similar to the Large Deployable Reflector (LDR) backup structure. The structure has a total of 111 titanium joints; the joint in the center of the truss element is a near-center latch joint. The results of this research indicate that linear deployable-type structures can be built, but difficulties do exist in extracting modes with identical frequencies; gravitational loading does affect the ground test results; and prediction of truss-type-structure dynamic characteristics is not trivial. Author

N90-13483*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LDR STRUCTURAL EXPERIMENT DEFINITION
R. A. RUSSELL *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 124-125 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

A system study to develop the definition of a structural flight experiment for a large precision segmented reflector on the Space Station was accomplished by the Boeing Aerospace Company for NASA's Langley Research Center. The objective of the study was to use a Large Deployable Reflector (LDR) baseline configuration as the basis for focusing an experiment definition, so that the resulting accommodation requirements and interface constraints could be used as part of the mission requirements data base for Space Station. The primary objectives of the first experiment are to construct the primary mirror support truss and to determine its structural and thermal characteristics. Addition of an optical bench, thermal shield and primary mirror segments, and alignment of the optical components, would occur on a second experiment. The structure would then be moved to the payload point system for pointing, optical control, and scientific optical measurement for a third experiment. Experiment 1 will deploy the primary support truss while it is attached to the instrument module structure. The ability to adjust the mirror attachment points and to attach several dummy primary mirror segments with a robotic system will also be demonstrated. Experiment 2 will be achieved by adding new components and equipment to experiment one. Experiment 3 will demonstrate advanced control strategies, active adjustment of the primary mirror alignment, and technologies associated with optical sensing. Author

N90-13485*# Astro Aerospace Corp., Santa Barbara, CA.
HYBRID DEPLOYABLE SUPPORT TRUSS DESIGNS FOR LDR
J. HEDGEPETH *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 128-129 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 13/2

Concepts for a 20-meter diameter Large Deployable Reflector (LDR) deployable truss backup structure, and analytical predictions of its structural characteristics are discussed. The concept shown is referred to as the SIXPAC; It is a combination of the PACTRUSS concept and a single-fold beam, which would make up the desired backup structure. One advantage of retaining the PACTRUSS concept is its packaging density and its capability for synchronous deployment. Various 2-meter hexagonal panel arrangements are possible for this Hybrid PACTRUSS structure depending on the panel-to-structure attachment strategies used. Static analyses of the SIXPAC using various assumptions for truss designs and panel masses of 10 kg sq meters were performed to predict the tip displacement of the structure when supported at the center. The tip displacement ranged from 0.20 to 0.44 mm without the panel mass, and from 0.9 to 3.9 mm with the panel mass (in a 1-g field). The data indicate that the structure can be adequately ground tested to validate its required performance in space, assuming the required performance in space is approximately 100 microns. The static displacement at the tip of the structure when subjected to an angular acceleration of 0.001 rad/sec squared were estimated to range from 0.8 to 7.5 microns, depending on the type of truss elements. Author

N90-13486*# Boeing Aerospace Co., Seattle, WA.
EFFECTS OF JOINTS IN TRUSS STRUCTURES
R. IKEGAMI *In* Jet Propulsion Lab., California Inst. of Tech.,

Report of the Asilomar 3 LDR Workshop p 130-131 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 13/2

The response of truss-type structures for future space applications, such as Large Deployable Reflector (LDR), will be directly affected by joint performance. Some of the objectives of research at BAC were to characterize structural joints, establish analytical approaches that incorporate joint characteristics, and experimentally establish the validity of the analytical approaches. The test approach to characterize joints for both erectable and deployable-type structures was based upon a Force State Mapping Technique. The approach pictorially shows how the nonlinear joint results can be used for equivalent linear analysis. Testing of the Space Station joints developed at LaRC (a hinged joint at 2 Hz and a clevis joint at 2 Hz) successfully revealed the nonlinear characteristics of the joints. The Space Station joints were effectively linear when loaded to plus or minus 500 pounds with a corresponding displacement of about plus or minus 0.0015 inch. It was indicated that good linear joints exist which are compatible with errected structures, but that difficulty may be encountered if nonlinear-type joints are incorporated in the structure. Author

N90-13488*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
LDR STRUCTURAL TECHNOLOGY ACTIVITIES AT JPL
BEN WADA *In its* Report of the Asilomar 3 LDR Workshop p 134-135 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

The status of the Large Deployable Reflector (LDR) technology requirements and the availability of that technology in the next few years are summarized. The research efforts at JPL related to these technology needs are also discussed. LDR requires that a large and relatively stiff truss-type backup structure have a surface accurate to 100 microns in space (initial position with thermal distortions) and the dynamic characteristics predictable and/or measurable by on-orbit system identification for micron level motion. This motion may result from the excitation of the lower modes or from wave-type motions. It is also assumed that the LDR structure can be ground tested to validate its ability to meet mission requirements. No program manager will commit a structural design based solely on analysis, unless the analysis is backed by a validation test program. Author

N90-13489*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
JOINTS IN DEPLOYABLE SPACE TRUSS STRUCTURES
M. RHODES *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 136-137 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

Since the response of deployable structural concepts being considered for the Large Deployable Reflector (LDR) backup structure will be dominated by the response of joints, the joint characteristics are significant. An overview is given of the research activities at LaRC on the static behavior of joints for deployable space truss structures. Since a pin-clevis-type joint will be utilized in deployable structures, an experimental research program to characterize the joint parameters which affect stiffness was conducted. An experimental research program was conducted on a second type of joint, referred to as a near-center latch joint. It was used in the center of members on the deployable truss structure for the Control of Flexible Structures (COFS) flight experiment. The test results of the near-center latch joint and the member with the joints indicated that the stiffness of the near-center joint is linear and stiffer than the stiffness of the total member, and that non-linearities in the stiffness characteristics of the total member were due to bending introduced at the ends of the member. The resulting data indicates that stiff linear folding joints can be designed and that bending load paths should be avoided whenever possible. In summary, for deployable structures, special attention to the joint and the structure design is required to minimize the undesirable structural non-linearities. Author

N90-13512# European Space Agency, Paris (France).
THE SPACECRAFT STRUCTURE
T. VANDERLAAN and E. JAEKEL *In its* The Hipparcos Mission. Prelaunch Status. Volume 1: The Hipparcos Satellite p 121-125 Jun. 1989
Copyright Avail: NTIS HC A16/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The spacecraft structure for the Hipparcos program is presented. The mass budget of this aluminum made structure is given. The central thrust tube, which carries the satellite assemblies and forms the interface to the Ariane launcher, is examined. The secondary structure, which consists of the shade structure, the fill-in antenna boom and the support structures for the cold gas and hydrazine tanks, is outlined. ESA

N90-13807*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A STUDY ON THE SENSITIVITY AND SIMULTANEOUS ADJUSTMENT OF A HOOP-COLUMN ANTENNA SURFACE
KYONG BEEN LIM, JER-NAN JUANG, and PEIMAN MAGHAMI (Old Dominion Univ., Norfolk, VA.) Jan. 1989 15 p
(NASA-TM-101538; NAS 1.15:101538) Avail: NTIS HC A03/MF A01 CSCL 20/11

The results of a recent surface adjustment of the 15-meter diameter hoop-column antenna are presented. A least-squares differential algorithm is used to adjust the surface shape as close as possible to a perfect parabola. Since the desired perfect parabola is not uniquely known a priori, parameters of the perfect parabola are included in the design vector along with the cable length changes. As an extension to an earlier study, lateral sensitivity is included in the least-squares adjustment procedure. In addition, the effect of cable length uncertainties on the surface RMS error is considered and an error bound is derived. The results in this study indicate an improvement over earlier studies. The sensitivity analysis provided a quantitative measure of the needed accuracy of the cable adjustments in the laboratory. Recommendations are included to further enhance shape adjustment. Author

N90-16292*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYSIS AND TESTING OF AXIAL COMPRESSION IN IMPERFECT SLENDER TRUSS STRUTS
MARK S. LAKE and NICHOLAS GEORGIADIS Washington Feb. 1990 30 p
(NASA-TM-4174; L-16712; NAS 1.15:4174) Avail: NTIS HC A03/MF A01 CSCL 20/11

The axial compression of imperfect slender struts for large space structures is addressed. The load-shortening behavior of struts with initially imperfect shapes and eccentric compressive end loading is analyzed using linear beam-column theory and results are compared with geometrically nonlinear solutions to determine the applicability of linear analysis. A set of developmental aluminum clad graphite/epoxy struts sized for application to the Space Station Freedom truss are measured to determine their initial imperfection magnitude, load eccentricity, and cross sectional area and moment of inertia. Load-shortening curves are determined from axial compression tests of these specimens and are correlated with theoretical curves generated using linear analysis. Author

N90-17673# Aerospace Corp., El Segundo, CA. Electronics Research Lab.
A SPACE-FED LOCAL OSCILLATOR FOR SPACEBORNE PHASED ARRAYS
GWENDOLYN M. SHAW and ROBERT B. DYBDAL 21 Dec. 1989 27 p
(Contract F04701-85-C-0086)
(AD-A216526; TR-0088(3925-05)-1; SSD-TR-89-89) Avail: NTIS HC A03/MF A01 CSCL 22/2

Deployable, spaceborne phase-array antennas require lightweight structures that are nonrigid and deform dynamically in orbit. These array deformations are described by a time- and amplitude-weighted sum of characteristic mechanical modes of

the array structure. These mechanical deformations degrade the array's radiation performance by reducing the gain, increasing the sidelobes, and generating pointing errors. The effects of these mechanical deformations can be partially compensated for by a space-fed local oscillator. This space-fed local oscillator uses a radiator on the back of the array to transmit the local oscillator signal to pickup elements connected to the array elements. This technique also potentially lowers the array's weight, eases its mechanical deployment, and reduces the complexity of its design. GRA

N90-17761# Nippon Electric Co. Ltd., Kanagawa (Japan).
SFU SOLAR ARRAY
Y. SHIBAYAMA, H. ARAI, K. MATSUI, K. HAMA, A. USHIROKAWA, M. NATORI, K. TAKAHASHI, N. WAKASUGI, and T. ANZAI (Institute for Unmanned Space Experiments Free Flyer, Tokyo, Japan) *In* ESA, European Space Power, Volume 2 p 557-562 Aug. 1989 Sponsored by the New Energy and Industrial Technology Development Organization
Copyright Avail: NTIS HC A16/MF A03

The Space Flyer Unit (SFU) equipped with two flexible solar array wings is described. The SFU is a reusable, multi-purpose free flyer to be launched by the Japanese H-2 launch vehicle in early 1994. Unique features of the flexible solar array are described. The solar array wing is made of a single extendible mast with fold-out solar cells. Deployed and stowed configurations of the wing are shown. The results of qualification tests performed on the solar array are presented. ESA

N90-17787# Aerospatiale, Cannes (France).
THE ITALSAT SOLAR ARRAY
G. GIACOMETTI, G. A. MARTIN, W. SCHULTZE, and K. RIBBE (Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn, Germany, F.R.) *In* ESA, European Space Power, Volume 2 p 715-719 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

The structural, mechanical, and electrical performance of the ITALSAT solar array are described. The two wings of the solar generator are described. The high power to weight ratio of these wings makes them well suited for use on communication satellites. The satellite is designed for a five year lifetime. Simplification in the hold-down and release systems for the solar arrays compared to previous, closely related, satellite wings, are outlined. ESA

N90-18453*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUPPORT TRUSSES FOR LARGE PRECISION SEGMENTED REFLECTORS: PRELIMINARY DESIGN AND ANALYSIS
TIMOTHY J. COLLINS and W. B. FICHTER Mar. 1989 24 p (NASA-TM-101560; NAS 1.15:101560) Avail: NTIS HC A03/MF A01 CSCL 22/2

Precision Segmented Reflector (PSR) technology is currently being developed for a range of future applications such as the Large Deployable Reflector. The structures activities at NASA-Langley are outlined in support of the PSR program. Design concepts are explored for erectable and deployable support structures which are envisioned to be the backbone of these precision reflectors. Important functional requirements for the support trusses related to stiffness, mass, and surface accuracy are reviewed. Proposed geometries for these structures and factors motivating the erectable and deployable designs are discussed. Analytical results related to stiffness, dynamic behavior, and surface accuracy are presented and considered in light of the functional requirements. Results are included for both a 4-meter-diameter prototype support truss which is currently being designed as the Test Bed for the PSR technology development program, and for two 20-meter support structures. Author

N90-18454*# Lockheed Missiles and Space Co., Sunnyvale, CA.
PROCESS DEVELOPMENT AND FABRICATION OF SPACE STATION TYPE ALUMINUM-CLAD GRAPHITE EPOXY STRUTS
L. R. RING Jan. 1990 37 p
(Contract NAS1-18229)
(NASA-CR-181873; NAS 1.26:181873; LMSC/F186352) Avail: NTIS HC A03/MF A01 CSCL 22/2

The manufacture of aluminum-clad graphite epoxy struts, designed for application to the Space Station truss structure, is described. The strut requirements are identified, and the strut material selection rationale is discussed. The manufacturing procedure is described, and shop documents describing the details are included. Dry graphite fiber, Pitch-75, is pulled between two concentric aluminum tubes. Epoxy resin is then injected and cured. After reduction of the aluminum wall thickness by chemical milling the end fittings are bonded on the tubes. A discussion of the characteristics of the manufactured struts, i.e., geometry, weight, and any anomalies of the individual struts is included. Author

N90-19253*# Rockwell International Corp., Seal Beach, CA. Satellite and Space Electronics Div.
LARGE SPACE ANTENNA CONCEPTS FOR ESGP
ALLAN W. LOVE *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 65-68 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 20/14

It is appropriate to note that 1988 marks the 100th anniversary of the birth of the reflector antenna. It was in 1888 that Heinrich Hertz constructed the first one, a parabolic cylinder made of sheet zinc bent to shape and supported by a wooden frame. Hertz demonstrated the existence of the electromagnetic waves that had been predicted theoretically by James Clerk Maxwell some 22 years earlier. In the 100 years since Hertz's pioneering work the field of electromagnetics has grown explosively: one of the technologies is that of remote sensing of planet Earth by means of electromagnetic waves, using both passive and active sensors located on an Earth Science Geostationary Platform (ESEP). For these purposes some exquisitely sensitive instruments were developed, capable of reaching to the fringes of the known universe, and relying on large reflector antennas to collect the minute signals and direct them to appropriate receiving devices. These antennas are electrically large, with diameters of 3000 to 10,000 wavelengths and with gains approaching 80 to 90 dB. Some of the reflector antennas proposed for ESGP are also electrically large. For example, at 220 GHz a 4-meter reflector is nearly 3000 wavelengths in diameter, and is electrically quite comparable with a number of the millimeter wave radiotelescopes that are being built around the world. Its surface must meet stringent requirements on rms smoothness, and ability to resist deformation. Here, however, the environmental forces at work are different. There are no varying forces due to wind and gravity, but inertial forces due to mechanical scanning must be reckoned with. With this form of beam scanning, minimizing momentum transfer to the space platform is a problem that demands an answer. Finally, reflector surface distortion due to thermal gradients caused by the solar flux probably represents the most challenging problem to be solved if these Large Space Antennas are to achieve the gain and resolution required of them. Author

N90-19254*# Lockheed Missiles and Space Co., Sunnyvale, CA.
LARGE-DIAMETER GEOSTATIONARY MILLIMETER WAVELENGTH ANTENNA CONCEPT
W. S. GREGORWICH, H. A. MALLIOT, and A. K. SINHA *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 69-81 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 22/2

The concept of a curved reflecting surface by means of an electrostatic membrane appeared as early as 1932 in the British patent by Muller. The use of the electrostatic membrane in space applications as large-reflector antennas was proposed. A schematic of the concept is provided. Advantages of wrap-rib; wrap-radial-rib command surface; electromembrane applied to laser mirrors; membrane control concept; dual band elements; millimeter wavelength reflector; and the proof of concept and demonstration model are briefly presented. B.G.

N90-19255*# Lockheed Missiles and Space Co., Sunnyvale, CA.
DESIGN OF A LOW-FREQUENCY (5-20 GHZ), 15-METER-DIAMETER PASSIVE RADIOMETER FOR GEOSTATIONARY EARTH SCIENCE PLATFORMS
A. K. SINHA *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 83-108 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 14/2

The Wrap-Rib Antenna is a deployable lightweight shaped reflector. It consists of a central hub, parabolic ribs, and an rf reflector mesh. The wrap-rib reflector approximates the desired surface by means of pie-shaped segments of parabolic cylinders. The elements of the total system and the feasibility of the system are discussed. B.G.

N90-19256*# Astro Aerospace Corp., Carpinteria, CA.
STRUCTURES FOR REMOTELY DEPLOYABLE PRECISION ANTENNAS
J. M. HEDGEPETH *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 109-128 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 20/14

Future space missions such as the Earth Science Geostationary Platform (ESGP) will require highly accurate antennas with apertures that cannot be launched fully formed. The operational orbits are often inaccessible to manned flight and will involve expendable launch vehicles such as the Delta or Titan. There is therefore a need for completely deployable antenna reflectors of large size capable of efficiently handling millimeter wave electromagnetic radiation. The parameters for the type of mission are illustrated. The logarithmic plot of frequency versus aperture diameter shows the regions of interest for a large variety of space antenna applications, ranging from a 1500-meter-diameter radio telescope for low frequencies to a 20-meter-diameter infrared telescope. For the ESGP, a major application is the microwave radiometry at high frequencies for atmospheric sounding. Almost all existing large antenna reflectors for space employ a mesh-type reflecting surface. Examples are shown and discussed which deal with the various structural concepts for mesh antennas. Fortunately, those concepts are appropriate for creating the very large apertures required at the lower frequencies for good resolution. The emphasis is on the structural concepts and technologies that are appropriate to fully automated deployment of dish-type antennas with solid reflector surfaces. First the structural requirements are discussed. Existing concepts for fully deployable antennas are then described and assessed relative to the requirements. Finally, several analyses are presented that evaluate the effects of beam steering and segmented reflector design on the accuracy of the antenna. Author

N90-19257*# Composite Optics, Inc., San Diego, CA.
UNFURLABLE, CONTINUOUS-SURFACE REFLECTOR CONCEPT
J. E. STUMM and S. KULICK *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 129-136 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 20/14

Various concepts for large, deployable reflectors were developed and some have flown. In each case the surface material was either a continuous mesh of some sort or an assembly of rigid, continuous-surface facets or petals. Performance issues arise in each case. For mesh, reflectance diminishes with increasing frequency. For rigid sections, seams and relative positioning of the segments have to be dealt with. These two issues prompted the evolution of the concept of an unfurlable, continuous-surface reflector. The concept is described and what is learnt is presented, what is suspected will be learned, and also questions raised yet to be addressed. Author

N90-19258*# L'Garde, Inc., Tustin, CA.
ADVANCES IN LARGE INFLATABLE REFLECTORS
M. THOMAS and G. WILLIAMS *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 137-151 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 20/14

For most applications in space for which they were tried, inflatable structures show a significant weight reduction when compared to mechanical structures. Inflatables are unmatched when compared to mechanical structures when packaged volume is considered. The reliability of deployment of inflatable structures was known for years. When properly designed, such a system is inherently more reliable because it has very few points of failure. Fully inflatable vs. rigidized inflatable structures are discussed. The L'Garde solar concentrator experience is described. Reflector surface and cylinder rigidization, improvement in gore design tools, and expected advances in rigidization schemes with near future are examined. B.G.

N90-19260*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MILLIMETER RADIOMETER SYSTEM TECHNOLOGY
W. J. WILSON and P. N. SWANSON *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 167-177 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 14/2

JPL has had a large amount of experience with spaceborne microwave/millimeter wave radiometers for remote sensing. All of the instruments use filled aperture antenna systems from 5 cm diameter for the microwave Sounder Units (MSU), 16 m for the microwave limb sounder (MLS) to 20 m for the large deployable reflector (LDR). The advantages of filled aperture antenna systems are presented. The requirements of the 10 m Geoplat antenna system, 10 m multified antenna, and the MLS are briefly discussed. B.G.

N90-19263*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
LARGE ANTENNA MEASUREMENT AND COMPENSATION TECHNIQUES
Y. RAHMATSAMII *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 203-215 Jul. 1989 Presented at the 11th ESTEC Antenna Workshop on Antenna Measurements, Gothenburg, Sweden, 20-22 Jun. 1988
Avail: NTIS HC A17/MF A03 CSCL 20/14

Antennas in the range of 20 meters or larger will be an integral part of future satellite communication and scientific payloads. In order to commercially use these large, low sidelobe and multiple-beam antennas, a high level of confidence must be established as to their performance in the 0-g and space environment. It is also desirable to compensate for slowly varying surface distortions which could results from thermal effects. An overview of recent advances in performing rf measurements on large antennas is presented with emphasis given to the application of a space-based far-field range utilizing the Space Shuttle. The concept of surface distortion compensation is discussed by providing numerical and measurement results. Author

N90-19264*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A COMPARISON OF REFLECTOR ANTENNA DESIGNS FOR WIDE-ANGLE SCANNING
M. ZIMMERMAN, S. W. LEE, B. HOUSHMAND, Y. RAHMATSAMII (Jet Propulsion Lab., California Inst. of Tech., Pasadena.), and R. J. ACOSTA *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 217-240 Jul. 1989 Previously announced as N89-21138
Avail: NTIS HC A17/MF A03 CSCL 20/14

Conventional reflector antennas are typically designed for up to + or - 20 beamwidths scan. An attempt was made to stretch this scan range to some + or - 300 beamwidths. Six single and dual reflector antennas were compared. It is found that a symmetrical parabolic reflector with f/D = 2 and a single circular waveguide feed has the minimum scan loss (only 0.6 dB at Theta sub 0 = 8 deg, or a 114 beamwidths scan). The scan is achieved by tilting the parabolic reflector by an angle equal to the half-scan

angle. The f/D may be shortened if a cluster 7 to 19 elements instead of one element is used for the feed. The cluster excitation is adjusted for each new beam scan direction to compensate for the imperfect field distribution over the reflector aperture. The antenna can be folded into a Cassegrain configuration except that, due to spillover and blockage considerations, the amount of folding achievable is small. Author

N90-19265*# Atlantic Research Corp., Rome, NY.
ARRAYS FOR SPACE APPLICATIONS
HARVEY K. SCHUMAN, PAUL ANTONIK, and CARMEN MALAGISI *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 241-263 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 20/14

Concepts that were studied for application in space based radar (SBR) systems are presented. These antenna systems were for low earth orbit and require large fields of view (FOV). The systems included both space-fed and corporate-fed arrays. B.G.

N90-19266*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CONJUGATE FIELD APPROACHES FOR ACTIVE ARRAY COMPENSATION
R. J. ACOSTA *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 265-271 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 20/14

Two approaches for calculating the compensating feed array complex excitations are namely, the indirect conjugate field matching (ICFM) and the direct conjugate field matching (DCFM) approach. In the ICFM approach the compensating feed array excitations are determined by considering the transmitting mode and the reciprocity principle. The DCF, in contrast calculates the array excitations by integrating directly the induced surface currents on the reflector under a receiving mode. DCFM allows the reflector to be illuminated by an incident plane wave with a tapered amplitude. The level of taper can effectively control the sidelobe level of the compensated antenna pattern. Both approaches are examined briefly. Author

N90-19268*# North Carolina State Univ., Raleigh. Dept. of Electrical and Computer Engineering.
MESH SURFACES FOR REFLECTOR APPLICATIONS
FRANK KAUFFMAN *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 295-311 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 20/14

The topics of mesh reflectors, methods of analysis, measurements, problems of current interest, and future research, are those which should be addressed in assessing the current state of metallic mesh technology for spaceborne reflector antennas. The study of the properties of the conducting mesh material is discussed. To calculate the radiation patterns of antennas with conducting mesh reflectors, the electromagnetic properties of the mesh material must be integrated into an appropriate reflector antenna computer code. Such a code would take into account such factors as the curvature of the reflector surface, the radiation pattern(s) of the feed(s), etc. Many organizations have developed their own codes for these calculations. An excellent example of such a code is the one developed by Rahmat-Samii and Lee. Author

N90-19269*# TRW Electronic Systems Group, Redondo Beach, CA. Antenna Systems Lab.
ANTENNAS FOR 20/30 GHZ AND BEYOND
C. HARRY CHEN, WILLIAM C. WONG, and S. JIM HAMADA *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 313-327 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 20/14

Antennas of 20/30 GHz and higher frequency, due to the small wavelength, offer capabilities for many space applications. With the government-sponsored space programs (such as ACTS) in recent years, the industry has gone through the learning curve of designing and developing high-performance, multi-function antennas in this frequency range. Design and analysis tools (such as the computer modelling used in feedhorn design and reflector surface and thermal distortion analysis) are available. The components/devices (such as BFN's, weight modules, feedhorns and etc.) are space-qualified. The manufacturing procedures (such as reflector surface control) are refined to meet the stringent tolerance accompanying high frequencies. The integration and testing facilities (such as Near-Field range) also advance to facilitate precision assembling and performance verification. These capabilities, essential to the successful design and development of high-frequency spaceborne antennas, shall find more space applications (such as ESGP) than just communications. Author

N90-19617*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A TRANSIENT PLASTICITY STUDY AND LOW CYCLE FATIGUE ANALYSIS OF THE SPACE STATION FREEDOM PHOTOVOLTAIC SOLAR ARRAY BLANKET
SASAN C. ARMAND, MEI-HWA LIAO, and RONALD W. MORRIS (Sverdrup Technology, Inc., Cleveland, OH.) 1990 16 p Presented at the 1990 MSC World Users Conference, Los Angeles, CA, 26-30 Mar. 1990; sponsored by Macneal-Schwendler Corporation
(NASA-TM-102516; E-5321; NAS 1.15:102516) Avail: NTIS HC A03/MF A01 CSCL 20/11

The Space Station Freedom photovoltaic solar array blanket assembly is comprised of several layers of materials having dissimilar elastic, thermal, and mechanical properties. The operating temperature of the solar array, which ranges from -75 to +60 C, along with the material incompatibility of the blanket assembly components combine to cause an elastic-plastic stress in the weld points of the assembly. The weld points are secondary structures in nature, merely serving as electrical junctions for gathering the current. The thermal mechanical loading of the blanket assembly operating in low earth orbit continually changes throughout each 90 min orbit, which raises the possibility of fatigue induced failure. A series of structural analyses were performed in an attempt to predict the fatigue life of the solar cell in the Space Station Freedom photovoltaic array blanket. A nonlinear elastic-plastic MSC/NASTRAN analysis followed by a fatigue calculation indicated a fatigue life of 92,000 to 160,000 cycles for the solar cell weld tabs. Additional analyses predict a permanent buckling phenomenon in the copper interconnect after the first loading cycle. This should reduce or eliminate the pulling of the copper interconnect on the joint where it is welded to the silicon solar cell. It is concluded that the actual fatigue life of the solar array blanket assembly should be significantly higher than the calculated 92,000 cycles, and thus the program requirement of 87,500 cycles (orbits) will be met. Another important conclusion that can be drawn from the overall analysis is that, the strain results obtained from the MSC/NASTRAN nonlinear module are accurate to use for low-cycle fatigue analysis, since both thermal cycle testing of solar cells and analysis have shown higher fatigue life than the minimum program requirement of 87,500 cycles. Author

07

VIBRATION & DYNAMIC CONTROLS

Design and analysis of structural dynamics. Includes descriptions of analytical techniques and computer codes, trade studies, requirements and descriptions of orbit maintenance systems, rigid and flexible body attitudesensing systems and controls.

A90-10251* Iowa Univ., Iowa City.
A VARIATIONAL APPROACH TO DYNAMICS OF FLEXIBLE MULTIBODY SYSTEMS
SHIH-CHIN WU, EDWARD J. HAUG, and SUNG-SOO KIM (Iowa, University, Iowa City) Mechanics of Structures and Machines

(ISSN 0890-5452), vol. 17, no. 1, 1989, p. 3-32. refs
(Contract NASA ORDER L-5308-C; AF-AFOSR-86-0032)

This paper presents a variational formulation of constrained dynamics of flexible multibody systems, using a vector-variational calculus approach. Body reference frames are used to define global position and orientation of individual bodies in the system, located and oriented by position of its origin and Euler parameters, respectively. Small strain linear elastic deformation of individual components, relative to their body references frames, is defined by linear combinations of deformation modes that are induced by constraint reaction forces and normal modes of vibration. A library of kinematic couplings between flexible and/or rigid bodies is defined and analyzed. Variational equations of motion for multibody systems are obtained and reduced to mixed differential-algebraic equations of motion. A space structure that must deform during deployment is analyzed, to illustrate use of the methods developed. Author

A90-10252* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A CONTROLLER DESIGN FOR MULTI-BODY LARGE ANGLE MANEUVERS
PEIMAN GHAEMMAGHAMI and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 17, no. 1, 1989, p. 33-52. refs

Active large angle slewing maneuvers of a multi-body flexible dynamic system are investigated. An appropriate state variable transformation and a feedback linearization technique are employed to transform the dynamics of the nonlinear system to a new state that is more amenable to control design procedures. Closed-loop feedback algorithms are implemented to perform slewing maneuvers, while simultaneously suppressing flexural vibrations of the system. Stability of this class of nonlinear systems is also investigated, whereby a sufficient condition for asymptotic stability of the system is established. Numerical examples are presented to demonstrate the proposed active control algorithms. Author

A90-10253
DYNAMIC FAILURE AND ARREST IN LARGE SPACE STRUCTURES
RAYMOND J. NAGEM and JAMES H. WILLIAMS, JR. (MIT, Cambridge, MA) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 17, no. 1, 1989, p. 53-71.

Some concepts associated with fracture mechanics and some aspects of wave propagation theory are combined to produce an analysis of dynamic failure in a simple lattice structure. For the given model, the conditions for failure propagation and failure arrest in the lattice are derived and the location of failure arrest (if any) is computed. It is shown that failure arrest may be achieved by the introduction of a wave deflector that has material properties different from those of the remainder of the structure. With the proper choice of the material properties of the deflector, the failure process is arrested after it has passed into the deflector system. This paper is an example of one of the applications of the study of wave propagation in lattice structures and may serve as a basis for more complicated models of dynamic failure in such structures. Author

A90-10255
STRUCTURAL OPTIMIZATION WITH STIFFNESS AND FREQUENCY CONSTRAINTS
R. A. CANFIELD, V. B. VENKAYYA (USAF, Wright-Patterson AFB, OH), and R. V. GRANDHI (Wright State University, Dayton, OH) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 17, no. 1, 1989, p. 95-110. refs

Automated preliminary design algorithms for large aerospace structures require an efficient and reliable method to economically minimize weight, while satisfying multiple types of constraints. Often structural optimization is started with a few cycles of Fully Stressed Design, using the stress ratio method, because of its simplicity and computational efficiency. The present approach is to generalize more sophisticated optimality criteria for more than one type of constraint. The goal is to account for more than just stress constraints, while retaining the computational efficiency of the simple stress ratio method. Previous optimality criteria methods for static and frequency constraints are combined in a new algorithm that handles both types of constraints simultaneously. Two trusses and one wing structure are used to demonstrate the validity of an Optimality Criteria method for multiple behavior constraints. Author

A90-10256
CONTROL FORMULATION FOR FLEXIBLE STRUCTURES USING PHYSICAL COORDINATES
HARLEY H. CUDNEY and DANIEL J. INMAN (New York, State University, Amherst) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 17, no. 1, 1989, p. 111-130. refs

A procedure for calculating feedback gain matrices for the control of lumped parameter models of flexible structures is developed, using partitioned matrices. This method is based on modal control, but unlike previously published modal control methods, does not require the uncontrolled equations of motion to decouple. The resulting feedback gain matrices fulfill damping and stiffness design of the controlled modes while maintaining partial decoupling of the controlled modes from the uncontrolled modes. The advantages of this method are that the gain matrices are calculated in physical coordinates, which increases insight into the design process and allows the control gains to be used directly. The use of partitioned matrices reduces the number of calculations that are necessary to obtain the gain matrices. In addition, several decoupling conditions in the presence of control are introduced and discussed. Author

A90-10475
CONTINUUM MODELS OF SPACE STATION STRUCTURES
JOHN O. DOW and STEPHEN A. HUYER (Colorado, University, Boulder) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 2, Oct. 1989, p. 220-238. refs

The equivalent continuum properties of a structure composed of repeated patterns of discrete elements with both displacement and rotation coordinates are determined. These nodal coordinates are transformed to rigid body and strain gradient variables using a polynomial representation. The set of independent strain gradient variables is identified by inspection and depends on the geometry of the structure being modeled. The procedure is applied to six example problems, including two in which the effect of structural damage is analyzed. Author

A90-10621*# DYNACS Engineering Co., Inc., Clearwater, FL.
PARALLEL PROCESSING ENVIRONMENT FOR MULTI-FLEXIBLE BODY DYNAMICS
RAVI VENUGOPAL, MANOJ N. KUMAR, RAMEN P. SINGH (Dynacs Engineering Co., Clearwater, FL), and LAWRENCE W. TAYLOR, JR. (NASA, Langley Research Center, Hampton, VA) AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989. 6 p.
(AIAA PAPER 89-3015)

The implementation of a dynamics solution algorithm with inherent parallelism which is applicable to the dynamics of large flexible space structures is described. The algorithm is unique in that parts of the solution can be computed simultaneously by working with different branches of its tree topology. The algorithm exhibits close to 0(n) type behavior. The data flow within the solution algorithm is discussed along with results from its implementation in a multiprocessing environment. A model of the United States Space Station is used as an example. The results show that, with fast multiple scalar processors, an efficient algorithm, and symbolically generated equations of motion, real-time performance can be achieved with present-day hardware technology, even with complex dynamical models. C.D.

A90-11066
ON GYROSTAT DYNAMICS AND RECOVERY
M. GUELMAN (Rafael Armament Development Authority, Haifa, Israel) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 37, Apr.-June 1989, p. 109-119. refs
Copyright

A qualitative study of free torque gyrostat behavior was carried out and a relation was established between the stable equilibrium points and flat spin recovery. A two-step control law which assures recovery from any arbitrary initial state is presented. The control law requires knowledge of the spacecraft mass properties and measurement of the rotor and platform spin rates. The simple control law assures recovery for different classes of spacecraft with various mass properties from arbitrary initial conditions. K.K.

A90-11071
MODULAR LARGE SPACE STRUCTURES DYNAMICS
F. BERNELLI-ZAZZERA, A. E. FINZI, M. FRANCI, and P. MANTEGAZZA (Milano, Politecnico, Milan, Italy) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 37, Apr.-June 1989, p. 195-210. refs
Copyright

The dynamics of modular repetitive structures is here investigated through the analysis of dispersion relations, and the results obtained with two different approaches, periodic and equivalent continuum, are compared. Since these structures are known to behave as filters to propagating waves, the possible relation between structural parameters and filtering effects is analyzed, and the inadequacy of the continuum approach is confirmed. To this end, within the periodic approach, a transfer matrix between two successive modules, related to the stiffness and mass matrices of the repetitive module, is introduced; the propagation constants are then computed by solving the eigenvalue problem derived from application of Floquet theory on partial differential equations to the structural transfer matrix. The results confirm that a periodic structure behaves as a mechanical filter and show how the nature of passing and stopping bands is related to the eigenfrequencies of the repetitive module. Author

A90-11931*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GLOBAL SENSITIVITY ANALYSIS IN CONTROL-AUGMENTED STRUCTURAL SYNTHESIS
CHRISTINA L. BLOEBAUM (NASA, Langley Research Center, Hampton, VA) AIAA Student Journal (ISSN 0001-1460), vol. 27, Summer 1989, p. 17-26. Previously cited in issue 09, p. 1399, Accession no. A89-25613. refs
(Contract NAG1-688)
Copyright

A90-12852#
FREE ROTATION OF A CIRCULAR RING WITH AN UNBALANCED MASS
L. T. WATSON (Virginia Polytechnic Institute and State University, Blacksburg) and C. Y. WANG (Michigan State University, East Lansing) AIAA Journal (ISSN 0001-1452), vol. 27, Nov. 1989, p. 1650-1652. refs
Copyright

A model of a space station in which the ring rotating about its axis of symmetry is unbalanced by a mass attached to a point on the ring is presented. The curvatures or normalized moments are shown. K.K.

A90-13296#
APPLICATION OF THE MOBILE CONTROL PRINCIPLE FOR A SPACE STATION DESIGN
V. S. BUDNIK, A. P. ALPATOV, P. A. BELONOZHKO, and N. F. SVIRIDENKO IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-080) Copyright

Mobile control models for application in space station design are discussed. Methodological issues are addressed which result from particular model forms of controlled motion associated with the alternative connection of control channels. Methods of system stability analysis and mobile control algorithm synthesis are proposed. Application problems associated with space station geometry control, the development of combined power control systems on the basis of highly power-intensive flywheels, and emergency control are considered. It is shown that the mobile control method makes it possible to solve space station attitude control problems by using widely applicable controlling units on the space stations. C.E.

A90-13460#
RECENT ADVANCES IN DESIGN AND VERIFICATION OF SPACECRAFT STRUCTURES
C. STAVRINIDIS (ESTEC, Noordwijk, Netherlands) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p. refs
(IAF PAPER 89-330) Copyright

There is a growing tendency to combine analysis and test in the development of spacecraft. For an effective combination of analysis and test it is important not only to verify analytical and test results in areas where both are highly accurate but to support analysis by tests in areas where the analytical data are inadequate. For example, the sizing of main load carrying parts of a structure is adequately covered by competent employment of finite element capabilities. On the other hand, the verification by test of the dynamic response of a flexible part of a structure, at an excitation level comparable to that in flight, is particularly valuable. The dynamic response contains information on the hardware mass, stiffness, damping, nonlinearities, and complex stiffness due to the influence of mechanisms where applicable. Author

A90-13461#
ACOUSTIC RESPONSE ANALYSIS OF LARGE LIGHT SPACE STRUCTURES
H. DEFOSSE (Intespace, Toulouse, France) and F. MERCIER (CNES, Toulouse, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. Research supported by CNES. refs
(IAF PAPER 89-331) Copyright

The dynamic behavior of large lightweight aerospace structures under reverberant acoustic excitation is investigated. A review of the modal superposition theory is presented, along with an improved analysis method of air mass and acoustic radiation damping effects. An efficient postprocessor uses classic finite element codes to compute structural responses up to medium frequencies. Experiments performed on a honeycomb panel demonstrate the importance of two factors for the accurate analysis of the vibroacoustic responses of such aerospace structures: specifically, it is shown that the low frequency response calculations should include correlation characteristics of the excitation pressure field, and the test data processing should include pressure cross spectra calculations. Theoretical and analytical results are compared to assess air effects on a rigid circular plate. Dynamic analysis of large lightweight aerospace structures under a vacuum hypothesis may lead to a significant overestimation of predicted levels. C.E.

A90-13463*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON-ORBIT VIBRATION TESTING FOR SPACE STRUCTURES
JAY-CHUNG CHEN and JAMES L. FANSON (JPL, Pasadena, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(IAF PAPER 89-333) Copyright

A simulated on-orbit modal test using active members as the excitation source has been performed on the Precision Truss. Using the step sine testing technique, the frequency response functions are obtained and the modal parameters are extracted by the curve-fitting method. A total of 10 global modes and 3 local modes are obtained. The results are compared with those obtained by the conventional external excitation test. Author

A90-13464#
VIBRATION SUPPRESSION OF SPACE TRUSS BY STIFFNESS VARIATION
JUNJIRO ONODA, NAOYUKI WATANABE (Institute of Space and Astronautical Science, Sagamihara, Japan), TAKAO ENDO, and HIDEHIKO TAMAOKI (Nissan Motor Co., Ltd., Tokyo, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-334) Copyright

A new concept of vibration suppression of a flexible structure by a variable-stiffness structural element is presented. The stiffness of a structural element is varied by disengaging/engaging a piezoelectric clamping mechanism. The characteristic of this type of variable-stiffness system is shown to be different from the previously studied type of variable-stiffness system. Taking advantage of this characteristic, two kinds of control logic are proposed and investigated. Theoretical investigation on a single-degree-of-freedom system and numerical simulation of a multidegree-of-freedom system show the high capability of vibration suppression compared with the previous system. A variable-stiffness truss member is fabricated and demonstrates the reality of the concept. Author

A90-13465#
VIBRATION CONTROL OF MEMBRANE SPACE STRUCTURES THROUGH THE CHANGE OF SUPPORT TENSION
MICHIHIRO NATORI, KAZUO ICHIDA (Institute of Space and Astronautical Science, Sagamihara, Japan), KOHICHI MIURA (Nihon University, Funabashi, Japan), and FUMIHIRO KUWAO (Toshiba Corp., Komukai Works, Kawasaki, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. refs
(IAF PAPER 89-335) Copyright

A basic concept of vibration control for space structures with tension elements through the time variation of support tension is investigated. The concept is demonstrated through the analysis concerning an experiment of string and a numerical simulation of membrane. Two-dimensionality deployable array experiment onboard a space flyer unit including the evaluation of the concept is also introduced. Author

A90-13469*# Lockheed Engineering and Sciences Co., Houston, TX.
A CONTINUUM MODEL FOR DYNAMIC ANALYSIS OF THE SPACE STATION
SEGUN THOMAS (Lockheed Engineering and Sciences, Co., Houston, TX) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(Contract NAS9-17900)
(IAF PAPER 89-341) Copyright

Dynamic analysis of the International Space Station using MSC/NASTRAN had 1312 rod elements, 62 beam elements, 489 nodes and 1473 dynamic degrees of freedom. A realtime, man-in-the-loop simulation of such a model is impractical. This paper discusses the mathematical model for realtime dynamic simulation of the Space Station. Several key questions in structures and structural dynamics are addressed. First, to achieve a significant reduction in the number of dynamic degrees of freedom, a continuum equivalent representation of the Space Station truss structure which accounted for the unsymmetry of the basic configuration and resulted in the coupling of extensional and transverse deformation, is developed. Next, dynamic equations for the continuum equivalent of the Space Station truss structure are formulated using a matrix version of Kane's dynamical equations. Flexibility is accounted for by using a theory that accommodates extension, bending in two principal planes and shear displacement. Finally, constraint equations suitable for dynamic analysis of flexible bodies with closed loop configuration are developed and solution of the resulting system of equations is based on the zero eigenvalue theorem. Author

A90-13470#
A POSSIBLE ON ORBIT DYNAMIC IDENTIFICATION OF LARGE SPACE STRUCTURES BY PHOTOGRAMMETRIC TECHNIQUES
A. E. FINZI, P. MANTEGAZZA (Milano, Politecnico, Milan, Italy), and C. BOTTASSO IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-342) Copyright

An innovative photogrammetric method for measuring structural motions is presented. The method adopts a finite element model as an a priori structured interpolation. The method is shown to decrease drastically the variance of the unknown parameters and to permit a reconstruction of the deformed object closer to reality. C.D.

A90-13472#
STRUCTURAL DYNAMICS PROBLEMS OF LARGE SPACE SYSTEMS - EXPERIMENTAL ASPECTS
H. HUENERS (DLR, Institut fuer Aeroelastik, Goettingen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-344)

Dynamic verification of today's spacecraft focuses mainly on the qualification of structures with respect to the anticipated dynamic loads during launch. The large space systems of the future, which have been under discussion in recent years will, however, require an extension of this verification approach. Designed to deploy parts of their primary structures in space, they will feature a much higher degree of flexibility in their on-orbit configurations compared with the core structures of current spacecraft. This will, in many cases, make it mandatory to take relevant load events during and after deployment into account as well. Dynamic testing, if still required as a fundamental part of the verification process, will not only have to deal with the new test item configurations simulating the on-orbit conditions but also with more complex launch configurations. This is mainly a consequence of the obvious need to achieve an economic dense pack geometry of the structures during launch. Some promising test methods and strategies, aimed at solving the related problems, are discussed in this paper. Both system identification and dynamic qualification are addressed in an attempt to sketch a suitable verification process for the low frequency environment. Author

A90-13473#
LARGE SPACE STRUCTURES COMMERCIAL TESTBED OPERATIONS USING THE OUTPOST PLATFORM IN ORBIT
WILLIAM A. GOOD, THOMAS C. TAYLOR (Global Outpost, Inc., Alexandria, VA), and WENDEL R. WENDEL (Starnet Structures, Inc., West Babylon, NJ) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(IAF PAPER 89-345) Copyright

This paper proposes a simple and practical plan for testing for Large Scale Structure test bed for use in orbit. The concept uses the External Tank (ET) of the Space Shuttle as the platform for these tests. The platform concept is described, including the role of the ET, and future uses of the ET are addressed. C.D.

A90-13474#
MODELING AND ANALYSIS OF LARGE SPACE STRUCTURES
N. V. BANICHUK and A. V. SHARANIUK (AN SSSR, Institut Problem Mekhaniki, Moscow, USSR) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-346) Copyright

One of the primary modeling objectives for large space structures is to produce relatively simple and reliable structural models for use in design and analysis. Effective methods for reducing the order of the models and preserving sufficient precision are also necessary for describing the most essential characteristics of the structures. Here, a rational procedure is developed for predicting the modified structure (mass and stiffness matrices) which correlates most closely with a given set of measured modal frequencies. A sensitivity analysis method for effective calculation

of basic functional variations depending on mass and rigidity variations is developed. The method, based on the use of adjoint variables and adjoint systems of equations, permits the domains in the structure to be defined where the remodeling appears to be most effective. C.D.

A90-13485#
OPTIMIZATION OF THE SOLAR SPACE POWER STATION ATTITUDE CONTROL
V. V. BELETSKII and E. D. KOVALEVA (AN SSSR, Institut Prikladnoi Matematiki, Moscow, USSR) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-364)
The stabilization system of the Solar Space Power Station (SSPS) should be able to orient the solar panels toward the sun and the antenna toward the earth. Such a system may employ the stabilization effect of the solar radiation pressure and the earth's gravity field, respectively, with additional active stabilization by low-thrust engines. Here the problem of SSPS stabilization is formulated as an optimization problem, and a numerical solution method is proposed. V.L.

A90-13489#
MATHEMATICAL MODELLING OF THE MIR ORBITAL STATION ATTITUDE CONTROL BY MEANS OF GYRODINES
V. A. SARYCHEV, V. V. SAZONOV (AN SSSR, Institut Prikladnoi Matematiki, Moscow, USSR), M. IU. BELIAEV, S. G. ZYKOV, V. M. STAZHKOV (Nauchno-Proizvodstvennoe Ob'edinenie Energia, USSR) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-372) Copyright
The mathematical models that cover two main types of attitude control by gyrodines of the Mir orbital station are described. These controls involve maintaining the fixed orientation of the station in the inertial and orbital coordinate systems and the rotation of the station about its axis fixed in one of these coordinate systems. Examples of the use of the models are given. C.D.

A90-13491#
THE OPTIMAL LQG DIGITAL SHAPE AND ORIENTATION CONTROL OF AN ORBITING SHALLOW SPHERICAL SHELL SYSTEM
GUANGQIAN XING and PETER M. BAINUM (Howard University, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 13 p. refs
(Contract F33615-88-C-3208)
(IAF PAPER 89-375) Copyright
The analysis and design of the optimal LQG digial shape and orientation control of an orbiting shallow spherical shell system are presented. In this paper, the emphasis is placed on the mathematical models of the dynamics and observation, and the analysis and design of LQG optimal digital controllers and observers. The problem of determining the number and locations of the actuators is also studied by means of the concept of the degree of controllability and related simulations. The analysis and design of the optimal LQG digital control system for the shell has been certified by simulations. Typical figures showing the transient responses of LQG control are included here to show the influence of the different combinations of the controller and observer pole locations on the estimate and control process; also studied here are the influence of different numbers of actuators and for a fixed number of actuators, the effect of varying the actuator locations on the LQG control process. Author

A90-13493#
MANIPULATOR CONTROL ALGORITHM TO MINIMIZE THE EFFECT OF ARM MOVEMENT ON THE SPACECRAFT ATTITUDE AND TRANSLATIONAL MOTION
Y. OHKAMI, O. OKAMOTO, I. YAMAGUCHI, and T. KIDA (National Aerospace Laboratory, Chofu, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-377) Copyright
This paper presents a new algorithm for manipulator control to minimize the effect of the arm motion on the spacecraft attitude and translational motion. The method is based on the unified matrix approach, and also on the introduction of a 'virtual' hinge that restricts the spacecraft motion to a desired motion. This algorithm can be applied not only to digital simulation of the system in order to evaluate the controller performance or actuator gains but also to generation of the real time control law. Some numerical results are shown for illustration as applied to the spacecraft consisting of a main body and 4 arm manipulator. Author

A90-13494#
CONTROL OF A TIP MASS DEFLECTION OF A FLEXIBLE SPACE STRUCTURE
HIRONORI FUJII, SATOSHI UDOU, and TOKIZOU MOTOJIMA (Tokyo Metropolitan Institute of Technology, Hino, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-378) Copyright
A control method of reorientation for a mass at the tip of a flexible beam is studied experimentally. The control uses the mission function control algorithm of the Liapunov method. The model used in the experiment consists of a central body, flexible beam and a tip mass. The experimental model is set on a zero-gravity simulation table with a horizontal test surface. The table is used to simulate behavior in the space of two-dimensional motion of the flexible beam and the tip mass with little influence of the earth gravity on their behavior. Experimental results confirm that the algorithm may be applied for reorientation of a flexible space structure with any sensing device at the tip and for manipulation of flexible arms of space robots. Author

A90-13766
STATE OBSERVATION AND VARIABLE STRUCTURE CONTROL OF ROTATIONAL MANEUVERS OF A FLEXIBLE SPACECRAFT
ZHI-QIANG QU and WEI-BING GAO (Beijing University of Aeronautics and Astronautics, People's Republic of China) Acta Astronautica (ISSN 0094-5765), vol. 19, Aug. 1989, p. 657-667. Research supported by the Scientific Foundation of the Manufacturing of Aeronautics of China. refs
Copyright
In this paper, a state observation approach and a variable structure control strategy are presented for single-axis large-angle maneuvers of a flexible spacecraft. According to special structures of high-dimensional and nonlinear equations of the motion, a linear time-varying and partial-order state observer with exponentially decaying error is constructed so that the elastic modes of the spacecraft can be available at all instants of time using fewer sensors. Furthermore, a dynamic output feedback variable structure control using outputs of the system and states of the observer is applied to the flexible spacecraft. Some new properties of this simultaneously observed and controlled system are presented. Simulation results demonstrated for a control maneuver from one attitude to another effectively justify the solutions developed in this paper. Author

A90-14612#
ON MULTIVARIABLE MODEL REFERENCE ADAPTIVE CONTROL IN THE PRESENCE OF UNCERTAIN DISTURBANCES
PINGAN BAO and XINHAI CHEN (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, Oct. 1989, p. 424-434. In Chinese, with abstract in English. refs
The sigma modification scheme for SISO systems is extended to a class of multivariable system with uncertain disturbance. The overall adaptive control system is shown to be stable, and the tracking error is shown to tend to zero after the uncertain disturbance disappears. The effectiveness of the proposed scheme is demonstrated by a two-input, two-output example. C.D.

A90-14734*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
ACCURACY OF EIGENVALUE DERIVATIVES FROM REDUCED-ORDER STRUCTURAL MODELS
CHRIS A. SANDRIDGE and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B, p. 622-628) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 822-829. Previously cited in issue 14, p. 2173, Accession no. A87-33714. refs
(Contract NAG1-603)

A90-14735#
INFLUENCE OF GEOMETRIC NONLINEARITIES IN THE DYNAMICS OF FLEXIBLE TREELIKE STRUCTURES
S. K. IDER and F. M. L. AMIROUCHE (Illinois, University, Chicago) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 830-837. refs
Copyright

A comprehensive computer algorithm used in the dynamic analysis of multibody systems is presented. The procedures developed combine Kane's equations, the strain energy, and modal analysis to describe the elastic bodies. The equations of motion are expressed in a form in which their coefficients are based on the partial velocity and partial angular velocity arrays and are easily coded for computers. The nonlinear geometric stiffness matrix is developed for three-dimensional beams that account for the couplings between the deformation components having significant effects in high-speed systems. The method presented in this paper is tailored for structures with variable cross-sectional beam elements such as spacecraft antennae, helicopter rotor blades, robot systems, and mechanisms. The effects of rotary inertia as well as shear deformation are automatically included into the equations of motion. A method for obtaining the shape function matrix consisting of assumed dynamic modes is also presented. In addition, the preceding formulations are used in a simulation of a space-based robotic manipulator, and the results are compared with those obtained by Kane et al. Author

A90-14737#
REDUCED-ORDER MODELS OF A LARGE FLEXIBLE SPACECRAFT
KAZUO TSUCHIYA, TOSHIO KASHIWASE, and KATSUHIKO YAMADA (Mitsubishi Electric Corp., Amagasaki, Japan) (IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987, IAF Paper 87-356) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 845-850. Previously cited in issue 04, p. 464, Accession no. A88-16046. refs
Copyright

A90-14738#
AN INVESTIGATION OF THE TIME REQUIRED FOR CONTROL OF STRUCTURES
JEFFREY K. BENNIGHOF and ROBERT L. BOUCHER (Texas, University, Austin) (Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987, p. 391-406) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 851-857. Previously cited in issue 02, p. 203, Accession no. A89-11676. refs
Copyright

A90-14739#
MISSION-FUNCTION CONTROL FOR SLEW MANEUVER OF A FLEXIBLE SPACE STRUCTURE
HIRONORI FUJI and SHINTARO ISHIJIMA (Tokyo Metropolitan Institute of Technology, Japan) (IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987, IAF Paper 87-354) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 858-865. Previously cited in issue 04, p. 464, Accession no. A88-16044. refs
Copyright

A90-14741#
APPLICATION OF ACTUATORS TO CONTROL BEAM FLEXURE IN A LARGE SPACE STRUCTURE
SHALOM FISHER (U.S. Navy, Naval Research Laboratory, Washington, DC) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 874-879. refs

This paper describes a flexible-body control methodology for performing a nonlinear slew of a large space structure and simultaneously regulating the associated flexural vibrations by linear methods. Degree of controllability methods are used as guidelines for the positioning of proof-mass actuators on the structure. The goal is to determine the importance of location of the actuators on regulator performance, and the utility of the degree of controllability methods. A numerical simulation is made of a 20 deg slew maneuver of the spacecraft laboratory experiment (SCOLE). The SCOLE model treated here is the spacecraft version. It includes three bodies: the Space Shuttle, a reflector antenna, and a flexible beam of length 39.62 m connecting them. In the simulation, the beam vibration is fully coupled to the dynamics of the slewing motion. Regulation of the beam vibration is addressed by means of proof-mass actuators on the beam, and by Vernier thrusters on the Shuttle and antenna bodies. Repeated simulations are made with different actuator placements. The results show that with the actuators placed within a region of strong control effectiveness, damping and flexural amplitude are changed only slightly by changes in actuator location. However, the damping is significantly reduced for actuator location in regions of low-control effectiveness, although the amplitude of the vibrations changes only slightly. Author

A90-14750#
CONTROL OF DISTRIBUTED STRUCTURES WITH SMALL NONPROPORTIONAL DAMPING
L. MEIROVITCH and M. A. NORRIS (Virginia Polytechnic Institute and State University, Blacksburg) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 930-932. Previously cited in issue 22, p. 3637, Accession no. A87-50414.
(Contract F33615-86-C-3233)
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A90-15159
ASYMPTOTIC BEHAVIOUR AND BOUNDEDNESS OF LINEAR SYSTEMS WITH TIME VARYING COEFFICIENTS
S. PRADEEP and S. K. SHRIVASTAVA (Indian Institute of Science, Bangalore, India) Acta Astronautica (ISSN 0094-5765), vol. 19, Oct. 1989, p. 787-795.
Copyright

An analysis is conducted of the asymptotic behavior and boundedness of the solution for a unique class of time-varying systems in which each term appears as the sum of a constant and a time-varying element, with a view to spacecraft dynamics applications. Four theorems are developed which explore the relationships between the asymptotic behavior/boundedness of the constant coefficient system (obtained by equating the time-varying terms to zero) to the corresponding behavior of the time-varying system. The results obtained show the behavior of the two systems to be intimately related. Attention is given to two illustrative problems. O.C.

A90-15249
ACTIVE VIBRATION CONTROL USING WAVE CONTROL CONCEPTS
JIAWEI LU, M. J. CROCKER, and P. K. RAJU (Auburn University, AL) Journal of Sound and Vibration (ISSN 0022-460X), vol. 134, Oct. 22, 1989, p. 364-368. Research supported by Auburn University and SDIO. refs
(Contract DNA001-85-C-0183)
Copyright

A control model for a string of finite length is discussed in regard to the wave absorption mechanism of vibration damping. The suppresion of the resonance of a vibrating system by a wave-absorbing termination is emphasized, and the results for the total vibrational energy (kinetic energy plus strain energy) of a string with and without suppressing the resonance are compared. The study is relevant to the active vibration control of future large flexible space structures. S.A.V.

A90-16178
STATIC AND DYNAMIC ANALYSIS OF SPACE FRAMES WITH NON-LINEAR FLEXIBLE CONNECTIONS
G. SHI and S. N. ATLURI (Georgia Institute of Technology, Atlanta) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 28, Nov. 1989, p. 2635-2650. Research supported by USAF. refs
Copyright

This paper deals with the effect of nonlinearly flexible hysteretic joints on the static and dynamic response of space frames. It is shown that a complementary energy approach based on a weak form of the compatibility condition as a whole of a frame member, and of the joint equilibrium conditions for the frame, is best suited for the analysis of flexibly jointed frames. The present methodology represents an extension of earlier work on rigidly connected frames. In the present case also, an explicit expression for the tangent stiffness matrix is given when (1) each frame member, along with the flexible connection at its ends, is represented by a single finite element, (2) each member can undergo arbitrarily large rigid rotations and only moderate relative rotations and (3) the nonlinear bending-stretching coupling is accounted for in each member. Several examples, with both quasi-static and dynamic loading, are included, to illustrate the accuracy and efficiency of the developed methodology. Author

A90-16516
DYNAMICS OF CONTROLLED MECHANICAL SYSTEMS; PROCEEDINGS OF THE IUTAM/IFAC SYMPOSIUM, EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH, ZURICH, SWITZERLAND, MAY 30-JUNE 3, 1988
G. SCHWEITZER, ED. and M. MANSOUR, ED. (Zuerich, Eidgenoessische Technische Hochschule, Zurich, Switzerland) Symposium sponsored by IUTAM, IFAC, U.S. Army, et al. Berlin and New York, Springer-Verlag, 1989, 392 p. For individual items see A90-16517 to A90-16525.
Copyright

Theoretical and applications aspects of control systems are discussed in reviews and reports. Sections are devoted to modeling, design tools, graphical tools, the dynamics of controlled mechanical systems, sensors and actuators, aerospace applications, robotics, and vehicles. Particular attention is given to model verification using finite-effect sequences, hardware-software interfaces for dynamical simulations, graphical verification of complex multibody motion in space applications, a magnetic-bearing control system for compensating unbalance force, the orientation of large orbital stations, modeling and control of an elastic robot arm with a prismatic joint, a decomposed-parameter identification approach for robot dynamics, and Japanese research on biped robots. T.K.

A90-16517
STATE EQUATIONS OF MOTION FOR FLEXIBLE BODIES IN TERMS OF QUASI-COORDINATES
LEONARD MEIROVITCH (Virginia Polytechnic Institute and State University, Blacksburg) IN: Dynamics of controlled mechanical systems; Proceedings of the IUTAM/IFAC Symposium, Zurich, Switzerland, May 30-June 3, 1988. Berlin and New York, Springer-Verlag, 1989, p. 37-48. refs
(Contract F49620-88-C-0044)
Copyright

Generalized equations of motion for flexible bodies in space are considered analytically. Starting from the extended Hamilton principle for distributed systems (Meirovitch, 1980), hybrid Lagrange equations of motion are obtained in general quasi-coordinates and then expressed in terms of quasi-coordinates representing rigid-body motions, greatly facilitating the analysis. As an example the hybrid equations for a spacecraft comprising a rigid hub and a flexible appendage (such as an antenna) are derived. T.K.

A90-16520
PLACING DYNAMIC SENSORS AND ACTUATORS ON FLEXIBLE SPACE STRUCTURES
GREGORY A. NORRIS and ROBERT E. SKELTON (Purdue University, West Lafayette, IN) IN: Dynamics of controlled mechanical systems; Proceedings of the IUTAM/IFAC Symposium, Zurich, Switzerland, May 30-June 3, 1988. Berlin and New York, Springer-Verlag, 1989, p. 149-160. refs
Copyright

A technique for selecting the type, number, and location of sensors and actuators on large flexible space structures is developed analytically, with a focus on the treatment of dynamic sensors and actuators (i.e., devices with responses governed by dynamics). In this approach, an augmented system model is derived; its controllability and observability are analyzed; and the effectiveness of each dynamic actuator or sensor in minimizing the cost function is estimated. The application of this method to the NASA Spacecraft Control Laboratory Experiment (Taylor and Balakrishnan, 1984) is discussed, and it is shown that even uniform actuator dynamics can affect the optimal selection. T.K.

A90-16837#
GENERAL DYNAMIC MODELS OF FLEXIBLE MULTIBODY SYSTEM
LIANG JIN (Beijing Institute of Control Engineering, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 10, Sept. 1989, p. A 501-A 506. In Chinese, with abstract in English.

This paper presents the general dynamic equations of flexible multibody space system. The system topology is restricted to a tree configuration which is defined as an arbitrary set of flexible and rigid bodies connected by hinges characterizing relative translations and rotations of two adjoining bodies. The equations of motion are derived via Lagrange and Newton-Euler method. Author

A90-16955
INTERNATIONAL MODAL ANALYSIS CONFERENCE, 7TH, LAS VEGAS, NV, JAN. 30-FEB. 2, 1989, PROCEEDINGS. VOLUMES 1 & 2
Conference sponsored by the Union College and SEM. Bethel, CT, Society for Experimental Mechanics, Inc., 1989. Vol. 1, 747 p.; vol. 2, 931 p. For individual items see A90-16956 to A90-17043
Copyright

Papers are presented on experimental case histories, analytical methods, structural dynamics modification, the linking of structural analysis and testing, modal data processing, modal test methods, modal techniques for rotating machinery, structural modeling, finite element analysis, noise/acoustic modes, matrix methods for modal analysis, system identification, substructuring, instrumentation, and transducers. Additional papers are presented on space structures, the dynamics of structural joints, modal models for moving vehicles, nonintrusive transducers, machinery diagnostics, nonlinear structures, seismic considerations, and structural damping. S.A.V.

A90-16971
FOUNDATION AND APPLICATION OF THE SPECTRAL CONDENSATION TECHNIQUE FOR DYNAMIC ANALYSIS OF LARGE STRUCTURES
N. B. ROOZEN, R. F. C. KRIENS (Fokker Aircraft, Schiphol, Netherlands), A. DE KRAKER, and D. H. VAN CAMPEN (Eindhoven, Technische Universiteit, Netherlands) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 1. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 233-242. refs
Copyright

Spectral condensation is a method developed by Arduini which reduces the number of dynamic equations, resulting from a finite element code, to a smaller size. The reduced system represents the original system as well as possible in a user-defined frequency range with lower bound not necessarily zero. A number of extensions to the basic technique are developed here: (1) generalization of the technique to systems with consistent mass formulation; (2) recovery of the eliminated degrees of freedom enabling the calculation of complete eigenvectors and vibration responses; (3) improved approximation procedure yielding higher computational accuracy and speed; and (4) exchange of the selection criterion proposed by Arduini by the regular frequency criterion, again resulting in improved accuracy and speed.
Author

A90-16981* Engineering Mechanics Association, Inc., Torrance, CA.
EVALUATION OF PREDICTIVE ACCURACY IN STRUCTURAL DYNAMIC MODELS
T. K. HASSELMAN and JON D. CHROSTOWSKI (Engineering Mechanics Associates, Inc., Torrance, CA) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 1. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 360-366.
(Contract NAS7-1020)
Copyright
The evaluation of the predictive accuracy of dynamic models for future large space structures is addressed. Mass and stiffness uncertainties derived from a comparison of analytical and experimental modes are used to evaluate the uncertainty of response predictions based on the analytical model. S.A.V.

A90-17001* SDRC, Inc., San Diego, CA.
MODAL SELECTION IN STRUCTURAL DYNAMICS
PAUL A. BLELLOCH (SDRC, Inc., San Diego, CA) and KELLY S. CARNEY (NASA, Lewis Research Center, Cleveland, OH) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 742-749. refs
Copyright
An overview of two modal selection procedures for lightly damped structural dynamic models is presented. Both procedures order the modes in terms of their contribution to the input/output dynamics of the model. A complex model of the Phase I Space Station is used to illustrate the application of these procedures to a realistic structure. Author

A90-17002
EXPERIMENTAL MODAL SURVEYS ON THE ALUMINUM BEAM EXPANDER STRUCTURE (ABES)
DAVID FOUNDS and PHILIP REAMY (USAF, Weapons Laboratory, Kirtland AFB, NM) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 750-756.
Copyright
Results of experimental modal surveys on an optical truss model are presented. The model is a 6-meter telescope with a first mode at 7.1 Hz. Over 200 hours of data have been collected on this truss over a 1-year period. A comparison of results obtained using several excitation methods is presented. The low degree of damping, less than 0.1 percent, limits the utility of some methods of excitation and degrades the performance of some curve fitters.
Author

A90-17005* Lowell Univ., MA.
IDENTIFICATION OF LOCAL MODES USING MODAL MASS DISTRIBUTIONS
CHAUR-MING CHOU (Lowell, University, MA) and RICHARD S. PAPPA (NASA, Langley Research Center, Hampton, VA) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 772-776. refs
Copyright
An approach for local modal identification using a modal mass spatial distribution matrix is proposed. This modal mass matrix is obtained by overlay multiplying the modal matrix to the product of the mass and the modal matrices of the structure. Each column in the spatial modal mass matrix can be interpreted as a measure of the kinetic energy distribution over the physical degrees of freedom for the corresponding mode. Local modes are identified due to the highly concentrated kinetic energy distribution in the localized regions. This spatial modal mass approach is more sensitive than the modal amplitude ratio method, since kinetic energy is in the quadratic form of modal amplitudes. Numerical examples involving identification of local modes using the proposed modal mass spatial distribution matrix approach are presented and discussed. C.E.

A90-17008
ANALYSIS OF FLEXIBLE STRUCTURES WITH NONLINEAR JOINTS
ALDO A. FERRI (Georgia Institute of Technology, Atlanta) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 836-842. Research supported by Honeywell, Inc. refs
(Contract NSF MSM-87-07846)
Copyright
A simplified model of a flexible space structure consisting of three visco-elastic beams and two nonlinear sleeve joints is investigated. Numerical results showing the relationship between system dynamic behavior and various joint properties are presented. It is found that system damping appears to be directly dependent on amplitude. It is also found that even a small amount of play in the sleeve joints causes nonlinear, hardening spring behavior to become evident in free and forced response. Author

A90-17012
EXPERIMENTAL STUDY OF ACTIVE VIBRATION CONTROL OF FLEXIBLE STRUCTURES SUBJECT TO FORCED VIBRATION
Q. ZHANG, S. SHELLEY, X. N. LUO, R. J. ALLEMANG, D. L. BROWN (Cincinnati, University, OH) et al. IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 926-933. refs
Copyright
This paper focuses on active vibration control of flexible structures which are undergoing forced vibration. The test structure is a cantilever steel beam subject to a sinusoidal excitation and the control objective is to reduce the vibrational motion of the free end of the beam. This simple test model is representative of problems such as vibration control of flexible robot arms and space structures pointing control. The eigenspace assignment used for the controller design is described in this paper. The controller is implemented in a digital computer. The practical problems encountered in the controller implementation, such as effective control loop delay, actuator dynamics, stability of uncontrolled higher frequency modes and location of actuators are discussed in detail. Author

A90-17016
EXPERIENCE WITH IDENTIFICATION OF MOMENTUM COEFFICIENTS AND MODAL IDENTITY PARAMETERS
Y. SOUCY, R. K. SINGAL, and F. R. VIGNERON (CDC, Communications Research Centre, Ottawa, Canada) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 1028-1036. refs
Copyright
This paper presents experience gained with recently-developed procedures for the identification of modal momentum coefficients and modal identity parameters from laboratory test data. The procedures are based on the processing of driven-base and

portable exciter modal test data. The results for two structures of different complexity are presented. The first structure consists of a simple cantilever steel beam, for which the results from three independent sets of data are compared with each other and with corresponding theoretical results. The results demonstrate that the procedures successfully identify the modal parameters. The second structure, called FLECS, is similar to a typical spacecraft in terms of mass properties and modal density. The FLECS results confirm that the identification procedures can be applied to complex structures although attention has to be given to many details of the tests in order to obtain good estimates of these parameters. Author

A90-17023
A MODAL PARAMETER IDENTIFICATION TECHNIQUE AND ITS APPLICATION TO LARGE COMPLEX STRUCTURES WITH MULTIPLE STEADY SINUSOIDAL EXCITATION
JIE-SHENG JIANG, YAN-JU WANG (Northwestern Polytechnical University, Xian, People's Republic of China), QI-HANG YAO, and SONG-NIAN GU (Ministry of Aerospace Industry, Strength Research Institute, Xian, People's Republic of China) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 1167-1173.
Copyright

A modal parameter identification technique with multiple steady sinusoidal excitation is proposed whereby the force amplitudes are proportional to each other and the phases are either coincident or opposite. The frequency response function is not suitable to be used in this case. Therefore, the Laplace transform of the response is taken as the object of curve fitting directly, according to the principle of superposition for linear system. Some advanced measures for improving accuracy of the identified parameters are adopted. The application of this techique to some aircraft to replace the traditional ground vibration testing approach shows an accuracy almost as good as that of the phase resonance method, with the test period cut down as a result of omitting the force adjustment, frequency tuning, and multiple input/output FFT process. Author

A90-17043
ACOUSTIC RESPONSE ANALYSIS OF LARGE SPACE STRUCTURES
F. MERCIER, D. GANGLOFF, and A. MAMODE (CNES, Toulouse, France) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 1611-1615. refs
Copyright

A formulation is presented for predicting acoustic response and loads when large space structures are subjected to a reverberant field in an acoustic chamber. The formulation is based on modal superposition which predicts loads as random accelerations or energy power spectral density. The derived formulation can be employed for a better understanding of particular events during sine tests. The method is applied to predict loads experienced by a two-meter diameter antenna reflector and a 1.5 m x 2 m solar panel. A correlation of analysis and test results is presented. S.A.V.

A90-17699#
SOFT-CONSTRAINED TIME-OPTIMAL MANEUVERING OF FLEXIBLE SPACECRAFT
JOSEPH Z. BEN-ASHER, EUGENE M. CLIFF, and JOHN A. BURNS (Virginia Polytechnic Institute and State University, Blacksburg) IN: Israel Annual Conference on Aviation and Astronautics, 30th, Tel Aviv and Haifa, Israel, Feb. 15, 16, 1989, Collection of Papers. Haifa, Technion - Israel Institute of Technology, 1989, p. 218-225. refs
(Contract AF-AFOSR-85-0287)

The optimal maneuvering problem of flexible spacecraft is considered. The cost is a weighted combination of the terminal time and a measure of the control effort. The system is discretized by the assumed-modes method and then transformed to modal space. Optimal solutions are obtained by the maximum principle. A singular perturbation approach is introduced whereby the system is partitioned into a reduced subsystem with 'slow' response, and a residual subsystem with 'fast' response. Author

A90-18127* Catholic Univ. of America, Washington, DC.
ACTIVE CONTROL OF BUCKLING OF FLEXIBLE BEAMS
A. BAZ and L. TAMPE (Catholic University of America, Washington, DC) IN: Failure prevention and reliability - 1989; Proceedings of the Eighth ASME Biennial Conference, Montreal, Canada, Sept. 17-21, 1989. New York, American Society of Mechanical Engineers, 1989, p. 211-218. refs
(Contract NAG5-520; NAG5-749)
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Mathematical models are presented that simulate the dynamic characteristics of shape memory alloy actuators made of nickel-titanium alloy (Nitinol) controlling the buckling of compressive structural members. A closed-loop computer-controlled system has been designed, based on the proposed mathematical models, and has been implemented to control the buckling of simple beams. The performance of the computer-controlled system is evaluated experimentally and compared with the theoretical predictions to validate the developed models. The results emphasized the importance of buckling control and suggest the potential of shape memory alloy actuators as attractive means for controlling structural deformation in a simple and reliable way. C.E.

A90-18155*# Texas A&M Univ., College Station.
NONDESTRUCTIVE CONSTRUCTION ERROR DETECTION IN LARGE SPACE STRUCTURES
NORRIS STUBBS (Texas A & M University, College Station), TAFT H. BROOME (Howard University, Washington, DC), and ROBERTO OSEGUEDA (Texas, University, El Paso) AIAA Journal (ISSN 0001-1452), vol. 28, Jan. 1990, p. 146-152. Research supported by Texas A & M University. Previously cited in issue 12, p. 1892, Accession no. A88-31383. refs
(Contract NAG1-383)
Copyright

A90-19557*# Howard Univ., Washington, DC.
NUMERICAL APPROACH FOR SOLVING RIGID SPACECRAFT MINIMUM TIME ATTITUDE MANEUVERS
FEIYUE LI and PETER M. BAINUM (Howard University, Washington, DC) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 38-45. Previously cited in issue 07, p. 966, Accession no. A88-22505. refs
(Contract NSG-1414)
Copyright

A90-19558#
REDUCED-ORDER COMPENSATOR DESIGN FOR A FLEXIBLE STRUCTURE
PH. C. OPDENACKER, E. A. JONCKHEERE, M. G. SAFONOV, J. C. JUANG (Southern California, University, Los Angeles, CA), and M. S. LUKICH (TRW, Inc., Redondo Beach, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 46-56. refs
(Contract F49620-88-C-0067; AF-AFOSR-85-0256)
Copyright

A low-order controller is designed for an experimental truss structure. The objective is to achieve good disturbance attenuation, while at the same time preserving good stability margin and other robustness properties. The method used is linear quadratic Gaussian (LQG) with frequency dependent weights and colored noises for shaping singular-value Bode plots. Controller reduction is accomplished through the open-loop balancing scheme applied to the full-order compensator. A typical design result shows that it is possible to obtain a very low-order design that meets the preceding specification. Author

A90-19559#
NEAR-MINIMUM TIME, CLOSED-LOOP SLEWING OF FLEXIBLE SPACECRAFT

S. R. VADALI, J. L. JUNKINS (Texas A & M University, College Station), and R. M. BYERS Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 57-65. Research supported by the Martin Marietta Corp. refs
(Contract F49620-86-K-0014)
Copyright

The near-minimum time single-axis slewing of a flexible spacecraft with simultaneous suppression of vibration of elastic modes is considered. The hyperbolic tangent (tanh) function is used as a smooth approximation to the discontinuous sgn function occurring in the rigid body 'bang-bang' control. Variable structure control concepts are used to identify the necessary characteristics of the control switching line. Simulations of the rest-to-rest and tracking maneuvers indicate that the elastic energy can be reduced by several orders of magnitude with only a modest increase in the maneuver time. Author

A90-19560*# *Structural Dynamics Research Corp., San Diego, CA.*
ROBUST LINEAR QUADRATIC GAUSSIAN CONTROL FOR FLEXIBLE STRUCTURES
P. A. BLELLOCH (Structural Dynamics Research Corp., San Diego, CA) and D. L. MINGORI (California, University, Los Angeles) (Guidance, Navigation and Control Conference, Williamsburg, VA, Aug. 18-20, 1986, Technical Papers, p. 314-318) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 66-72. Previously cited in issue 23, p. 3487, Accession no. A86-47434. refs
(Contract NAS7-918)
Copyright

A90-19561*# North Carolina State Univ., Raleigh.
INTERACTIONS BETWEEN RIGID-BODY AND FLEXIBLE-BODY MOTIONS IN MANEUVERING SPACECRAFT
LARRY M. SILVERBERG and SUNGTAE PARK (North Carolina State University, Raleigh) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 73-81. refs
(Contract NCC1-103)
Copyright

The present consideration of the significant interactions between rigid-body and flexible-body motions in maneuvering spacecraft proceeds by distinguishing between the two types of motion on the basis of a tracking coordinate system which coincides with the rigid-body component of the motion, as well as by maintaining the motion relative to the tracking coordinate as orthogonal to the rigid-body motion. The elastic motion is excited by the rigid-body motion via Coriolis terms, angular acceleration terms, and centrifugal terms. These interactions are illustrated for spacecraft undergoing bidirectional elastic motions via the dynamics of constantly rotating free-free beams subject to combined bending and longitudinal vibration. O.C.

A90-19562*# Florida Univ., Gainesville.
ON THE NATURE OF THE INTERACTION BETWEEN STRUCTURES AND PROOF-MASS ACTUATORS
DAVID C. ZIMMERMAN (Florida, University, Gainesville) and DANIEL J. INMAN (Brown University, Providence, RI) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 82-88. refs
(Contract NGT-33-183-801; NAG1-985; AF-AFOSR-85-0220; AF-AFOSR-85-0119; NSF NSM-83-51807; F49620-86-C-0111)
Copyright

This paper presents an analysis of the interaction between a structure, an actuator used to control the vibration of the structure, and the control law to be implemented by the actuator. The control hardware used is a proof-mass actuator with experimentally verified dynamics capable of being used in a space structure configuration. A local rate-feedback control law is used. The control of two different structures is presented. The first structure is a cantilevered beam constructed of a quasi-isotropic composite material that is controlled by a single actuator forming the experimental component of the investigation. The second structure is a finite-element model of a truss system controlled by a single actuator. Models of both structures predict the presence of potential instabilities in system performance if proper consideration is not given to interactions between the control law, the structure, and the actuator. Author

A90-19563#
SPACECRAFT MOMENTUM UNLOADING - THE CELL MAPPING APPROACH
H. FLASHNER (Southern California, University, Los Angeles, CA) and T. F. BURNS (TRW, Inc., Redondo Beach, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 89-98. Previously cited in issue 21, p. 3509, Accession no. A88-50232. refs
Copyright

A90-19564*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
SPACECRAFT MASS PROPERTY IDENTIFICATION WITH TORQUE-GENERATING CONTROL
E. BERGMANN (Charles Stark Draper Laboratory, Inc., Cambridge, MA) and J. DZIELSKI (Pennsylvania State University, University Park) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 99-103. refs
(Contract NAS9-17560)
Copyright

Previous studies indicated that an applied force was necessary to perform in-flight identification of the mass and center of mass of a spacecraft. This paper shows that the mass and center of mass of a rigid spacecraft can be determined using only torque-producing actuators such as control-moment gyros or reaction wheels, and commonly available sensors, e.g., rate gyros and accelerometers. A space-station application is presented. Author

A90-19572*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF OUTPUT FEEDBACK VS LINEAR QUADRATIC REGULATOR
ZORAN N. MARTINOVIC, GEORGE C. SCHAMEL, II, RAPHAEL T. HAFTKA, and WILLIAM L. HALLAUER, JR. (Virginia Polytechnic Institute and State University, Blacksburg) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 160-167. Previously cited in issue 22, p. 3550, Accession no. A87-50474. refs
(Contract NAG1-224)

A90-19972*# California Univ., Los Angeles.
MICRODYNAMIC MODELLING OF JOINT-DOMINATED TRUSS-BASED STRUCTURES
P. K. C. WANG (California, University, Los Angeles) and F. Y. HADAEGH (JPL, Pasadena, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p. refs
(Contract NSF ECS-87-18473)
(AIAA PAPER 90-0661) Copyright

A methodology for the mathematical modeling of preloaded joint-dominated truss-based space structures applicable in the microdynamic regime is presented. First, various factors which could affect the microdynamic behavior of joint-dominated truss structures are examined. Then, mathematical models for various types of joints involving contact deformations are derived from Hertzian contact theory. Their dynamic behavior is studied analytically and numerically by means of computer simulation. It was found that both synchronous and asynchronous oscillations having the same orders of magnitude are excited by sinusoidal load perturbations in the microdynamic regime. These oscillations persist even in the presence of light linear damping. The integration of the derived joint models with those for the elastic links of preloaded planar truss structures is discussed. Author

A90-19973*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
REDUCED ORDER COMPONENT MODELS FOR FLEXIBLE MULTIBODY DYNAMICS SIMULATIONS
WALTER S. TSUHA and JOHN T. SPANOS (JPL, Pasadena, CA)

AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. refs
(AIAA PAPER 90-0662) Copyright

Many flexible multibody dynamics simulation codes require some form of component description that properly characterizes the dynamic behavior of the system. A model reduction procedure for producing low order component models for flexible multibody simulation is described. Referred to as projection and assembly, the method is a Rayleigh-Ritz approach that uses partitions of the system modal matrix as component Ritz transformation matrices. It is shown that the projection and assembly method yields a reduced system model that preserves a specified set of the full order system modes. Unlike classical component mode synthesis methods, the exactness of the method described is obtained at the expense of having to compute the full order system modes. The paper provides a comprehensive description of the method, a proof of exactness, and numerical results demonstrating the method's effectiveness. C.E.

A90-19974#
NEAR-MINIMUM-TIME MANEUVERS OF FLEXIBLE VEHICLES - A LIAPUNOV CONTROL LAW DESIGN METHOD

J. L. JUNKINS, Z. H. RAHMAN, and H. BANG (Texas A & M University, College Station) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 17 p. Research supported by the Texas Advanced Technology Program. refs
(Contract F49620-87-C-0078)
(AIAA PAPER 90-0663) Copyright

A method for designing globally stable feedback control laws for maneuvers of flexible dynamical systems is presented. Both analytical and experimental results are discussed. The approach readily accommodates known nonlinearities and applies to systems described by hybrid coupled sets of ordinary and partial differential equations. A proof of Lyapunov stability is given which does not rely upon spatially discretizing distributed parameter systems. Feedforward/feedback tracking-type control laws are developed to null the departure of the system state from an a priori determined smooth target trajectory. The target trajectory may be an exact or an approximate solution of the system equations of motion. This approach can be used to generate, for example, near-minimum-time feedback controllers which accommodates general 'torque'shaping' to achieve a judicious compromise between near-minimum-time and competing performance indices such as levels of sensitivity to model errors, disturbances, and control implementation errors. The analytical and experimental results jointly provide strong analytical justification and conclusive experimental evidence of the practical merit of this approach to design of controllers for distributed parameter systems. Author

A90-20001#
A GENERIC MULTIBODY DYNAMICS, CONTROLS SIMULATION TOOL FOR SPACE STATION - SSSIM REV. 1.1

K. W. LONDON (Honeywell, Inc., Clearwater, FL), R. P. SINGH, and B. SCHUBELE (Dynacs Engineering Co., Inc., Clearwater, FL) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 7 p.
(AIAA PAPER 90-0745) Copyright

Space Station Freedom progresses through a series of uniquely differing configurations during its buildup phase and ultimately will be a very large and complex orbiting assembly. This paper describes a very general, yet not overly generic, tool for dynamic simulation and controls design of the Space Station. An order n solution algorithm is used to keep computer run time to a minimum. In addition to modeling the main Space Station components, the software is able to model multibodied subsystems such as the Mobile Servicing System (MSS) undergoing prescribed relative rotations or translations. Simulated Station response is demonstrated during a 6-step MSS activity that includes plane change and ends with release of the payload. The baseline HI CMG controller is able to manage this particular scenario without a change in gains. Author

A90-20005#
DYNAMICS AND CONTROL OF AN ORBITING FLEXIBLE MOBILE MANIPULATOR

J. K. CHAN and V. J. MODI (British Columbia, University, Vancouver, Canada) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p.
(Contract NSERC-5-80029)
(AIAA PAPER 90-0749) Copyright

This paper presents a Lagrangian formulation for studying the dynamics and control of the proposed Space Station based Mobile Servicing System (MSS) for a particular case of inplane libration and maneuvers. The simplified case is purposely considered to help focus on the effects of structural and joint flexibility parameters of the MSS on the complex interactions between the station and manipulator dynamics during slewing and translational maneuvers. The response results suggest that under critical combinations of parameters, the system can become unstable. During maneuvers, the deflection of the MSS can become excessive, leading to positioning error of the payload. At the same time the libration error can also be significant. A linear quadratic regulator is designed to control the deflection of the manipulator and maintain the station at its operating configuration. Author

A90-20006#
TRANSIENT DYNAMICS OF THE PROPOSED SPACE STATION DURING INTEGRATION - A GENERAL FORMULATION AND RESPONSE ANALYSIS

V. J. MODI, A. C. NG, and A. SULEMAN (British Columbia, University, Vancouver, Canada) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs
(Contract NSERC-STR-32682)
(AIAA PAPER 90-0750) Copyright

A relatively general formulation for studying the dynamics of spacecraft with interconnected flexible bodies is developed accounting for solar radiation induced flexural deformations. Versatility of the formulation is illustrated through simulation of the dynamics of two evolving Space Station configurations. The results suggest nominal equilibrium orientations of the configurations to be inherently unstable in librations. Of some interest is the beat response of the power boom and stinger. The information is fundamental to the design of damping devices, control system and desired locations for the payloads. Author

A90-20008#
ROBUST CONTROL OF A FLEXIBLE SPACE STRUCTURE IN THE PRESENCE OF PARAMETER VARIATIONS AND UNMODELED DYNAMICS

SHARON A. HEISE, SIVA S. BANDA, and HSI-HAN YEH (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs
(AIAA PAPER 90-0752)

The control of a flexible truss structure is discussed with respect to robustness against parameter uncertainty and unmodeled HF dynamics. Emphasis is placed on providing vibration suppression and improving system damping in the presence of these uncertainties. A robust control design is achieved by simultaneously optimizing both the LQG performance index and the H(infinity) norm of a specific disturbance transfer matrix. Closed-loop simulation is performed to determine the effectiveness of the control design, and possible directions for future research are discussed. Author

A90-21146#
OPTIMAL, COUPLED-MODAL CONTROL OF DISTRIBUTED PARAMETER SYSTEMS WITH DISCRETE ACTUATORS

IRADJ G. TADJBAKHSH and YUAN-AN SU (Rensselaer Polytechnic Institute, Troy, NY) ASME, Transactions, Journal of Applied Mechanics (ISSN 0021-8936), vol. 56, Dec. 1989, p. 941-946. Research supported by the U.S. Army and State University of New York. refs
Copyright

Optimal control of flexible continuous structures subjected to

arbitrary time-varying distributed loads is considered. The control is to be implemented by discrete sets of sensors and actuators that monitor the response and apply the necessary forces. The dynamics of the uncontrolled structure is assumed to be governed by a linear, self-adjoint partial differential equation. The control forces at any time are determined on the basis of minimization of the total energy of the system at that time. This leads to a causal optimal algorithm whereby control forces are determined solely on the basis of information available up to the time at which control is being implemented. The effectiveness of the algorithm is demonstrated by applying it to a beam subjected to an impulse. Author

A90-21400
DYNAMIC ANALYSIS OF LARGE SPACE STRUCTURES USING TRANSFER MATRICES AND JOINT COUPLING MATRICES
RAYMOND J. NAGEM (Boston University, MA) and JAMES H. WILLIAMS, JR. (MIT, Cambridge, MA) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 17, Sept. 1989, p. 349-371. Research supported by USAF. refs
Copyright

Linear dynamic analysis of lattice structures using transfer matrices and joint coupling matrices is presented. A lattice structure is defined as a network of one-dimensional members that are connected by joints. Two examples are considered to illustrate how transfer matrices and joint coupling matrices may be used to compute natural frequencies of vibration. These two examples indicate that the tranfer matrix and joint coupling matrix analysis is numerically accurate over a wide range of frequencies and becomes increasingly efficient, compared to the finite element method, as the frequency increases. Some suggestions for further improvements in computational efficiency and some comments about applicability to numerical analysis of wave propagation problems are given. Author

A90-21528
CONCEPT DESIGN AND PERFORMANCE TEST OF A MAGNETICALLY SUSPENDED SINGLE-GIMBAL CONTROL MOMENT GYRO
KATSUMI KITO (Mitsubishi Heavy Industries, Ltd., Space Systems Engineering Dept., Nagoya, Japan), HIROSHI KANKI, and SHINYA ISHII (Mitsubishi Heavy Industries, Ltd., Takasago Research and Development Center, Japan) IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989, p. 25-30.
(AAS PAPER 89-002) Copyright

Space vehicles are growing large in size and weight and attitude control systems require higher torque and momentum capability. As a primary attitude actuator for future platform type space vehicles, concept design model of a single-gimbal control moment gyro was built and tested. Based on the consideration of potential requirements for long life, low energy consumption, and vibration reduction, this concept design model adopts electromagnetic bearings which suspend two wheels. This single-gimbal control moment gyro has nominal angular momentum capacity of 100 Nms. The concept design model was tested and showed satisfactory results. Author

A90-21532* Allied-Signal Aerospace Co., Teterboro, NJ.
DESIGN, FABRICATION AND TEST OF A PROTOTYPE DOUBLE GIMBAL CONTROL MOMENT GYROSCOPE FOR THE NASA SPACE STATION
JOSEPH BLONDIN, ERIC HAHN, JOHN KOLVEK (Allied-Signal Aerospace Co., Guidance Systems Div., Teterboro, NJ), LEWIS COOK, PAUL GOLLEY (NASA, Marshall Space Flight Center, Huntsville, AL) et al. IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989, p. 101-118.
(Contract NAS8-36628)
(AAS PAPER 89-006) Copyright

Recognizing the need to develop future technologies in support of the Space Station, NASA's Advanced Development Program (ADP) placed as its goal the design and fabrication of a prototype 4750 Newton-meter-second (3500 ft-lb-sec) Control Moment Gyroscope (CMG). The CMG uses the principle of momentum exchange to impart control torques for counteracting vehicle disturbances. This paper addresses the selection of the double gimbal CMG over the single gimbal and describes the major subassemblies of the prototype design. Particular attention is given to the choice of the materials, fabrication and design details dictated by the man-rated mission requirement. Physical characteristics and the results of functional testing are presented to demonstrate the level of system performance obtained. Comparisons are made of the measured system responses against design goals and predictions generated by computer simulation. Author

A90-21537
REMOTE ATTITUDE MEASUREMENT SENSOR ADVANCES - SMALL-MOTION DETECTION CAPABILITY
MARY L. SULLIVAN and HUGH W. DAVIS (Ball Corp., Ball Aerospace Systems Group, Boulder, CO) IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989, p. 205-214.
(AAS PAPER 89-017) Copyright

A NASA supported study resulted in the development, by Ball Aerospace Systems Group (BASG), of a position sensor for monitoring arcsecond structural motions. BASG's Remote Attitude Measurement Sensor (RAMS) is described as a noncontacting, optical-position sensor designed to measure the small motion of vibrating structures or surfaces by multiple-location monitoring. The paper examines the current RAMS prototype, including sensor design, processing electronics, and optical configuration options. Several applications suitable for remote sensing are reviewed, and RAMS enhancements planned to meet these growing needs are outlined. C.E.

A90-22241*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A HOMOTOPY APPROACH FOR COMBINED CONTROL-STRUCTURE OPTIMIZATION - CONSTRUCTIVE ANALYSIS AND NUMERICAL EXAMPLES
R. E. SCHEID, M. H. MILMAN, M. SALAMA, R. BRUNO (JPL, Pasadena, CA), and J. S. GIBSON (California, University, Los Angeles) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. refs
(AIAA PAPER 90-0658) Copyright

This paper outlines the development of methods for the combined control-structure optimization of physical systems encountered in the technology of large space structures. The objectives of the approach taken in this paper is not to produce the 'best' optimized design, but rather to efficiently produce a family of design options so as to assist in early trade studies, typically before hard design constraints are imposed. The philosophy is that these are candidate designs to be passed on for further considerations, and their function is more to guide the development of the system design rather than to represent the ultimate product. A homotopy approach involving multi-objective functions is developed for this purpose. Analytical and numerical examples are also presented. Author

A90-23116*# Purdue Univ., West Lafayette, IN.
GLOBAL-LOCAL APPROACH TO SOLVING VIBRATION OF LARGE TRUSS STRUCTURES
C. T. SUN and S. W. LIEBBE (Purdue University, West Lafayette, IN) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 2, p. 248-255) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 303-308. Previously cited in issue 18, p. 2658, Accession no. A86-38907. refs
(Contract NAG1-581)
Copyright

A90-24301
CONTROL AND STABILIZATION OF A FLEXIBLE BEAM ATTACHED TO A RIGID BODY
O. MORGUL (Bilkent University, Maltepe, Turkey) International Journal of Control (ISSN 0020-7179), vol. 51, Jan. 1990, p. 11-31. Research supported by the Scientific and Technical Research Council of Turkey. refs
(Contract NSF ECS-85-00993)
Copyright

A flexible spacecraft is modeled as a rigid body rotating in inertial space; a light flexible beam is clamped to the rigid body at one end and is free at the other. The equations of motion are obtained by using free-body diagrams. It is shown that suitable boundary controls applied to the free end of the beam and a control torque applied to the rigid body stabilize the system. The proof is obtained by using the energy of the system as a Lyapunov functional. Author

A90-25980#
DYNAMICS OF AN ARBITRARY FLEXIBLE BODY IN LARGE ROTATION AND TRANSLATION
ARUN K. BANERJEE and JOHN M. DICKENS (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 221-227. refs
(AIAA PAPER 89-1308) Copyright

Conventional theories underlying many multibody codes used for simulating the behavior of elastic structures undergoing large rotation and translation with small vibrations fail to predict dynamic stiffening of the structures. This can lead to significantly incorrect simulations in many practical situations. A theory that does not suffer from this defect and is valid for an arbitrary structure is given here. The formulation is based on Kane's equations and consists of two steps: First, generalized inertia forces are written for an arbitrary structure for which one is forced to linearize prematurely in the modal coordinates; next, this defect in linearization is compensated for by the introduction of contributions to the generalized active forces from the 'motion stiffness' of the structure. The stress associated with the motion stiffness is identified as due to 12 sets of inertia forces and nine sets of inertia couples distributed throughout the body during the most general motion of its flying reference frame. An algorithm is set for a reader wishing to implement the theory, and illustrative examples are given to demonstrate the validity and generality of the formulation. Author

A90-25981#
GRAVITY EFFECTS ON DAMPING OF A SPACE STRUCTURE WITH PINNED JOINTS
STEVEN L. FOLKMAN and FRANK J. REDD (Utah State University, Logan) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 228-233. Previously cited in issue 12, p. 1892, Accession no. A88-31378. refs
Copyright

A90-25982#
CONTROL OF LINEAR DAMPERS FOR LARGE SPACE STRUCTURES
J. K. HAVILAND, T. W. LIM, W. D. PILKEY, and H. POLITANSKY (Virginia, University, Charlottesville) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 234-240. Research supported by USAF. Previously cited in issue 22, p. 3549, Accession no. A87-50415. refs
Copyright

A90-25983#
DYNAMICS AND CONTROL OF SPACECRAFT WITH RETARGETING FLEXIBLE ANTENNAS
LEONARD MEIROVITCH and MOON K. KWAK (Virginia Polytechnic Institute and State University, Blacksburg) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3, p. 1584-1592) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 241-248. Previously cited in issue 12, p. 1840, Accession no. A88-32341. refs
(Contract F33615-86-C-3233)
Copyright

A90-25986#
FOURIER-BASED OPTIMAL CONTROL APPROACH FOR STRUCTURAL SYSTEMS
VINCENT YEN and MARK L. NAGURKA (Carnegie-Mellon University, Pittsburgh, PA) (1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3, p. 2082-2087) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 265-276. Research supported by Carnegie-Mellon University. Previously cited in issue 24, p. 4010, Accession no. A88-54643. refs
Copyright

A90-25988#
HINGES-FREE AND HINGES-LOCKED MODES OF A DEFORMABLE MULTIBODY SPACE STATION - A CONTINUUM ANALYSIS
HARI B. HABLANI (Rockwell International Corp., Satellite and Space Electronics Div., Seal Beach, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 286-296. refs
Copyright

An analytical theory of two classes of vehicle modes for a multibody, deformable Space Station is presented: (1) hinges-free modes and (2) hinges-locked modes. Both modes are defined for the Space Station completely free in space; the former modes refer to free hinges, and the latter to locked hinges. Associated eigenvalue problems and orthogonality properties are developed and used to arrive at concise linear motion equations. The conciseness transpires because, with these vehicle modes, the translational and rotational deformations of an inboard body at a hinge have a simple modal expansion. Modal momental coefficients associated with both classes of modes are formulated. They play a pivotal role in discretization of partial differential equations governing the dynamics. The analysis is general: elastic deformationis three dimensional, structures have arbitrary geometry and obey Hooke's law of elasticity, and hinges are universal joints. The modal coefficients and dynamics of the Space Station are illustrated, and the pitfalls in using hinges-locked vehicle modes to predict hinges-free response are identified. A continuum formulation of dynamics of the Space Station with a mobile manipulator is also furnished. Author

A90-25989*# Georgia Inst. of Tech., Atlanta.
APPROXIMATE LOOP TRANSFER RECOVERY METHOD FOR DESIGNING FIXED-ORDER COMPENSATORS
ANTHONY J. CALISE and J. V. R. PRASAD (Georgia Institute of Technology, Atlanta) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 297-302. Research supported by the U.S. Army. Previously cited in issue 21, p. 3584, Accession no. A88-50184. refs
(Contract NAG1-243)
Copyright

A90-25991#
GAIN-SENSITIVITY AUGMENTATION FOR NEAR-OPTIMAL CONTROL OF LINEAR PARAMETER-DEPENDENT PLANTS
PETER L. GRAF and RAHMAT SHOURESHI (Purdue University, West Lafayette, IN) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 310-320. refs
Copyright

This paper develops a parameter-adaptive version of the steady-state linear quadratic Gaussian controller for plants with structured parameter dependencies. Both scalar and vector parameter perturbations are treated. The design method, referred to as gain-sensitivity augmentation, is based on approximating the optimal parameter-dependent regulator and filter gain matrices with truncated Taylor series expansions. The coefficient matrices of the Taylor series expansions are referred to as gain-sensitivity

matrices and are precomputed off-line. Parameter information, assumed to be available on-line by direct measurement or estimation, is used to adjust the gain matrices to near-optimal values. Author

A90-25993#
SUPPRESSION OF UNDESIRED INPUTS OF LINEAR SYSTEMS BY EIGENSPACE ASSIGNMENT
QIANG ZHANG, G. L. SLATER, and R. J. ALLEMANG (Cincinnati, University, OH) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 330-336. refs
Copyright

In this paper, a method using output feedback is proposed to suppress the response of linear systems to undesired inputs and, in particular, to reduce the vibration response of flexible structures to these inputs. This method does not need to measure undesired inputs (or external forces). The analysis assumes that the location of the undesired inputs are known, although the general time dependency is unknown. The feedback gain matrix is calculated to assign the eigenvalues and left-hand eigenvectors of the closed-loop system to specified values. The effect of the undesired inputs on a closed-loop system can be altered or significantly reduced by properly choosing the left-hand eigenvectors of the system. The stability of the control system is guaranteed by properly choosing the output matrix, which can decouple the controlled modes from the uncontrolled modes. An example of forced vibration of a simple flexible structure is presented to demonstrate the proposed method. Author

A90-26074
ACTIVE CONTROL OF NONLINEAR DYNAMIC RESPONSE OF SPACE-FRAMES USING PIEZO-ELECTRIC ACTUATORS
G. SHI and S. N. ATLURI (Georgia Institute of Technology, Atlanta) Computers and Structures (ISSN 0045-7949), vol. 34, no. 4, 1990, p. 549-564. Research supported by USAF. refs
Copyright

A scheme for active control of nonlinear vibration of space structures, wherein each member is modeled as a beam-column, is presented. The expressions for shear stresses transmitted to the structural member by the distributed segmented piezoelectric actuators, which are bonded on the surfaces of the member, are derived in the general case in which the structural member is subjected to moments, transverse shear forces and an axial force. Based on the weak form of the governing equations, and a complementary energy approach based on assumed stress fields, the viability of active control of nonlinear dynamic response of lattice-type space structures, using piezo actuators, is studied. Four examples are given to demonstrate the feasibility of the approaches in this paper. Author

A90-26076
DEFORMATION MODE SELECTION AND MODE ORTHONORMALIZATION FOR FLEXIBLE BODY SYSTEM DYNAMICS
HUAHN-FERN YEH and BERNHARD DOPKER (Iowa, University, Iowa City) Computers and Structures (ISSN 0045-7949), vol. 34, no. 4, 1990, p. 615-627. refs
Copyright

Equations of motion of a flexible body system, combined with finite element information of components, are derived by the Lagrange method, using virtual rotations. The combinations of static correction modes, Ritz vectors, and vibration normal modes are used in this paper to capture the effect of concentrated loads such as joint reaction forces and suspension forces. In order to obtain well conditioned equations of motion, deformation modes derived from the consistent mass matrix are orthonormalized with respect to the lumped mass matrix in an optimal way. An example is used to demonstrate the results. Author

A90-26776
AIAA DYNAMICS SPECIALISTS CONFERENCE, LONG BEACH, CA, APR. 5, 6, 1990, TECHNICAL PAPERS
Washington, DC, American Institute of Aeronautics and Astronautics, 1990, 567 p. For individual items see A90-26777 to A90-26828.
Copyright

The papers contained in this volume provide an overview of recent developments in dynamics-related research. General topics discussed include control structure interaction, dynamic systems identification, localization, nonlinear dynamics, and multibody dynamics. Papers are presented on integrated structure-control optimization of space structures, dynamics and control of tethered spacecraft, modal interactions in composite structures, chaotic response of aerosurfaces with structural nonlinearities, large angle maneuver experiments in ground-based laboratories, and active control of vibration isolation with discrete frequency agitation for space experiments. V.L.

A90-26777*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
INTEGRATED STRUCTURE-CONTROL OPTIMIZATION OF SPACE STRUCTURES
RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1-9. refs
(Contract NAG1-224)
(AIAA PAPER 90-1190) Copyright

In the past few years there has been substantial interest in the integrated design of large space structures and their vibration control systems. This paper overviews two aspects of integrated control-structure design. The first is the calculation of derivatives of control system stability margins with respect to structural parameters, and the effect of modal truncation on the accuracy of these derivatives. The second aspect is the various formulations used to define an integrated design optimization problem. Author

A90-26778*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST EIGENSYSTEM ASSIGNMENT FOR SECOND-ORDER DYNAMIC SYSTEMS
JER-NAN JUANG and PEIMAN G. MAGHAMI (NASA, Langley Research Center, Hampton, VA) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 10-18. refs
(AIAA PAPER 90-1191) Copyright

A novel approach for the robust eigensystem assignment of flexible structures using full state or output feedback is developed. Using the second-order dynamic equations, the approach can assign the eigenvalues of the system via velocity and displacement feedbacks, or acceleration and velocity feedbacks. The eigenvalues and eigenvectors of the system are assigned, via the second-order eigenvalue problem for the structural system, in two steps. First, an orthonormal basis spanning the attainable closed-loop eigenvector space corresponding to each desired closed-loop eigenvalue is generated using the Singular Value or QR decompositions. Second, a sequential procedure is used to choose a set of closed-loop eigenvectors that are as close as possible to the column space of a well-conditioned target matrix. Among the possible choices of the target matrix, the closest unitary matrix to the open-loop eigenvector matrix appears to be a suitable choice. A numerical example is given to illustrate the proposed algorithm. Author

A90-26779#
CONTROLLER DESIGN BY EIGENSPACE ASSIGNMENT
G. L. SLATER and Q. ZHANG (Cincinnati, University, OH) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 19-31. refs
(AIAA PAPER 90-1193) Copyright

Eigenstructure assignment using constrained state, or output feedback, as a general approach to control design for linear

multi-variable systems is reviewed. Applications on flexible structures are shown which: (1) are of high (possible infinite) dimension, and (2) may be modeled only through a limited set of experimental modal data. Items addressed are, the problem of eigenvector shaping to achieve desired modal characteristics while maintaining 'reasonable' magnitude constraints on the control vector, and designing controls to reduce response to harmonic or other types of excitation. The proposed methods are illustrated by several examples. Numerical simulation results and experimental results for the active vibration control of a laboratory beam are presented. Author

A90-26786#
STRUCTURAL SYSTEM IDENTIFICATION USING MULTIPLE TESTS
ALEX BERMAN and JON-SHEN FUH (Kaman Aerospace Corp., Bloomfield, CT) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 99-104. refs
(AIAA PAPER 90-1200) Copyright

A new approach is presented for analytical model improvement using data from multiple tests. The algorithm minimally changes an analytical model to match all desired modal parameters from various test configurations with known support characteristics. The approach allows imposing physically measured elastic modes and frequencies, as well as rigid body modes determined a priori. In addition, multiple tests reduce the possibility of missing crucial modes of a complex structure with high modal density in the frequency range of interest. This procedure is especially useful for the identification of a free, large, flexible, space structure where ground tests to simulate operational conditions are virtually impossible. The algorithm derived is noniterative and numerically efficient. Author

A90-26787*# SDRC, Inc., San Diego, CA.
SELECTION OF COMPONENT MODES
PAUL A. BLELLOCH (SDRC, Inc., Engineering Services Div., San Diego, CA) and KELLY S. CARNEY (NASA, Lewis Research Center, Cleveland, OH) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 105-112. refs
(AIAA PAPER 90-1201) Copyright

Structural dynamic models of complex spacecraft are often assembled from a number of component models. In this paper, three methods for reducing the order of these component models are presented by selecting 'important' fixed interface component modes. These methods are applied to two component structures of the Space Station Freedom: a photovoltaic (PV) array and a solar dynamic collector. The reduced order models of these components retain a small fraction of the number of modes in the original models while accurately representing a set of outputs chosen by the user. Author

A90-26791#
A MINIMUM SENSITIVITY DESIGN METHOD FOR OUTPUT FEEDBACK CONTROLLERS
JOHN L. JUNKINS (Texas A & M University, College Station) and YOUDAN KIM IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 142-152. refs
(AIAA PAPER 90-1206) Copyright

A method is introduced to design globally stable output feedback controllers for second order systems. To optimize over a stable family of gains, a homotopy method is introduced to sweep through a sequence of nearest neighbor designs to impose inequality constraints on the closed loop eigenvalues. To enhance robustness, the condition number of the closed loop modal matrix is minimized. Two control design examples are given which support the practical value of this approach. The second example is a 60-DOF representation of a three-input, six-output flexible structure. Author

A90-26792*# Purdue Univ., West Lafayette, IN.
MODEL REDUCTION BY WEIGHTED COMPONENT COST ANALYSIS
JAE H. KIM and ROBERT E. SKELTON (Purdue University, West Lafayette, IN) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 153-160. refs
(Contract NAG1-958)
(AIAA PAPER 90-1207) Copyright

Component Cost Analysis considers any given system driven by a white noise process as an interconnection of different components, and assigns a metric called 'component cost' to each component. These component costs measure the contribution of each component to a predefined quadratic cost function. A reduced-order model of the given system may be obtained by deleting those components that have the smallest component costs. The theory of Component Cost Analysis is extended to include finite-bandwidth colored noises. The results also apply when actuators have dynamics of their own. Closed-form analytical expressions of component costs are also derived for a mechanical system described by its modal data. This is very useful to compute the modal costs of very high order systems. A numerical example for MINIMAST system is presented. Author

A90-26794#
EFFICIENCY MODES ANALYSIS OF STRUCTURE-CONTROL SYSTEMS
HAYRANI OZ (Ohio State University, Columbus) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 176-188. refs
(Contract F33615-86-C-3212)
(AIAA PAPER 90-1210) Copyright

An efficiency eigenvalue problem is recognized, associated with a previous definition of structure-control system efficiency. The particular eigenvalue problem leads to the definition of controller (efficiency) modes alongside the familiar structural modes. Characterization of the internal structure of the control-structure interaction is made through a spectral decomposition of the control power matrices of the structure-control design and a correlation between the structure and controller modes is established. Relatedly, component efficiencies and efficiency components of the system are defined. A link between the initial disturbance and the control system design is also identified. The analysis reveals that the control task is one of insuring a good match between the structural modes and the controller (efficiency) modes. The analysis is demonstrated on representative space structures, ACOSS-4 and ACOSS-6 (Model 2) of CSDL. Author

A90-26798*# California Univ., Los Angeles.
MODE LOCALIZATION IN MULTI-SPAN BEAMS
S. D. LUST, P. P. FRIEDMANN, and O. O. BENDIKSEN (California, University, Los Angeles) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 225-235. refs
(Contract JPL-958410)
(AIAA PAPER 90-1214) Copyright

The influence of numerous effects on mode localization in multi-span beams is investigated. Finite-element methods are used to study localization as a function of: Timoshenko beam effects; beam end conditions; span length, mass, and stiffness imperfection; viscous damping; axial force; transverse support and rotational coupling stiffness; and modeling resolution. Three configurations are studied, commencing with two different two-span models, and culminating in a ten-span configuration resembling lattice-type large space structures. Results indicate that, in addition to the ratio of imperfection to coupling stiffness being an important localization

parameter, transverse support stiffness and Timoshenko beam effects greatly affect the tendency of a structure to exhibit localized modes. Author

A90-26801#
EXPERIMENTAL MODAL IDENTIFICATION OF THE MINI-MAST CSI TESTBED
MICHAEL J. ROEMER and D. JOSEPH MOOK (New York, State University, Buffalo) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 255-260. refs
(AIAA PAPER 90-1217) Copyright

The Mini-Mast is a 20 meter long, three-dimensional, deployable/retractable truss structure designed to imitate future trusses in space. This structure has undergone various static and dynamic experiments at NASA Langley to identify its modal properties so that control laws can be developed and tested. This paper discusses a robust (with respect to measurement noise sensitivity) time domain, modal identification technique for identifying the modal properties of the Mini-Mast structure even in the face of noisy measurements. Two testing/analysis procedures are considered, they include: (1) sinusoidal excitation near the resonant frequencies of the Mini-Mast, and (2) frequency response function averaging of several modal tests. The modal identification results of these tests are compared with respect to basic filtering techniques and combining identification and state estimation algorithms. Author

A90-26802*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
SIMULTANEOUS EXPANSION AND ORTHOGONALIZATION OF MEASURED MODES FOR STRUCTURE IDENTIFICATION
SUZANNE WEAVER SMITH and CHRISTOPHER A. BEATTIE (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 261-270. refs
(Contract NAG1-960)
(AIAA PAPER 90-1218) Copyright

Tests of large structures on-orbit will be performed with measurements at a relatively few structure points. Values for the unmeasured degrees of freedom (dofs) can be estimated based on measured dofs and analytical model dynamic information. These 'expanded' mode shapes are useful for optimal-update identification and damage location as well as test/analysis correlation. A new method of expansion for test mode shape vectors is developed from the orthogonal Procrustes problem from computational linear algebra. A subspace defined by the set of measured dofs is compared to a subspace defined by mode shapes from an analytical model of the structure. The method simultaneously expands and orthogonalizes the mode shape vectors. Two demonstration problems are used to compare the new method to current expansion techniques. One demonstration uses test data from a laboratory scale-model truss structure. Performance of the new method is comparable or superior to that of the previous expansion methods which require separate orthogonalization. Author

A90-26805#
A RECURSIVE ALGORITHM FOR DISCRETE TIME DOMAIN PARAMETER IDENTIFICATION
J. J. HOLLKAMP (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) and S. M. BATILL (Notre Dame, University, IN) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 289-298. Research supported by the University of Notre Dame and USAF. refs
(AIAA PAPER 90-1221)

A time-domain modeling algorithm known as the reduced backward method (RBM) is studied. The RBM uses simultaneous input-output data processed entirely in the time domain to provide an accurate reduced-order model. Order overspecification and truncated singular-value solution reduce the influence of noise. An order-recursive version of the method provides models for many different order overspecifications and is computationally more efficient than the original version. Data from ground vibration tests of a space truss and a subscale sailplane are used to study the effects of the truncated singular-value solution and of varying order overspecifications. Results show that the added computational expense of the singular-value decomposition is in many cases unwarranted since the recursive algorithm provides accurate reduced-order models. Author

A90-26809*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A LINE-OF-SIGHT PERFORMANCE CRITERION FOR CONTROLLER DESIGN OF A PROPOSED LABORATORY MODEL
KYONG B. LIM and LUCAS G. HORTA (NASA, Langley Research Center, Hampton, VA) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 349-359.
(AIAA PAPER 90-1226) Copyright

A line-of-sight performance criterion is derived for a proposed Controls Structures Interaction model, and its many uses in the control design process for fine pointing control are illustrated. A linearized line-of-sight (LOS) criterion is used for direct controller design and as a performance measure to judge different control methodologies. Numerical simulation results are shown where the three approaches: linear quadratic Gaussian theory, robust eigensystem assignment, and local velocity feedback are used for vibration control. Results indicate that the linear quadratic Gaussian controller, which incorporates a linearized LOS weighting matrix directly, yields good performance without wasting energy to control motions that have no influence on the LOS. Author

A90-26812#
NONLINEAR FLEXURAL-FLEXURAL-TORSIONAL DYNAMICS OF METALLIC AND COMPOSITE BEAMS
PERNGJIN F. PAI and ALI H. NAYFEH (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 380-386. refs
(Contract DAAL03-89-K-0180; F49620-87-C-0088)
(AIAA PAPER 90-1229) Copyright

Three nonlinear integro-differential equations of motion are used to investigate the forced nonlinear vibration of a symmetric laminated graphite-epoxy composite beam. The analysis focuses on the case of primary resonance of the first flexural mode when its frequency is approximately two times the frequency of the first out-of-plane flexural-torsional mode. A combination of the fundamental-matrix method, the Galerkin procedure, and the method of multiple scales is used to derive four first-order ordinary-differential equations describing the modulation of the amplitudes and phases of the interacting modes with damping, nonlinearity, and resonances. The eigenvalues of the Jacobian matrix of the modulation equations are used to determine the stability of constant solutions, and Floquent theory is used to determine the stability and bifurcations of limit-cycle solutions. Hopf bifurcations, symmetry-breaking bifurcations, amplitude- and phase-modulated motions, period-multiplying sequences, and chaotic motions are studied. The results show that the motion can be planar and/or nonplanar although the input force is planar. Nonplanar responses may be periodic motions, amplitude- and phase-modulated motions, or chaotically modulated motions. Author

A90-26818*# Colorado Univ., Boulder.
A COMPUTATIONAL PROCEDURE FOR MULTIBODY SYSTEMS INCLUDING FLEXIBLE BEAM DYNAMICS
J. D. DOWNER, K. C. PARK, and J. C. CHIOU (Colorado, University, Boulder) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American

Institute of Aeronautics and Astronautics, 1990, p. 443-458. refs (Contract NGT-50254)
(AIAA PAPER 90-1237) Copyright

A computational procedure suitable for the solution of equations of motions for flexible multibody systems has been developed. A fully nonlinear continuum approach capable of accounting for both finite rotations and large deformations has been used to model a flexible beam component. The beam kinematics are referred directly to an inertial reference frame such that the degrees of freedom embody both the rigid and flexible deformation motions. As such, the beam inertia expression is identical to that of rigid body dynamics. The nonlinear coupling between gross body motion and elastic deformation is contained in the internal force expression. Numerical solution procedures for the integration of spatial kinematic systems can be directly applied to the generalized coordinates of both the rigid and flexible components. An accurate computation of the internal force term which is invariant to rigid motions is incorporated into the general solution procedure. Author

A90-26822#
STATISTICAL ANALYSIS OF SPACE STATION FREEDOM/PAYLOAD POINTING SYSTEM STRUCTURES AND CONTROLS INTERACTION
R. R. KAUFFMAN and R. P. ISENBERG (General Electric Co., Astro-Space Div., Philadelphia, PA) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 495-501.
(AIAA PAPER 90-1242) Copyright

This paper describes a statistical analysis performed to evaluate payload pointing accuracy on Space Station Freedom. A statistical model of the disturbance environment on board Space Station Freedom has been developed. This environment has been imposed upon NASTRAN finite element model of the Space Station Freedom/Payload Pointing System (PPS) including control loops for both the PPS and Freedom Station. All models that were employed were linear, and friction effects in the gimbal joints were not considered. A Monte Carlo analysis was performed to assess the pointing performance of the Payload Pointing System when mounted on Space Station Freedom and exposed to the statistical disturbance environment. It was found that pointing performance requirements were met in this linear analysis. Author

A90-26823*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
BRIDGE FEEDBACK FOR ACTIVE DAMPING AUGMENTATION
G.-S. CHEN and B. J. LURIE (JPL, Pasadena, CA) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 502-510. refs
(AIAA PAPER 90-1243) Copyright

A method is described for broadband damping augmentation of a structural system in which the active members (with feedback control) were developed such that their mechanical input impedance can be electrically adjusted to maximize the energy dissipation rate in the structural system. The active member consists of sensors, an actuator, and a control scheme. A mechanical/electrical analogy is described to model the passive structures and the active members in terms of their impedance representation. As a result, the problem of maximizing dissipative power is analogous to the problem of impedance matching in the electrical network. Closed-loop performance was demonstrated for single- and multiple-active-member controlled truss structure. Author

A90-26824#
ACTIVE CONTROL OF VIBRATION ISOLATION WITH DISCRETE FREQUENCY AGITATION FOR SPACE EXPERIMENTS
HEATHER M. HARRIS (Miami, University, Coral Gables, FL) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 511-516. refs
(AIAA PAPER 90-1244) Copyright

NASA-Lewis' six-degree-of-freedom active vibration-isolation system can perform its isolation function for frequencies in the 0.1-100 Hz range, and permits the control of agitations in three degrees-of-freedom. Active frequency-rejection of payloads has been demonstrated for 0-250 milli-inch amplitudes. Since the vibration-isolation system is implemented for a small operating region, the control theory is linearized; the superimposed agitation controls have also been linearized. The discrete signals used to implement agitation are generated within the program's simulation loop. O.C.

A90-26825#
ON THE MODELING OF FLEXIBLE MULTI-BODY SYSTEMS BY THE RAYLEIGH-RITZ METHOD
L. MEIROVITCH and M. K. KWAK (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 517-526. refs
(Contract F49620-89-C-0049)
(AIAA PAPER 90-1245) Copyright

This paper is concerned with the modeling of flexible multi-body systems by the substructure synthesis method. In regarding substructure synthesis as a Rayleigh-Ritz method, certain advantages can be accrued by using the variational approach to derive the eigenvalue problem. However, if the admissible functions used to represent the motion of the substructures are not chosen properly, convergence can suffer. This paper presents a new substructure synthesis method with superior convergence characteristics achieved by representing the motion by means of a recently developed class of functions, namely, the class of quasi-comparison functions. This improved convergence is shown to be related to improved approximation of the differential equations and the natural boundary conditions. The theory is demonstrated by means of a numerical example. Author

A90-26826*# Colorado Univ., Boulder.
STAGGERED SOLUTION PROCEDURES FOR MULTIBODY DYNAMICS SIMULATION
K. C. PARK, J. C. CHIOU, and J. D. DOWNER (Colorado, University, Boulder) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 527-537. refs
(Contract NAG1-756)
(AIAA PAPER 90-1246) Copyright

A computational procedure is presented for the direct integration of the multibody dynamical (MBD) equations with constraints. Numerical experiments conducted with this MBD procedure indicate that it yields robust solutions in cases where the step size furnishes more than 20 samples for the period of highest apparent response frequency in a given multibody system. The MBD solution procedure is implemented in two separate modules: the generalized coordinated solver, 'CINT', and the constraint Lagrange multiplier solver, 'LINT'. O.C.

A90-26976*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADAPTIVE NONCOLOCATED VELOCITY FEEDBACK FOR VIBRATION DAMPING
DAVID S. BAYARD and JOHN T. SPANOS (JPL, Pasadena, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 8 p. refs
(AIAA PAPER 90-0659) Copyright

A method is proposed for adaptive noncolocated velocity feedback control of flexible structure vibrations. The approach, denoted as auto-tuning, is to drive the system into a sequence of controlled oscillations to provide accurate knowledge of the plant characteristics in the vicinity of the phase cross-over frequencies. An allpass phase notch filter cascade is used as the control architecture to phase stabilize each destabilizing mode in the plant

transfer function. The allpass phase notch filter cascade is tuned precisely by the information extracted from the controlled oscillations. Author

A90-27645
ROBUST CONTROLLER DESIGN USING NORMALIZED COPRIME FACTOR PLANT DESCRIPTIONS
DUNCAN C. MCFARLANE (BH Pacific Pty., Ltd., Melbourne Research Laboratories, Clayton, Australia) and KEITH GLOVER (Cambridge, University, England) Research supported by BH Pacific Pty., Ltd. Berlin and New York, Springer-Verlag (Lecture Notes in Control and Information Sciences. Volume 138), 1990, 218 p. refs
Copyright

Techniques for the design of robust feedback controllers are developed analytically and demonstrated. Both the nominal-model transfer function and the class of systems for which stabilization by the controller is guaranteed are represented using the coprime-factor approach of Vidyasagar (1985). Chapters are devoted to the mathematical foundations of robust stabilization, uncertain systems, normalized coprime-factor plant descriptions, reduced-order controller design, and a loop-shaping design procedure. Results from applications to (1) the attitude control of a flexible spacecraft, (2) the attitude control of a flexible space platform, and (3) the control of aircraft vertical-plane dynamics are presented in tables and graphs and discussed in detail. T.K.

A90-27946
CHATTER ELIMINATION IN VARIABLE STRUCTURE CONTROL MANEUVERING OF FLEXIBLE SPACECRAFT
OSAMA MOSTAFA (Egyptian Air Force, Cairo, Egypt) and HAYRANI OZ (Ohio State University, Columbus) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 37, Oct.-Dec. 1989, p. 529-550. refs
Copyright

It is noted that variable structure control systems (VSCS) represent a real-time implementable approach to control in contrast to algorithmic approaches, and therefore eliminate the computational burden. However, a practical problem in the implementation of VSCS theory is the possibility of chatter about hypersurfaces known as sliding regimes. This paper extends the author's previous work in application of the VSCS theory to the maneuvering of flexible spacecraft by presenting three methods of chatter elimination. These methods are global asymptotic reaching, local asymptotic reaching of sliding regimes, and digital input prefiltering. It is shown that the first two approaches eliminate chatter completely while the prefiltering approach reduces the chatter frequency. Examples are given for a single-axis rest-to-rest maneuver of a flexible spacecraft, demonstrating the success of the three methods in alleviating the chatter phenomenon. R.E.P.

A90-27994#
MODE SHAPE IDENTIFICATION AND ORTHOGONALIZATION
ALVAR M. KABE (Aerospace Corp., El Segundo, CA) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3, p. 1143-1150) AIAA Journal (ISSN 0001-1452), vol. 28, April 1990, p. 711-716. Previously cited in issue 12, p. 1889, Accession no. A88-32294. refs
Copyright

A90-27995*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
POSITIVE POSITION FEEDBACK CONTROL FOR LARGE SPACE STRUCTURES
J. L. FANSON (JPL, Pasadena, CA) and T. K. CAUGHEY (California Institute of Technology, Pasadena) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B, p. 588-598) AIAA Journal (ISSN 0001-1452), vol. 28, April 1990, p. 717-724. Previously cited in issue 14, p. 2116, Accession no. A87-33711. refs

A90-27996#
DYNAMIC CONTINUUM MODELING OF BEAMLIKE SPACE STRUCTURES USING FINITE-ELEMENT MATRICES
USIK LEE (Korea Institute of Aeronautical Technology, Seoul, Republic of Korea) AIAA Journal (ISSN 0001-1452), vol. 28, April 1990, p. 725-731. Previously cited in issue 12, p. 1859, Accession no. A89-30856. refs
Copyright

A90-27998*# Massachusetts Inst. of Tech., Cambridge.
JOINT DAMPING AND NONLINEARITY IN DYNAMICS OF SPACE STRUCTURES
MARY BOWDEN and JOHN DUGUNDJI (MIT, Cambridge, MA) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3, p. 1764-1773) AIAA Journal (ISSN 0001-1452), vol. 28, April 1990, p. 740-749. Research supported by McDonnell Douglas Astronautics Co. Previously cited in issue 12, p. 1911, Accession no. A88-32362. refs
(Contract NAGW-21)
Copyright

A90-29249*# California Univ., Los Angeles.
OPTIMAL PLACEMENT OF ACTUATORS AND SENSORS IN CONTROL AUGMENTED STRUCTURAL OPTIMIZATION
A. E. SEPULVEDA and L. A. SCHMIT, JR. (California, University, Los Angeles) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 217-240. refs
(Contract NSG-1490)
(AIAA PAPER 90-1055) Copyright

A control-augmented structural synthesis methodology is presented in which actuator and sensor placement is treated in terms of (0,1) variables. Structural member sizes and control variables are treated simultaneously as design variables. A multiobjective utopian approach is used to obtain a compromise solution for inherently conflicting objective functions such as strucutal mass control effort and number of actuators. Constraints are imposed on transient displacements, natural frequencies, actuator forces and dynamic stability as well as controllability and observability of the system. The combinatorial aspects of the mixed - (0,1) continuous variable design optimization problem are made tractable by combining approximation concepts with branch and bound techniques. Some numerical results for example problems are presented to illustrate the efficacy of the design procedure set forth. Author

A90-29250*# Florida Univ., Gainesville.
STRUCTURE/CONTROL SYNTHESIS WITH NONNEGLIGIBLE ACTUATOR MASS
DAVID C. ZIMMERMAN (Florida, University, Gainesville) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 241-246. refs
(Contract NAG1-1017)
(AIAA PAPER 90-1056) Copyright

The simultaneous design of a structure/active control system is addressed in which the mass of the actuators required to implement the active control is considered. An algorithm for estimating the required actuator mass given the control law and the desired maneuver is presented. A nonlinear optimization algorithm is used to direct the design process. Results are given for the design of a L shaped structure where it is desired to minimize the line of sight pointing error after a worst case slew maneuver. Author

A90-29254*# California Univ., Los Angeles.
IMPROVED APPROXIMATIONS FOR CONTROL AUGMENTED STRUCTURAL SYNTHESIS
H. L. THOMAS and L. A. SCHMIT (California, University, Los

Angeles) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 277-294. refs
(Contract NSG-1490)
(AIAA PAPER 90-1060) Copyright

A methodology for control-augmented structural synthesis is presented for structure-control systems which can be modeled as an assemblage of beam, truss, and nonstructural mass elements augmented by a noncollocated direct output feedback control system. Truss areas, beam cross sectional dimensions, nonstructural masses and rotary inertias, and controller position and velocity gains are treated simultaneously as design variables. The structural mass and a control-system performance index can be minimized simultaneously, with design constraints placed on static stresses and displacements, dynamic harmonic displacements and forces, structural frequencies, and closed-loop eigenvalues and damping ratios. Intermediate design-variable and response-quantity concepts are used to generate new approximations for displacements and actuator forces under harmonic dynamic loads and for system complex eigenvalues. This improves the overall efficiency of the procedure by reducing the number of complete analyses required for convergence. Numerical results which illustrate the effectiveness of the method are given. Author

A90-29265#
SHAPE SENSITIVITY ANALYSIS OF PIEZOELECTRIC STRUCTURES BY THE ADJOINT VARIABLE METHOD
R. ALSAN MERIC (Istanbul Technical University, Turkey) and SUNIL SAIGAL (Carnegie-Mellon University, Pittsburgh, PA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 394-402. refs
(AIAA PAPER 90-1138) Copyright

Shape sensitivity expressions are derived for linear piezoelectric structures with coupled mechanical and elastic fields. By adopting the quasi-electrostatic approximation for these inherently anisotropic materials, the adjoint variable method of optimization and the material derivative formulation of shape variations are utilized in a systematic procedure to evaluate the total variation of a general performance criterion with respect to shape variations. The material (total) derivative of the adopted integral functional is found in terms of primary and adjoint quantities, as well as the deformation velocity field. Since the structure is assumed to undergo dynamic response, domain integrations evaluated at the initial time are also needed in this formulation. Author

A90-29268*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ROBUSTNESS, GENERALITY AND EFFICIENCY OF OPTIMIZATION ALGORITHMS IN PRACTICAL APPLICATIONS
P. B. THANEDAR (NASA, Lewis Research Center, Cleveland, OH), J. S. ARORA, G. Y. LI, and T. C. LIN (Iowa, University, Iowa City) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 425-435. refs
(AIAA PAPER 90-1177) Copyright

The theoretical foundations of two approaches, sequential quadratic programming (SQP) and optimality criteria (OC), are analyzed and compared, with emphasis on the critical importance of parameters such as accuracy, generality, robustness, efficiency, and ease of use in large scale structural optimization. A simplified fighter wing and active control of space structures are considered with other example problems. When applied to general system identification problems, the OC methods are shown to lose simplicity and demonstrate lack of generality, accuracy and robustness. It is concluded that the SQP method with a potential constraint strategy is a better choice as compared to the currently prevalent mathematical programming and OC approaches. N.B.

A90-29410*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MULTIBODY MODEL REDUCTION BY COMPONENT MODE SYNTHESIS AND COMPONENT COST ANALYSIS
J. T. SPANOS (JPL, Pasadena, CA) and D. L. MINGORI (California, University, Los Angeles) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1914-1921. refs
(AIAA PAPER 90-1037) Copyright

The classical assumed-modes method is widely used in modeling the dynamics of flexible multibody systems. According to the method, the elastic deformation of each component in the system is expanded in a series of spatial and temporal functions known as modes and modal coordinates, respectively. This paper focuses on the selection of component modes used in the assumed-modes expansion. A two-stage component modal reduction method is proposed combining Component Mode Synthesis (CMS) with Component Cost Analysis (CCA). First, each component model is truncated such that the contribution of the high frequency subsystem to the static response is preserved. Second, a new CMS procedure is employed to assemble the system model and CCA is used to further truncate component modes in accordance with their contribution to a quadratic cost function of the system output. The proposed method is demonstrated with a simple example of a flexible two-body system. Author

A90-29414*# Engineering Mechanics Association, Inc., Torrance, CA.
STATISTICAL ANALYSIS OF MODELING ERROR IN STRUCTURAL DYNAMIC SYSTEMS
T. K. HASSELMAN and J. D. CHROSTOWSKI (Engineering Mechanics Associates, Inc., Torrance, CA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1945-1951.
(Contract NAS7-1064)
(AIAA PAPER 90-1041) Copyright

The paper presents a generic statistical model of the (total) modeling error for conventional space structures in their launch configuration. Modeling error is defined as the difference between analytical prediction and experimental measurement. It is represented by the differences between predicted and measured real eigenvalues and eigenvectors. Comparisons are made between pre-test and post-test models. Total modeling error is then subdivided into measurement error, experimental error and 'pure' modeling error, and comparisons made between measurement error and total modeling error. The generic statistical model presented in this paper is based on the first four global (primary structure) modes of four different structures belonging to the generic category of Conventional Space Structures (specifically excluding large truss-type space structures). As such, it may be used to evaluate the uncertainty of predicted mode shapes and frequencies, sinusoidal response, or the transient response of other structures belonging to the same generic category. Author

A90-29417#
EFFECT OF A STRUCTURAL DAMPING ON DYNAMIC STABILITY OF A FREE FLEXIBLE PLATE SUBJECTED TO A FOLLOWER FORCE
KEN HIGUCHI (Tokyo Denki University, Hatoyama, Japan) and EARL H. DOWELL (Duke University, Durham, NC) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1965-1971. refs
(AIAA PAPER 90-0940) Copyright

A plate-like large space structure may undergo dynamic instabilities when it is thrusted by a nonconservative compressive force. A flexible rectangular plate with four free edges, one of which is subjected to a tangential follower force, is considered.

The effects of structural damping are studied here, because small damping may destabilize the nonconservative system. The calculation shows that the thrusted free-edged plate with structural damping also has both divergence and flutter types of instability, and the flutter thrust load with small structural damping is drastically lower than that without damping. The destabilizing effect depends on the slenderness ratio of the rectangular plate. Author

A90-29422#
WAVE PROPAGATION IN TRUSS-TYPE STRUCTURAL NETWORKS
Y. YONG and Y. K. LIN (Florida Atlantic University, Boca Raton) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2026-2035. refs
(Contract AF-AFOSR-88-0005)
(AIAA PAPER 90-1082) Copyright

A systematic approach is proposed to determine the response of a large typical space structure which is composed of piece-wise periodic arrays of connected truss units. Each array of connected truss units is treated as a multi-channel waveguide, capable of transmitting several types of wave motions. Each waveguide or each junction where several waveguides intersect can be characterized by a wave scattering matrix, which is composed of the transmission and reflection sub-matrices. By use of wave scattering matrices in the formulation, the numerical computation always follows the directions of propagation of various waves. Numerical stability is assured, since the amplitude of wave motion decays as it propagates along a path due to structural damping. The numerical procedure proposed herein is considered more accurate than those previously published in the literature, since the actual truss-type construction is retained in this analysis. Application of the procedure is illustrated by an example. Author

A90-29423#
A REDUCED ORDER METHOD FOR PASSIVE SUBSTRUCTURES
Y. C. YIU and J. D. LANDESS (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2036-2044. refs
(AIAA PAPER 90-1083) Copyright

Passive substructures are not subject to external forces. The substructure is excited due to dynamic motions at the boundary points. Solution in the quasi-static and relative displacement coordinates allows special Ritz vectors to be used as the vector basis to represent the dynamics of the interior degrees of freedom. Flexibility and mass convergence can be implemented as each basis vector is computed. The method is mathematically consistent with Galerkin's and Ritz's solution techniques, and minimizes the error to the differential equation in the reduced subspace. Examples of satellite launch and on-orbit analyses demonstrate a 4 and 14 times reduction in the number of substructure coordinates and computation time of reduced structural matrices when compared with the conventional eigenspace solution. Author

A90-29431#
COUPLED SPACE STATION FREEDOM/PAYLOAD POINTING SYSTEM DYNAMIC ANALYSIS EMPLOYING MODAL SIGNIFICANT CRITERIA
R. P. ISENBERG and R. R. KAUFFMAN (General Electric Co., Astro Space Div., Philadelphia, PA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2110-2116.
(AIAA PAPER 90-0992) Copyright

A coupled analysis of a complex dynamic system is described involving structure and control system interaction. The system was comprised of the Space Station Freedom and the Payload Pointing System (PPS) structure, the Freedom Station and PPS control systems, and the disturbance environment that will be present on board Space Station Freedom. This coupled system analysis allowed preliminary estimates of the PPS pointing performance to be made and employed the use of a modal significance criteria to make the analysis tractable. Author

A90-29433*# NASA Space Station Program Office, Reston, VA.
A SUPERELEMENT METHODOLOGY FOR COUPLED LOADS ANALYSIS OF SPACE STATION FREEDOM
STEVE DEL BASSO, SUDEEP K. SINGH (Grumman SSEIC, Reston, VA), and ALAN J. LINDENMOYER (NASA, Space Station Freedom Program Office, Reston, VA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2126-2142. refs
(AIAA PAPER 90-0995) Copyright

A technique for calculating the effects of on-orbit loads on the structural dynamics of the International Space Station is developed on the basis of MSC/NASTRAN superelement solution sequences. The complexity of the Space Station program with its multiple configurations, international partners, and contractors is stressed, and the impact of this complexity on the dynamic-load analysis process is indicated. The MSC/NASTRAN-based approach is outlined, and its application to two versions of the Permanent Manned Capability configuration is described in detail, including component mode synthesis, GFSC/FLAME coupled-loads analysis (with components from the system FEM model or from the Work Package), and ISI/MATRIX-X generation of closed-loop forcing functions. The results of these sample analyses are presented in extensive tables and graphs and briefly characterized. T.K.

A90-29451*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON-ORBIT SYSTEM IDENTIFICATION USING ACTIVE MEMBERS
C. P. KUO, G.-S. CHEN, P. PHAM, and B. K. WADA (JPL, Pasadena, CA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2306-2316. refs
(AIAA PAPER 90-1129) Copyright

The capability to perform accurate on-orbit system identification for both open loop (passive) and closed loop (active) structural systems will be required for future NASA missions; especially those missions which require large precision structures. The information is required to accurately establish the dynamic characteristics of the operational structure in order to adjust the structure itself using the concepts of Adaptive Structures and/or the control system. This paper presents the test results of using Active Members in an adaptive structural system to excite a free-free structure to determine both open and closed loop dynamic characteristics. Author

A90-29456*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
AN ANALYTICAL STUDY OF A SIX DEGREE-OF-FREEDOM ACTIVE TRUSS FOR USE IN VIBRATION CONTROL
ROBERT H. WYNN, JR., HARRY H. ROBERTSHAW (Virginia Polytechnic Institute and State University, Blacksburg), and C. GARNETT HORNER (NASA, Langley Research Center, Hampton, VA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2351-2358. refs
(Contract NAG1-933)
(AIAA PAPER 90-1164) Copyright

An analytical study of the vibration control capabilities of three configurations of an active truss is presented. The truss studied is composed of two bays of an octahedral-octahedral configuration.

The three configurations of the active truss studies are: all six battens activated (6 DOF), the top three battens activated (3 DOF), and the bottom three battens activated (3 DOF). The closed-loop vibration control response of these three configurations are studied with respect to: vibration attenuation, energy utilized, and the effects of motor drive amplifier saturation non-linearities. Author

A90-29457#
VIBRATION SUPPRESSION BY VARIABLE-STIFFNESS MEMBERS
JUNJIRO ONODA, NAOYUKI WATANABE (Institute of Space and Astronautical Science, Kanagawa, Japan), TAKAO ENDO, and HIDEHIKO TAMAOKI (Nissan Motor Co., Ltd., Tokyo, Japan) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2359-2366. refs
(AIAA PAPER 90-1165) Copyright

An active vibration suppression concept, by varying the stiffness of a new type of variable-stiffness structural member, is proposed and investigated. The characteristics of this type of variable-stiffness system is shown to be different from previously studied types. The active vibration suppression with this type of variable-stiffness member is shown to be always stable. An investigation on a single-degree-of-freedom system shows potential high efficiency for this type of variable-stiffness system due to its unique characteristics. Two different types of control logic are proposed for realistic multi-degree-of-freedom structures with multiple variable-stiffness members. Numerical simulations demonstrate the effectiveness of the proposed strategy. Active vibration suppression experiments of truss structures are performed by using a variable-stiffness member and the proposed control logic, demonstrating the effectiveness of the proposed technique in actual structures. Author

A90-29458*# Duke Univ., Durham, NC.
INVERSE DYNAMICS OF ADAPTIVE SPACE CRANES WITH TIP POINT ADJUSTMENT
S. K. DAS, S. UTKU (Duke University, Durham, NC), and B. K. WADA (JPL, Pasadena, CA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2367-2374. refs
(AIAA PAPER 90-1166) Copyright

The 'space crane', which resembles a conventional solid-link robot but employs truss sections in place of links and length-adjustable bars in place of torque-generating motors, is presently characterized by means of two different inverse-dynamics schemes. While in the first of these the nominal angles are maintained between the links constituting the crane, the second scheme adjusts the nominal angles as a function of time in order to always maintain the tip of the crane along the desired (nomical) trajectory. Attention is given to the second scheme, and to a tip-adjustment method which keeps the high frequency flexibility vibration within limits and ensures numerical stability. O.C.

A90-29459*# Duke Univ., Durham, NC.
LOCATION SELECTION FOR VIBRATION CONTROLLERS IN SPACE CRANE AS ADAPTIVE STRUCTURES
L. Y. LU, S. UTKU (Duke University, Durham, NC), and B. K. WADA (JPL, Pasadena, CA) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2375-2380. refs
(Contract NAS7-100)
(AIAA PAPER 90-1167) Copyright

It is assumed that the space crane is vibrating about a known configuration which is reached at the end of some maneuver. For this configuration, r actuator locations are to be determined in order to control the first q of the structural vibration modes of the system optimizing the energy dissipation rate. A modified version of the control stratagem of Chang (1980) is applied using the structural modes of the uncontrolled crane, followed by algorithms for the actuator placement problem. Author

A90-29465#
SELF-TUNING ALGORITHMS FOR UNIFORM DAMPING CONTROL OF SPACECRAFT
LARRY SILVERBERG (North Carolina State University, Raleigh) and MARK A. NORRIS (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 2427-2436. Research supported by USAF. refs
(AIAA PAPER 90-1174) Copyright

A series of four self-tuning algorithms are developed for the uniform damping control of spacecraft. The first algorithm identifies the natural modes of vibration based on the correlation properties of the associated modal coordinates. The second algorithm identifies vibration decay rates using the modal coordinates identified by the first algorithm. The identification of the vibration decay rates is based on a modal least-squares approach. The third and fourth algorithms update the control gains to uniformly dampen the motion of the spacecraft. All four algorithms can be completed in batch or recursively in time. Numerical examples demonstrate the self-tuning algorithms. Author

A90-29466#
DYNAMICS OF THE EXOS-D SATELLITE - EFFECTS OF VARIOUS FLEXIBLE APPENDAGES
MICHIHIRO NATORI, ICHIRO NAKATANI, KEIKEN NINOMIYA (Institute of Space and Astronautical Science, Sagamihara, Japan), TOSHIHIRO KURII, and KEN MAEDA (NEC Corp., Space Development Div., Yokohama, Japan) AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990. 7 p. refs
(AIAA PAPER 90-0993) Copyright

The Japanese Exos-D satellite is examined, noting the satellite's deployable appendages for scientific measurements. The spacecraft configuration is illustrated and preliminary in-orbit data for the initial operation phase are presented. Consideration is given to the orbital parameters, attitude control system, and analytical investigations performed to predict the in-orbit behavior of the Exos-D. Wire antenna appendages such as a three-axis orthogonal loop antenna and coilable longeron extendible masts are used as electric field, VLF wave, and plasma wave detectors. The initial data on the effects of these appendages are presented, including changes in spin rate and spin period before and after deployment of the antennas. R.B.

A90-29724
EFFICIENT ALGORITHMS FOR THE DYNAMICAL SIMULATION OF STRUCTURALLY FLEXIBLE MANIPULATORS
D. F. GOLLA, K. J. BUHARIWALA (Spar Aerospace, Ltd., Weston, Canada), P. C. HUGHES, and G. M. T. D'ELEUTERIO (Dynacon Enteprises, Ltd., Downsview, Canada) Canadian Society for Mechanical Engineering, Transactions (ISSN 0315-8977), vol. 13, no. 4, 1989, p. 97-102. Research sponsored by NSERC. refs
Copyright

Consideration is given to the development of highly efficient computer codes for the simulation of the dynamics of space manipulators with structurally flexible members. A discussion of dynamical principles and symbology are limited to focus attention on how actually to solve the complex system of motion equations. Two types of algorithm are discussed: global algorithms of O(N3), in wich a single set of motion equations is written for the manipulator as a whole; and recursive algorithms of O(N), in which motion equations are solved on a body-by-body basis. The algorithms described are compared numerically for computational efficiency. The recursive algorithms show superior speed for structurally flexible manipulators, especially in space applications where the initial body (orbiter) is unconstrained. Author

A90-29725
MINIMIZATION OF VIBRATION OF AXIALLY MOVING BEAMS
S. KALAYCIOGLU and A. K. MISRA (McGill Universite, Montreal, Canada) Canadian Society for Mechanical Engineering, Transactions (ISSN 0315-8977), vol. 13, no. 4, 1989, p. 133-143. refs
(Contract NSERC-A-2181)
Copyright

The vibrations of axially moving beams, which may represent appendages being deployed from a spacecraft or a prismatic joint in a flexible manipulator, are considered for various deployment schemes in an attempt to minimize the vibrations. The schemes considered are: uniform deployment rate, exponential extension, uniform variation of the squared length, and sinusoidal extension. The first two schemes are found to lead to comparatively large vibratory displacements in comparison with the other two schemes. An optical deployment scheme is devised by minimizing an objective function involving the square of the vibratory displacement. The optimal scheme, however, has only a marginal advantage over sinusoidal extension. The latter is recommended since in this scheme the axial velocity changes slowly and is zero at the end of deployment. V.L.

A90-30062* Virginia Polytechnic Inst. and State Univ., Blacksburg.
VARIABLE GEOMETRY TRUSSES
H. H. ROBERTSHAW and C. F. REINHOLTZ (Virginia Polytechnic Institute and State University, Blacksburg) IN: Smart materials, structures, and mathematical issues; U.S. Army Research Office Workshop, Blacksburg, VA, Sept. 15, 16, 1988, Selected Papers. Lancaster, PA, Technomic Publishing Co., Inc., 1989, p. 105-120. refs
(Contract NAG1-570)
Copyright

Vibration control and kinematic control with variable-geometry trusses are covered. The analytical approach taken is to model each actuator with lumped masses and model a beam with finite elements, including in each model the generalized reaction forces from the beam on the actuator or vice versa. It is concluded that, from an operational standpoint, the variable-geometry truss actuator is more favorable than the inertia-type actuator. A spatial variable-geometry truss is used to test out rudimentary robotic tasks. V.T.

A90-30064
APPLICATIONS FOR SMART MATERIALS IN THE FIELD OF VIBRATION CONTROL
T. G. DUCLOS, J. P. COULTER, and L. R. MILLER (Lord Corp., Thomas Lord Research Center, Cary, NC) IN: Smart materials, structures, and mathematical issues; U.S. Army Research Office Workshop, Blacksburg, VA, Sept. 15, 16, 1988, Selected Papers. Lancaster, PA, Technomic Publishing Co., Inc., 1989, p. 132-146. refs
Copyright

Integration of control strategy and hardware is discussed with four vibration isolation examples: (1) isolation of a mass with a single degree of freedom; (2) isolation of a mass with multiple degrees of freedom; (3) isolation of an engine on a structure; and (4) isolation of a structure from distributed inputs. In each of the examples, some solutions for the problems including the potential use of smart materials are considered, and applications where the problems are prevalent are analyzed. V.T.

A90-30095* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MAXIMUM LIKELIHOOD ESTIMATION FOR DISTRIBUTED PARAMETER MODELS OF FLEXIBLE SPACECRAFT
L. W. TAYLOR, JR. and J. L. WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: Identification and system parameter estimation 1988; IFAC/IFORS Symposium, 8th, Beijing, People's Republic of China, Aug. 27-31, 1988, Selected Papers. Volume 1. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 415-420. refs
Copyright

A distributed-parameter model of the NASA Solar Array Flight Experiment spacecraft structure is constructed on the basis of measurement data and analyzed to generate a priori estimates of modal frequencies and mode shapes. A Newton-Raphson maximum-likelihood algorithm is applied to determine the unknown parameters, using a truncated model for the estimation and the full model for the computation of the higher modes. Numerical results are presented in a series of graphs and briefly discussed, and the significant improvement in computation speed obtained by parallel implementation of the method on a supercomputer is noted. T.K.

A90-30721
DESIGN OF CONTROLLERS FOR FLEXIBLE STRUCTURES USING UNCERTAIN MODELING TECHNIQUES AND FINITE-ELEMENT BASED CAV
BRUCE L. WALCOTT and CAO YONG (Kentucky, University, Lexington) IN: NAECON 89; Proceedings of the IEEE National Aerospace and Electronics Conference, Dayton, OH, May 22-26, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 439-445. Research supported by the University of Kentucky. refs
Copyright

A design methodology for controllers of flexible structures based on uncertain modeling techniques is presented. The particular problem which is addressed is the control of a single flexible link planar manipulator. An extremely simple control strategy is derived by treating the effects of compliance as an uncertain torque about which no a priori knowledge is assumed other than a bound. However, because the torque is modeled as an uncertainty, it is necessary to perform computer-aided verification (CAV) of the present design on a finite-element simulation program which is based on the standard Bernoulli-Euler model found in literature studies. I.E.

A90-30897* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
VIBRATION SUPPRESSION FOR PRECISION SEGMENTED REFLECTOR BACKUP STRUCTURE
G.-S. CHEN, J. A. GARBA, and B. K. WADA (JPL, Pasadena, CA) IN: Active telescope systems; Proceedings of the Meeting, Orlando, FL, Mar. 28-31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 508-520. refs
Copyright

An ongoing effort at the JPL on vibration suppression for the Precision Segmented Reflector backup structure is centered on the vibration damping augmentation through a system consisting of active and passive damping members. An active member is a structural member with built-in piezoelectric actuator and sensors. An efficient method was developed for optimal placement of active and passive damping members in the truss-type backup structure. A simple synergistic model between the active and passive damping was proposed based on a weighted energy dissipation criterion. A baseline passive member design with constrained viscoelastic material treatment was used as the source of passive damping. Author

A90-31450#
MODELING METHODS AND CONTROLLERS FOR DISTRIBUTED-PARAMETER SYSTEMS [MODELLISTICA E DISPOSITIVI DI CONTROLLO PER SISTEMI A PARAMETRI DISTRIBUITI]
G. CAPITANI and M. TIBALDI (Bologna, Universita, Italy) Alta Frequenza - Rivista di Elettronica (ISSN 1120-1908), vol. 1, Oct.-Dec. 1989, p. 247-257. In Italian. refs
Copyright

The dynamic analysis and control problem for flexible structures represented as distributed-parameter systems is examined in a review of current analytical approaches. Topics addressed include the general governing equations for flexible structures, the placement of sensors and actuators (controllability and

observability), models for simple flexible structures, techniques for reducing the order of a model, structural damping, and colocated sensors and actuators. Diagrams and graphs of typical numerical results are provided. T.K.

N90-10080*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PROCEEDINGS OF THE WORKSHOP ON COMPUTATIONAL ASPECTS IN THE CONTROL OF FLEXIBLE SYSTEMS, PART 1
LAWRENCE W. TAYLOR, JR., comp. May 1989 492 p Workshop held in Williamsburg, VA, 12-14 Jul. 1988
(NASA-TM-101578-PT-1; NAS 1.15:101578-PT-1) Avail: NTIS HC A21/MF A03 CSCL 22/2

Control/Structures Integration program software needs, computer aided control engineering for flexible spacecraft, computer aided design, computational efficiency and capability, modeling and parameter estimation, and control synthesis and optimization software for flexible structures and robots are among the topics discussed.

N90-10083*# Control Research Corp., Lexington, MA.
ADDITIONAL SOFTWARE DEVELOPMENTS WANTED FOR MODELING AND CONTROL OF FLEXIBLE SPACE SYSTEMS
JIGUAN GENE LIN *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 49-63 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Existing modeling and control software packages are either inadequate or inefficient for applications to flexible space structures. Some additional software developments are wanted for effective design and evaluation of the control systems. The following are discussed: (1) linear-quadratic optimal regulators as usual can be designed using various modern control design software packages, (2) modal dashpots are very effective output-feedback vibration controllers for flexible structures, not only effective for augmenting a small amount of active damping to a large number of vibration modes (like the so-called low-authority structural controllers), but also effective for quick suppression of large vibrations (like high-authority structural controllers), and (3) the actual performance of any control design needs to be evaluated against a faithful model of the flexible structure to be controlled. The potential of destabilization or serious performance degradation needs to be detected by numerical simulation of the structure with the control loops being closed. Author

N90-10084*# Communications Research Centre, Ottawa (Ontario).
FLEXIBLE STRUCTURE CONTROL EXPERIMENTS USING A REAL-TIME WORKSTATION FOR COMPUTER-AIDED CONTROL ENGINEERING
MICHAEL E. STIEBER *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 67-88 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A Real-Time Workstation for Computer-Aided Control Engineering has been developed jointly by the Communications Research Centre (CRC) and Ruhr-Universitaet Bochum (RUB), West Germany. The system is presently used for the development and experimental verification of control techniques for large space systems with significant structural flexibility. The Real-Time Workstation essentially is an implementation of RUB's extensive Computer-Aided Control Engineering package KEDDC on an INTEL micro-computer running under the RMS real-time operating system. The portable system supports system identification, analysis, control design and simulation, as well as the immediate implementation and test of control systems. The Real-Time Workstation is currently being used by CRC to study control/structure interaction on a ground-based structure called DAISY, whose design was inspired by a reflector antenna. DAISY emulates the dynamics of a large flexible spacecraft with the following characteristics: rigid body modes, many clustered vibration modes with low frequencies and extremely low damping. The Real-Time Workstation was found to be a very powerful tool for experimental studies, supporting control design and simulation, and conducting and evaluating tests withn one integrated environment. Author

N90-10087*# Structural Dynamics Research Corp., San Diego, CA.
CONTROL/STRUCTURE INTERACTION METHODS FOR SPACE STATION POWER SYSTEMS
PAUL BLELLOCH *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 121-137 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

The Structural Dynamics Research Corporation and the NASA Lewis Research Center have been working together to develop tools and methods for the analysis of control/structure interaction problems related to the space station power systems. Flexible modes of the solar arrays below 0.1 Hz, suggest that even for relatively slow control systems, the potential for control/structure interaction exists. The emphasis of the effort has been to develop tools which couple NASTRAN's powerful capabilities in structural dynamics with EASY5's powerful capabilities in control systems analysis. One product is an interface software package called CO-ST-IN for COntrol-STructure-INteraction. CO-ST-IN acts to translate data between NASTRAN and EASY5, facilitating the analysis of complex coupled problems. Interfaces to SDRC I-DEAS and MATRIXx are also offered. Beside transferring standard modal information, CO-ST-IN implements a number of advanced methods. These include a modal ordering algorithm that helps eliminate uncontrollable or unobservable modes from the analysis, an implementation of the more accurate mode acceleration algorithm for recovery of element forces and stresses directly in EASY5 and an implementation of fixed interface modes in NASTRAN, which reduces the error in the closed-loop model due to the use of truncated mode sets. Author

N90-10090*# Boeing Co., Seattle, WA.
MODELING AND CONTROL SYSTEM DESIGN AND ANALYSIS TOOLS FOR FLEXIBLE STRUCTURES
AMIR A. ANISSIPOUR, RUSSELL A. BENSON, and EDWARD E. COLEMAN *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 221-241 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Described here are Boeing software tools used for the development of control laws of flexible structures. The Boeing Company has developed a software tool called Modern Control Software Package (MPAC). MPAC provides the environment necessary for linear model development, analysis, and controller design for large models of flexible structures. There are two features of MPAC which are particularly appropriate for use with large models: (1) numerical accuracy and (2) label-driven nature. With the first feature MPAC uses double precision arithmetic for all numerical operations and relies on EISPAC and LINPACK for the numerical foundation. With the second feature, all MPAC model inputs, outputs, and states are referenced by user-defined labels. This feature allows model modification while maintaining the same state, input, and output names. In addition, there is no need for the user to keep track of a model variable's matrix row and colunm locations. There is a wide range of model manipulation, analysis, and design features within the numerically robust and flexible environment provided by MPAC. Models can be built or modified using either state space or transfer function representations. Existing models can be combined via parallel, series, and feedback connections; and loops of a closed-loop model may be broken for analysis. Author

N90-10091*# Mechanical Dynamics, Inc., Ann Arbor, MI. Product Technology Group.
LUMPED MASS FORMULATIONS FOR MODELING FLEXIBLE BODY SYSTEMS
RAJIV RAMPALLI *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the

Control of Flexible Systems, Part 1 p 243-264 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

The efforts of Mechanical Dynamics, Inc. in obtaining a general formulation for flexible bodies in a multibody setting are discussed. The efforts being supported by MDI, both in house and externally are summarized. The feasibility of using lumped mass approaches to modeling flexibility in a multibody dynamics context is examined. The kinematics and kinetics for a simple system consisting of two rigid bodies connected together by an elastic beam are developed in detail. Accuracy, efficiency and ease of use using this approach are some of the issues that are then looked at. The formulation is then generalized to a superelement containing several nodes and connecting several bodies. Superelement kinematics and kinetics equations are developed. The feasibility and effectiveness of the method is illustrated by the use of some examples illustrating phenomena common in the context of spacecraft motions.

Author

N90-10092*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

A COMPARISON OF SOFTWARE FOR THE MODELING AND CONTROL OF FLEXIBLE SYSTEMS

LAWRENCE W. TAYLOR, JR. *In its* Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 265-279 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A researcher proposes a cooperative effort among specialists who use or develop software for simulating and analyzing the control of flexible aerospace systems. A comparison of existing software for modeling control systems and flexible structures, applied to several example problems would be quite valuable. The comparison would indicate computational efficiency and capabilities with respect to handling nonlinearities and graphical output. Because of the diversity of applications of such software, the researcher believes that the proposed cooperative effort can transcend projects involving specific applications. Comparisons of software capability and efficiency can be made and gaps can be identified. In this way the results of the cooperative effort can provide guidance for individual projects. Several charts which outline the objectives and approach of the proposed cooperative effort are given here.

Author

N90-10093*# Comtek Co., Grafton, VA.

A FINITE ELEMENT APPROACH FOR LARGE MOTION DYNAMIC ANALYSIS OF MULTIBODY STRUCTURES IN SPACE

CHE-WEI CHANG *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 283-321 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A three-dimensional finite element formulation for modeling the transient dynamics of constrained multibody space sructures with truss-like configurations is presented. Convected coordinate systems are used to define rigid-body motion of individual elements in the system. These systems are located at one end of each element and are oriented such that one axis passes through the other end of the element. Deformation of each element, relative to its convected coordinate system, is defined by cubic flexural shape functions as used in finite element methods of structural analysis. The formulation is oriented toward joint dominated structures and places the generalized coordinates at the joint. A transformation matrix is derived to integrate joint degree-of-freedom into the equations of motion of the element. Based on the derivation, a general-purpose code LATDYN (Large Angle Transient DYNamics) was developed. Two examples are presented to illustrate the application of the code. For the spin-up of a flexible beam, results are compared with existing solutions available in the literature. For the deployment of one bay of a deployable space truss (the Minimast), results are verified by the geometric knowledge of the system and converged solution of a successively refined model.

Author

N90-10094*# Michigan Univ., Ann Arbor.

ENHANCED ELEMENT-SPECIFIC MODAL FORMULATIONS FOR FLEXIBLE MULTIBODY DYNAMICS

ROBERT R. RYAN *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 323-348 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

The accuracy of current flexible multibody formalisms based on assumed modes is examined in the context of standard spacecraft motions involving structural components undergoing both slow and fast overall translational and rotational motions as well as small deformations. Limitations of current techniques in treating: (1) element-specific coupling behavior of large motion and small deformation, and (2) motion-induced structural stiffness variations, are noted. The roles of nonlinear and linear elastic structural theories in accurately predicting transient large-displacement dynamic behavior of flexible multibody systems are examined in detail. Coupling effects between deformation and overall motion are carefully scrutinized in the context of assumed-mode discretization techniques. Consistently linearized beam, plate, and shell formulations involving in-plane stretch variables are proposed and shown to yield very accurate simulation results and extremely fast modal convergence for most motions involving small strains. In some particular cases, however, in which membrane stiffness dominates bending stiffness, a nonlinear strain formulation is required in order to capture proper coupling between deformation and overall motion.

Author

N90-10095*# DYNACS Engineering Co., Inc., Clearwater, FL.

EFFICIENCY AND CAPABILITIES OF MULTI-BODY SIMULATIONS

R. J. VANDERVOORT *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 349-369 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Simulation efficiency and capability go hand in hand. The more capability you have the lower the efficiency will be. The efficiency and capabilities are discussed. The lesson learned about generic simulation is: Don't rule out any capabilities at the beginning, but keep each one on a switch so it can be bypassed when warranted by a specific application.

Author

N90-10096*# TRW Space Technology Labs., Redondo Beach, CA.

EXPLICIT MODELING AND COMPUTATIONAL LOAD DISTRIBUTION FOR CONCURRENT PROCESSING SIMULATION OF THE SPACE STATION

R. GLUCK *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 371-413 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Two important aspects of concurrent processing under development at TRW are discussed. These are: (1) the derivation of explicit mathematical models of multibody dynamic systems, and (2) a balanced computational load distribution (BCLD) among loosely coupled computational units (processors) of a concurrent processing system. The developed methodologies are demonstrated by way of an application to the Phase 1 of the Space Station - a task being performed by TRW under NASA/JSC contract NAS9-17778. The mathematical model of the Space Station consists of three interconnected flexible bodies capable of undergoing large, rigid-body motion with respect to each other. Body 1 is the main central body and contains the pressurized modules inboard of the two Alpha gimbals. Bodies 2 and 3 are the starboard and port bodies connected to Body 1 at the Alpha gimbals and include all components on the transverse booms outboard of the Alpha gimbals (including the solar arrays). The control systems in the model maintain Body 1 in a prescribed 3-axis attitude control mode, while producing large-angle rotations of the flexible solar arrays to position them normal to the sun-line.

Author

N90-10097*# Michigan Univ., Ann Arbor.
SIMULATION OF FLEXIBLE STRUCTURES WITH IMPACT: EXPERIMENTAL VALIDATION Abstract Only
A. GALIP ULSOY *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 415 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

The simulation of the dynamic behavior of flexible structures with impact, is experimentally and numerically investigated. A radially rotating flexible beam attached to a rigid shaft is considered. Both experimental and numerical studies are undertaken. Experimental studies how excellent agreement with simulation studies using both the momentum balance (coefficient of friction), and spring-dashpot (impact pair) models. The simulation studies are even capable of predicting the high-speed multiple impacts which occur due to structural flexibility and which are experimentally observed using high-speed video photography. The results of the studies show that a simple momentum balance (coefficient of restitution) method for simulating the impact is sufficiently accurate in predicting the dynamic behavior of the system for most engineering applications. The momentum balance method cannot simulate the impact force which develops during the contact duration, but is computationally very efficient. The spring-dashpot model is more difficult to develop and requires significantly larger computation time, but can simulate impact forces and stresses due to impact. The momentum balance (coefficient of restitution) method, although strictly not applicable to flexible bodies, has been shown to provide an accurate and computationally efficient method for simulating the dynamic behavior of flexible structures with impact when contact stresses are not needed. Author

N90-10101*# Michigan Univ., Ann Arbor. Applied Dynamics International.
A PERFORMANCE COMPARISON OF INTEGRATION ALGORITHMS IN SIMULATING FLEXIBLE STRUCTURES
R. M. HOWE *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 495-514 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Asymptotic formulas for the characteristic root errors as well as transfer function gain and phase errors are presented for a number of traditional and new integration methods. Normalized stability regions in the lambda h plane are compared for the various methods. In particular, it is shown that a modified form of Euler integration with root matching is an especially efficient method for simulating lightly-damped structural modes. The method has been used successfully for structural bending modes in the real-time simulation of missiles. Performance of this algorithm is compared with other special algorithms, including the state-transition method. A predictor-corrector version of the modified Euler algorithm permits it to be extended to the simulation of nonlinear models of the type likely to be obtained when using the discretized structure approach. Performance of the different integration methods is also compared for integration step sizes larger than those for which the asymptotic formulas are valid. It is concluded that many traditional integration methods, such as RD-4, are not competitive in the simulation of lightly damped structures. Author

N90-10102*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OPTICAL PROCESSING FOR DISTRIBUTED SENSORS IN CONTROL OF FLEXIBLE SPACECRAFT
RAYMOND C. MONTGOMERY, SHARON S. WELCH, MICHAEL F. BARSKY, and IAN T. GALLIMORE *In its* Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 1 p 515-545 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A recent potential of distributed image processing is discussed. Applications in the control of flexible spacecraft are emphasized. Devices are currently being developed at NASA and in universities and industries that allow the real-time processing of holographic images. Within 5 years, it is expected that, in real-time, one may add or subtract holographic images at optical accuracy. Images are stored and processed in crystal mediums. The accuracy of their storage and processing is dictated by the grating level of laser holograms. It is far greater than that achievable using current analog-to-digital, pixel oriented, image digitizing and computing techniques. Processors using image processing algebra can conceptually be designed to mechanize Fourier transforms, least square lattice filters, and other complex control system operations. Thus, actuator command inputs derived from complex control laws involving distributed holographic images can be generated by such an image processor. Plans are revealed for the development of a Conjugate Optics Processor for control of a flexible object. Author

N90-10103*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PROCEEDINGS OF THE WORKSHOP ON COMPUTATIONAL ASPECTS IN THE CONTROL OF FLEXIBLE SYSTEMS, PART 2
LAWRENCE W. TAYLOR, JR., comp. May 1989 482 p *Workshop held in Williamsburg, VA, 12-14 Jul. 1988*
(NASA-TM-101578-PT-2; NAS 1.15:101578-PT-2) Avail: NTIS HC A21/MF A03 CSCL 22/2

The Control/Structures Integration Program, a survey of available software for control of flexible structures, computational efficiency and capability, modeling and parameter estimation, and control synthesis and optimization software are discussed.

N90-10105*# Boeing Commercial Airplane Co., Seattle, WA.
MINIMUM-VARIANCE REDUCED-ORDER ESTIMATION ALGORITHMS FROM PONTRYGIN'S MINIMUM PRINCIPLE Abstract Only
YAGHOOB S. EBRAHIMI *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 581 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A uniform derivation of minimum-variance reduced-order (MVRO) filter-smoother algorithms from Pontrygin's Minimum Principle is presented. An appropriate performance index for a general class of reduced order estimation problem is formulated herein to yield optimal results over the entire time interval of estimation. These results provide quantitative criteria for measuring the performance of certain classes of heuristically designed, suboptimal reduced-order estimators as well as explicit guidance to the suboptimal filter design process with both continuous and discrete filter-smoother algorithms being considered. By the duality principle, the algorithms of reduced-order estimation can be easily extended to the deterministic problems of optimal control (i.e., the regulator and linear tracking problem). Author

N90-10107*# Georgia Inst. of Tech., Atlanta.
AUTOMATED MODEL FORMULATION FOR TIME-VARYING FLEXIBLE STRUCTURES Abstract Only
B. J. GLASS and S. HANAGUD *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 631 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Presented here is an identification technique that uses the sensor information to choose a new model out of a finite set of discrete model space, in order to follow the observed changes to the given time varying flexible structure. Boundary condition sets or other information on model variations are used to organize the set of possible models laterally into a search tree with levels of abstraction used to order the models vertically within branches. An object-oriented programming approach is used to represent the model set in the search tree. A modified A (asterisk) best first search algorithm finds the model where the model response best matches the current observations. Several extensions to this methodology are discussed. Methods of possible integration of rules with the current search algorithm are considered to give weight to interpreted trends that may be found in a series of observations. This capability might lead, for instance, to identifying a model that incorporates a progressive damage rather than with incorrect paramenters such as added mass. Another new direction is to consider the use of noisy time domain sensor feedback

rather than frequency domain information in the search algorithm to improve the real-time capability of the developed procedure.
Author

N90-10108*# Calspan Advanced Technology Center, Buffalo, NY.
NUMERICALLY EFFICIENT ALGORITHM FOR MODEL DEVELOPMENT OF HIGH-ORDER SYSTEMS
L. O. PARADA *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 633-650 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A technique for estimating transfer functions in partial fraction expansion form from frequency response data for a high-order system is presented. The problem formulation avoids many of the numerical difficulties associated with high-order polynomials and has the advantage of having the option to fix the camping and frequency of a mode, if known, during the estimation process. The resulting transfer function(s) may be converted to Jordan-Form time domain equations directly. During the implementation of this technique, a frequency and amplitude normalizing window was developed that maximized the efficiency of the optimization algorithm. The combination of estimating the transfer function in factored form, the ability to fix preciously determined parameters and the effectiveness of the normalizing window led to a progressive approach to synthesizing transfer functions from frequency response data for high-order systems. Author

N90-10109*# California Univ., Los Angeles.
ON MODELLING NONLINEAR DAMPING IN DISTRIBUTED PARAMETER SYSTEMS
A. V. BALAKRISHNAN *In* NASA. Langley Research Center, Proceedings of the Workshop n Computational Aspects in the Control of Flexible Systems, Part 2 p 651-664 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Information is given in viewgraph form on the modeling of nonlinear damping in distributed parameter systems. Author

N90-10110*# Howard Univ., Washington, DC.
USE OF THE QUASILINEARIZATION ALGORITHM FOR THE SIMULATION OF LSS SLEWING
FEIYUE LI and P. M. BAINUM *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 665-690 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

The use of the Maximum Principle for the large angle slewing of large space structures (LSS) usually results in the so-called two-point boundary-value problem, in which many requirements (e.g., minimum time, small amplitude, and limited control power, etc.) must be satisfied simultaneously. The successful solution of this problem depends largely on the use of an efficient numerical algorithm. There are many candidate algorithms available for this problem (e.g., quasilinearization, gradient, etc.). Here researchers discuss only the quasilinearization method which has been used for several cases of large angle slewing of LSS. The basic idea of this algorithm is to make a series of successive approximations of the solution from a particular solvable case (linear or nonlinear) to a more general practical case. For the rigid spacecraft slewing problem with no constraints on the controls, the solution procedure can be found in the literature. This procedure needs to be modified if a minimum time for the slewing problem is desired with control limits given. Recently, an indirect method for finding the minimum time was developed to meet all these requirements. For the general mixed (including both rigid and flexible parts) problem, an additional constraint of small vibrational amplitude on the flexible parts is imposed. Author

N90-10111*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CONTROL LAW SYNTHESIS AND OPTIMIZATION SOFTWARE FOR LARGE ORDER AEROSERVOELASTIC SYSTEMS
V. MUKHOPADHYAY, A. POTOTZKY, and THOMAS NOLL *In its* Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 693-707 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A flexible aircraft or space structure with active control is typically modeled by a large-order state space system of equations in order to accurately represent the rigid and flexible body modes, unsteady aerodynamic forces, actuator dynamics and gust spectra. The control law of this multi-input/multi-output (MIMO) system is expected to satisfy multiple design requirements on the dynamic loads, responses, actuator deflection and rate limitations, as well as maintain certain stability margins, yet should be simple enough to be implemented on an onboard digital microprocessor. A software package for performing an analog or digital control law synthesis for such a system, using optimal control theory and constrained optimization techniques is described. Author

N90-10114*# Boeing Co., Seattle, WA.
CONTROLLING FLEXIBLE STRUCTURES: A SURVEY OF METHODS
RUSSELL A. BENSON and EDWARD E. COLEMAN *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 779-799 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Most of the presently available control system design techniques applicable to flexible structure problems were developed to design controllers for rigid body systems. Although many of these design methods can be applied to flexible dynamics problems, recently developed techniques may be more suitable for flexible structure controller design. The purpose of this presentation is to examine briefly the peculiarities of the dynamics of flexible structures and to stimulate discussion about top level controller design approaches when designing controllers for flexible structures. Presented here is a suggestion of a set of categories of design methods for designing controllers for flexible structures as well as a discussion of the advantages and disadvantages of each category. No attempt has been made herein to select one category of design techniques as the best for flexible structure controller design. Instead, it is hoped that the structure suggested by these categories will facilitate further discussion on the merits of particular methods that will eventually point to those design techniques suitable for further development. Author

N90-10118*# General Electric Co., Schenectady, NY. Corporate Research and Development Center.
INPUT-OUTPUT ORIENTED COMPUTATION ALGORITHMS FOR THE CONTROL OF LARGE FLEXIBLE STRUCTURES
K. D. MINTO *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 883-901 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

An overview is given of work in progress aimed at developing computational algorithms addressing two important aspects in the control of large flexible space structures; namely, the selection and placement of sensors and actuators, and the resulting multivariable control law design problem. The issue of sensor/actuator set selection is particularly crucial to obtaining a satisfactory control design, as clearly a poor choice will inherently limit the degree to which good control can be achieved. With regard to control law design, the researchers are driven by concerns stemming from the practical issues associated with eventual implementation of multivariable control laws, such as reliability, limit protection, multimode operation, sampling rate selection, processor throughput, etc. Naturally, the burden imposed by dealing with these aspects of the problem can be reduced by ensuring that the complexity of the compensator is minimized. Our approach to these problems is based on extensions to input/output oriented techniques that have proven useful in the design of multivariable control systems for aircraft engines. In particular, researchers are exploring the use of relative gain analysis and the condition number as a means of quantifying the process of sensor/actuator selection and placement for shape control of a large space platform.
Author

N90-10121*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
ACTIVE VIBRATION MITIGATION OF DISTRIBUTED PARAMETER, SMART-TYPE STRUCTURES USING PSEUDO-FEEDBACK OPTIMAL CONTROL (PFOC)
W. N. PATTEN, H. H. ROBERTSHAW, D. PIERPONT, and R. H. WYNN *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 957-981 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

A new, near-optimal feedback control technique is introduced that is shown to provide excellent vibration attenuation for those distributed parameter systems that are often encountered in the areas of aeroservoelasticity and large space systems. The technique relies on a novel solution methodology for the classical optimal control problem. Specifically, the quadratic regulator control problem for a flexible vibrating structure is first cast in a weak functional form that admits an approximate solution. The necessary conditions (first-order) are then solved via a time finite-element method. The procedure produces a low dimensional, algebraic parameterization of the optimal control problem that provides a rigorous basis for a discrete controller with a first-order like hold output. Simulation has shown that the algorithm can successfully control a wide variety of plant forms including multi-input/multi-output systems and systems exhibiting significant nonlinearities. In order to firmly establish the efficacy of the algorithm, a laboratory control experiment was implemented to provide planar (bending) vibration attenuation of a highly flexible beam (with a first clamped-free mode of approximately 0.5 Hz). Author

N90-10122*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
SHAPE CONTROL OF HIGH DEGREE-OF-FREEDOM VARIABLE GEOMETRY TRUSSES
R. J. SALERNO, C. F. REINHOLTZ, and H. H. ROBERTSHAW *In* NASA. Langley Research Center, Proceedings of the Workshop on Computational Aspects in the Control of Flexible Systems, Part 2 p 983-1002 May 1989
Avail: NTIS HC A21/MF A03 CSCL 22/2

Common static trusses are constrained to permit no relative motion between truss elements. A Variable Geometry Truss (VGT), however, is a truss which contains some number of variable length links. The extensible links allow the truss to change shape in a precise, controllable manner. These changes can also be used to control the vibrational response of a truss structure or to perform robotic tasks. Many geometric configurations, both planar and spatial, are possible candidates for VGT manipulators. Here, only two geometries are discussed; the three degree-of-freedom (DOF) spatial octahedral/octahedral truss and the three DOF planar tetrahedral truss. These truss geometries are used as the fundamental element in a repeating chain of trusses. This results in a highly dexterous manipulator with perhaps 30 to 60 degrees of freedom that retains the favorable stiffness properties of a conventional truss. From a fixed base, this type of manipulator could perform shape or vibration control while extending and snaking through complex passageways or moving around obstacles to perform robotic tasks. The approach taken here is to first concentrate on fully understanding the forward and inverse kinematics of the fundamental elements and then utilizing the insight thus gained to solve the more complex problem of the kinematic chains. Author

N90-10984# WEA, Cambridge, MA.
WAVE-MODE COORDINATE ANALYSIS OF L JUNCTION IN LSS Annual Report, 15 Jan. 1988 - 30 Mar. 1989
JAMES H. WILLIAMS, JR. and DERRICK S. WEBB 30 Mar. 1989 71 p
(Contract F49620-88-C-0036; AF PROJ. 2302)
(AD-A211116; AFOSR-89-1063TR) Avail: NTIS HC A04/MF A01 CSCL 22/2

The propagation of structural disturbances through large space structures is of practical interest in the design and nondestructive evaluation of such large space systems. Many wave propagation analyses of large space structures must consider the reflection and transmission of waves at interconnecting junctions. Using the concepts of wave-mode coordinate analysis, a frequency domain study of wave propagation through an L lattice junction is conducted. Each lattice member is modeled as a combined longitudinal rod and Timoshenko beam. The joint in the assembly is modeled as a rigid mass of negligible geometric extent with mass rotary inertia. In order to determine the input wave-mode vector, the joint coupling matrix is applied to a point along a lattice member which is subjected to externally applied sinusoidal loads. The input wave-mode vector contains a mathematical description of the waves generated by the applied sinusoidal loads. The joint coupling matrix for the rigid joint with mass and rotary inertia is presented and used to obtain the scattering matrix of the L junction. The scattering matrix contains the reflection and transmission coefficients which the incoming waves will encounter as they enter the joint. Finally, the frequency response function of each Fourier transformed state variable of the transmitted waves is presented analytically. GRA

N90-10985# Systems Engineering Labs., Inc., Greenbelt, MD.
FREQUENCY DOMAIN DESIGN OF ROBUST CONTROLLERS FOR SPACE STRUCTURES Final Report, Sep. 1988 - Feb. 1989
WILLIAM H. BENNETT and C. LAVIGNA Aug. 1989 60 p
(Contract F33615-88-C-3215)
(AD-A211172; SEI-89-03-15-WB; WRDC-TR-89-3089) Avail: NTIS HC A04/MF A01 CSCL 12/1

The purpose of the Phase 1 effort was to investigate and demonstrate the feasibility of a new class of computational algorithms for the design of high performance control laws for flexible space structures based on frequency response modeling and to consider advanced techniques for the implementation of real time control for precision (wide bandwidth) applications. Typical applications requiring advanced realtime control of flexible space structure include vibration suppression and isolation of payload subsystems. Performance of vibration suppression and isolation systems are critical factors effecting achievable levels of performance for space based optical systems. In the Phase 1 effort, a prototype software code was developed for testing computational algorithms for spectral factorization, causal projection, and coprime factorization-critical steps in frequency domain design of precision control laws. GRA

N90-10991# Communications Research Centre, Ottawa (Ontario).
EXPERIMENTAL IDENTIFICATION OF MODAL MOMENTUM COEFFICIENTS AND MODAL IDENTITY PARAMETERS OF THE FLECS STRUCTURE
F. R. VIGNERON, R. K. SINGAL, and Y. SOUCY *In* ESA, Spacecraft Structures and Mechanical Testing p 39-45 Jan. 1989 Prepared in cooperation with DFVLR, Porz, Fed. Republic of Germany
Copyright Avail: NTIS HC A99/MF E06

The Flexible European Communications Satellite type Structure (FLECS), representative of a typical modular spacecraft in terms of mass properties and modal density, is used to identify modal momentum coefficients and modal identity parameters. The results of laboratory tests aimed at assessing the practicality of the procedure in the case of a complex structure are described. It is concluded that the procedure can be used but that there are pitfalls to be avoided. These pitfalls and ways of avoiding them are described. ESA

N90-10992# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. of Aeroelasticity.
UPDATING OF FINITE ELEMENT MODEL BY MEANS OF NORMAL MODE PARAMETERS
N. NIEDBAL, E. KLUSOWSKI, and W. LUBER (Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn, Germany, F.R.) *In*

ESA, Spacecraft Structures and Mechanical Testing p 47-53 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The updating procedure used in reconciling two data sets in order to create a realistic and reliable dynamic model is presented. The updated mass and stiffness values of a truss structure are outlined. The use of finite element analysis and modal survey tests in structural dynamic qualification and verification of aerospace structures is described. The need of a method for reconciling discrepancies between analytical and experimental normal mode parameters is stressed. ESA

N90-10993# Imperial Coll. of Science and Technology, London (England).
A REVIEW OF THE ERROR OF MATRIX METHOD (EMM) FOR STRUCTURAL DYNAMIC MODEL COMPARISON
D. J. EWINS, J. HE, and N. LIEVEN *In* ESA, Spacecraft Structures and Mechanical Testing p 55-62 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The development of the Error Matrix Method (EMM) and some of the envisaged improvements of the method are discussed. Different model reduction methods as well as different graphic presentations of the results are called for. How the EMM method can be used in predicting vibration characteristics is described. The need for such methods in load prediction, stability analysis, system design, and structural coupling applications is discussed. ESA

N90-10997# Politecnico di Torino (Italy). Dept. of Aerospace Engineering.
A CONTRIBUTION TO THE STABILITY ANALYSIS OF LARGE SPACE STRUCTURES
E. ANTONA and M. DISCIUVA *In* ESA, Spacecraft Structures and Mechanical Testing p 85-89 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A general perturbation approach for the solution of linear eigenvalue problems is presented. The problems addressed deal with the vibration of structures subject to stability limit phenomena. A method for obtaining the critical stability modes from unloaded structure vibration modes is presented. A reiterative process is proposed and applied to some sample problems. A means of validating large space structures which are too large to be submitted to buckling tests on Earth is proposed. ESA

N90-10999# Ingemansson Anatrol A.B., Askim (Sweden).
VISCOELASTIC TUNED DAMPERS FOR CONTROL OF STRUCTURAL DYNAMICS
WILLIAM G. HALVORSEN *In* ESA, Spacecraft Structures and Mechanical Testing p 101-106 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The use of viscoelastic materials as the combined stiffness and damping element in the construction of tuned dampers is described. The variability of the dynamic mechanical properties of viscoelastic materials with environmental factors such as temperature, frequency, and dynamic strain amplitude lead to some difficulties in design and to possible instabilities in performance in certain applications. The effectiveness of tuned dampers is illustrated with an application for controlling low frequency fuselage response in a propeller aircraft. ESA

N90-11000# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
REDUCTION OF DYNAMIC RESPONSE OF SPACECRAFT STRUCTURES AND PAYLOADS
L. KOLSCH and H. BAIER *In* ESA, Spacecraft Structures and Mechanical Testing p 107-119 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

Different techniques of vibration reduction in spacecraft structures are presented. The merits and disadvantages of each technique are outlined. Dynamic response minimization is best carried out by separation of excitation and eigenfrequencies. Where such a tuning is not possible, the resulting dynamic loads have to be diminished either by damping, absorption or isolation. These anti-vibration provisions can be translated into reality either by passive or active measures. Some of these anti-vibration techniques are outlined. The need for more research in the field of high and low frequency vibration reduction is emphasized. ESA

N90-11001*# *Jet Propulsion Lab., California Inst. of Tech.*, Pasadena. Applied Technologies.
ADAPTIVE STRUCTURES TO MEET FUTURE REQUIREMENTS FOR LARGE PRECISION STRUCTURES
B. K. WADA, J. L. FANSON, J. A. GARBA, and G.-S. CHEN *In* ESA, Spacecraft Structures and Mechanical Testing p 121-126 Jan. 1989
(Contract NAS7-918)
Copyright Avail: NTIS HC A99/MF E06 CSCL 20/11

The role of adaptive structures in meeting the structural requirements for future NASA missions is described. Many of NASA's future missions require large precision truss type structures where prespecified locations on the structure must maintain micron level accuracies with respect to each other when subjected to manufacturing errors and static, thermal, and dynamic inputs. In many cases the incorporation of the adaptive structures concepts into the structural design to adjust the on-orbit structure will be the only feasible means to attain the desired accuracies. In order for the structures to be able to change structural characteristics on orbit they must be uncoupled and independent of the control system used to impart the required rigid body motion to the spacecraft. ESA

N90-11003# Rome Univ. (Italy). Dipt. Aerospaziale.
ANALYTIC SIGNALS IN THE DAMPING COEFFICIENT ESTIMATION
ALESSANDRO AGENNI and LUIGI BALIS CREMA *In* ESA, Spacecraft Structures and Mechanical Testing p 133-139 Jan. 1989 Sponsored in part by the Italian Ministry of Public Education
(Contract CNR-85/01244/11)
Copyright Avail: NTIS HC A99/MF E06

The analysis of the complex signal formed by the impulse response of a structure and its Hilbert transform is presented. Numerical simulations on damping factor estimation with particular reference to low frequencies and damping are shown. The numerical results prove the effectiveness of the approach and the possibility of obtaining significant results even when relatively limited time windows are used and highly truncated signals are considered. The advantages of the damping factor estimation method over the half power method are presented. ESA

N90-11004# Liege Univ. (Belgium).
A SUPER ELEMENT FOR MULTIBODY DYNAMICS
A. CARDONA and M. GERADIN *In* ESA, Spacecraft Structures and Mechanical Testing p 143-148 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A superelement formulation capable of handling large finite rotations is developed. It is based on a small rotation and displacement hypothesis in a local frame to the superelement. A standard component mode approach is adopted together with a lumped mass inertia approximation. The resulting degrees of freedom of the formulation are the positions and orientations at the so-called boundary nodes of the superelement, plus a given number of internal mode amplitudes. The use of these formulations in the deployment of an antenna-like structure is presented as a test case. ESA

N90-11005# Aerospatiale, Cannes (France).
GEMMES: A NEW TOOL FOR DYNAMIC MODELING
C. GARNIER and P. RIDEAU *In* ESA, Spacecraft Structures and Mechanical Testing p 149-154 Jan. 1989 Previously announced as N89-24078
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The new GEMMES software is presented as an alternative to currently used numerical simulation software. It computes the equations of the mechanical systems in a symbolic nonnumerical form. The GEMMES generated equations are just like hand written

ones, but the use of a computer provides faultless and infinitely faster calculations. The final version of GEMMES will be capable of modeling whatever system may arise from assembling rigid and/or flexible bodies together. The present version thoroughly handles tree like systems. It allows for description of the geometry of the mechanical system and of its flexible constituents. It provides complete calculations of the dynamic equations, routines useful for results simplification, and a FORTRAN interface that automatically generates a simulator of the system. Computation of the equations of a closed loop system is much more complicated. ESA

N90-11006# Katholieke Univ. te Leuven (Belgium). Mechanische Konstruktie en Produktie.
EMPLOYMENT OF MODAL SURVEY METHODOLOGIES IN DYNAMIC ANALYSIS PROCEDURES
W. HEYEN, T. JANTER, and P. SAS *In* ESA, Spacecraft Structures and Mechanical Testing p 155-159 Jan. 1989
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The use of modal analysis techniques in the vibration analysis of dynamic behavior in mechanical structures is outlined. The principle of this approach is to describe the dynamics of a structure by its modal parameters (resonance frequencies and mode shape vectors). The modal parameters can be determined through experimental testing or analytical modeling. The modal parameters are very useful for trouble shooting, locating the sources of dynamic problems, in determining the most efficient modifications, or for updating analytical models in the design or redesign process. ESA

N90-11007# Intespace, Toulouse (France).
INTEGRATION OF ANALYTICAL AND TEST SOFTWARE FOR OPTIMAL STRUCTURAL DESIGN UNDER DYNAMIC LOADS
L. P. BUGEAT, N. A. ROY, A. GIRARD, and J.-F. IMBERT *In* ESA, Spacecraft Structures and Mechanical Testing p 161-166 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

An approach which allows for efficient integration of dynamic analysis in design and qualification cycles is described. The three major categories of numerical tools: analysis, diagnosis, and optimization are considered. The organization of the software using a common analysis and test data base is presented. A brief description of software programs is given with two examples illustrating structural modification and sensitivity analysis. ESA

N90-11009# Aeronautical Research Inst. of Sweden, Bromma.
CALCULATION OF SOUND TRANSMISSION THROUGH A CYLINDRICAL SHELL USING ASKA ACOUSTICS
P. GORANSSON *In* ESA, Spacecraft Structures and Mechanical Testing p 175-180 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The transmission of an external acoustic field is calculated using a finite element model of an aluminum honeycomb cylindrical shell. The ASKA ACOUSTICS software program is used to analyze the results. From the eigenmodes of the coupled fluid structure system the frequency response is obtained for certain angles of incidence of the plane wave excitation. The noise reduction is calculated using the average of the acoustic pressure in the interior of the shell. The results of the analyses performed indicate that fluid-structure interaction is important in obtaining the reduction. This fact is accentuated by results obtained with helium in the interior. The predictions done with the finite element method are compared to measurements of similar configurations. The agreement is good for most frequencies. ESA

N90-11010# Centre National d'Etudes Spatiales, Toulouse (France).
ACOUSTIC RESPONSE ANALYSIS IN THE LOW FREQUENCY DOMAIN
F. MERCIER, D. GANGLOFF, and A. MAMODE *In* ESA, Spacecraft Structures and Mechanical Testing p 181-185 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The formulation of acoustic excitation responses in large light space structures based on modal superposition is presented. Loads are predicted as random acceleration or modal energy power. Acoustic analysis of several configurations of solar array and antenna reflectors is carried out. Modal parameters such as damping and added mass effects are assessed. The importance of such tests in calculating the dimensions of light satellite appendages is stressed. As such structures are good radiators the need for radiation correction to reach a stable energy balance is discussed. It is concluded that further study of intermodal coupling terms is needed. ESA

N90-11011# Texas Univ., Austin. Dept. of Aerospace Engineering and Engineering Mechanics.
USE OF LANCZOS VECTORS IN STRUCTURAL DYNAMICS
ROY R. CRAIG, JR., TZU-JENG SU, and HYOUNG M. KIM *In* ESA, Spacecraft Structures and Mechanical Testing p 187-192 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The use of Krylov vectors and Lanczos vectors for reduced order modeling in structural dynamics and control of flexible structures is illustrated. An unsymmetric block Lanczos method for systems with unsymmetric damping, Lanczos vectors and Krylov vectors for use in component synthesis, and control of flexible structures using reduced-order models based on Krylov vectors are discussed. New results obtained on the topic of control of flexible structures are given particular emphasis. ESA

N90-11012# Politecnico di Milano (Italy). Dipt. di Ingegneria Aerospaziale.
THERMOELASTIC BEHAVIOR OF LARGE SPACE STRUCTURES: MODELING AND CONTROL
F. BERNELLI-ZAZZERA, A. ERCOLI-FINZI, and P. MONTEGASSA *In* ESA, Spacecraft Structures and Mechanical Testing p 47-53 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A method for the analysis and control of thermally induced vibrations of flexible structures is presented. The structure is represented by a double finite element model, one for the structural displacements and one for the temperature distribution. Based on these two finite element models, the system is entirely described in terms of structural and thermal modal coordinates. The unstable coupling effects, which are shown to be present, are actively controlled by applying a digital suboptimal linear quadratic control technique to a reduced order modal model. ESA

N90-11014# Rome Univ. (Italy). Dipt. Aerospaziale.
EVALUATION OF DISPERSIVE BEHAVIOR IN PERIODIC STRUCTURES BY DISCRETE FOURIER TRANSFORM
S. SGUBINI and A. AGNENI *In* ESA, Spacecraft Structures and Mechanical Testing p 207-212 Jan. 1989 Sponsored by the Italian Ministry of Public Education
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A method for estimating the dispersion curves and the wave number versus angular frequency for periodic structures based on the Fourier transform algorithm is presented. These periodic structures present a nonlinear behavior, and have some frequency bands where the energy, given by the forcing system, is trapped in a few bays and the waves decrease their vibration amplitude as they move away from the section where the force is applied. An evaluation of the errors in wave number estimation is obtained by comparing the estimated values with the theoretical results for some structures with both longitudinal and transverse excitation. The application of this research to the modular design of large space structures is summarized. ESA

N90-11016# Rome Univ. (Italy). Dipt. Aerospaziale.
NUMERICAL TREATMENT OF THE THERMO-STRUCTURAL-DYNAMIC PROBLEMS: THE INTERPOLATION TECHNIQUES
C. ARDUINI, G. LANEVE, D. MORTARI, and M. PARISSE *In* ESA, Spacecraft Structures and Mechanical Testing p 219-224 Jan. 1989

(Contract ESA-6819/86/NL/PH(SC))
Copyright Avail: NTIS HC A99/MF E06

Results of thermostructural interfacing research are presented. An interpolation technique used when transferring thermal data from a general thermal model to a thermostructural one is described. Results of simulated interpolations are shown. Accurate interpolations are concluded possible once the thermal problem was remodeled. ESA

N90-11025*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
COMPARISON OF SINE DWELL AND BROADBAND METHODS FOR MODAL TESTING
JAY-CHUNG CHEN *In* ESA, Spacecraft Structures and Mechanical Testing p 285-292 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The objectives of modal tests for large complex spacecraft structural systems are outlined. The comparison criteria for the modal test methods, namely, the broadband excitation and the sine dwell methods, are established. Using the Galileo spacecraft modal test and the Centaur G Prime upper stage vehicle modal test as examples, the relative advantage or disadvantage of each method is examined. The usefulness or shortcomings of the methods are given from a practical engineering viewpoint. ESA

N90-11026# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. of Aeroelasticity.
MODAL ANALYSIS OF SPACE STRUCTURES WITH THE IBRAHIM TIME DOMAIN METHOD
A. SCHENK *In* ESA, Spacecraft Structures and Mechanical Testing p 293-299 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The use of the Ibrahim Time Domain (ITD) algorithm in extracting the structural modal parameters for the free vibration of test structures is described. The major advantage of this method is that no detailed information on excitation must be made available. The measurements are very short, covering only the free decay vibrations of conventional engineering structures, which usually last only a few seconds. To analyze operational vibration responses due to random excitation, ITD can be combined with the RDT (random decrement technique) method which prepares the free decay response such that ITD can be used. Other possible uses of the combined RDT and ITD methods are discussed. ESA

N90-11027# Communications Research Centre, Ottawa (Ontario).
COMPARISON OF PHASE RESONANCE, MODE SEPARATION, AND DRIVEN-BASE MODAL IDENTIFICATION METHODS APPLIED TO THE FLECS TEST STRUCTURE
R. K. SINGAL, F. R. VIGNERON, T. STEELE, A. BERTRAM, and M. DEGENER (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany, F.R.) *In* ESA, Spacecraft Structures and Mechanical Testing p 301-308 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The flexible ECS Structure (FLECS) was used to carry out validation tests of different dynamic identification methods. The methods tested are the phase resonance method with appropriated excitation, the mode separation method with excitation at locations on the structure with complex exponential and with ISSPA (identification of structural systems parameters), and a driven-base method with unidirectional base excitation. Since the structural damping level of FLECS is low compared to actual fully equipped satellite structures, the modal identification methods were also applied to a configuration of FLECS with supplemental non-proportional viscous damping. For this purpose, dampers were manufactured and integrated into the FLECS structure. Results of the validation tests are given and the merits of the different dynamic identification methods compared. ESA

N90-11028# Old Dominion Univ., Norfolk, VA.
A DIRECT TWO RESPONSE APPROACH FOR UPDATING ANALYTICAL DYNAMIC MODELS OF STRUCTURES WITH EMPHASIS ON UNIQUENESS
S. R. IBRAHIM, C. STAVRINIDIS, E. FISSETTE, and O. BRUNNER (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Spacecraft Structures and Mechanical Testing p 309-315 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

An approach, based on utilizing only two sets of structural responses and the enforcement of the conditions for a solution is presented for the updating of finite element models. The responses required can be either any two identified normal modes, any two identified complex modes, or two forced harmonic response vectors in the neighborhood of any two natural frequencies of the structure under test. The mass, stiffness, and damping matrices are interactively and simultaneously corrected in a direct noniterative procedure. A uniqueness factor is automatically computed in the procedure to indicate the correctability of the finite element model under consideration. The number of measurement locations is assumed to be less than the number of degrees of freedom of the analytical model. Provisions for completing and smoothing the measured or identified responses are included to reduce the effects of measurement, noise and identification errors. Preliminary results on simple models are presented in support of the proposed technique. ESA

N90-11039# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
TRANSIENT VIBRATION TESTING OF SPACECRAFT STRUCTURES. EXPERIENCE WITH MULTIAXIAL BASE MOTION AND COMBINED BASE MOTION AND POINT FORCE EXCITATION
K. MUEHLBAUER, U. SCHILDT, and W. RAASCH *In* ESA, Spacecraft Structures and Mechanical Testing p 395-400 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

Practical aspects of transient vibration testing were studied using both a multiaxis hydraulic and a uniaxial electrodynamic vibration test facility. The experimental investigations with the hydraulic system demonstrated that excitation in six degrees of freedom operates in principle but must be improved in its reproduction accuracy. Uniaxial transient vibration testing turned out to be feasible with the electrodynamic four shaker system available. An attempt was made to achieve more realistic test results by simulating the dominant translatory load by uniaxial base excitation and the secondary loading degrees of freedom by additionally applied point forces. The results show that this technique, although limited in its range of application, is able to produce more realistic structural loads than the uniaxial tests alone. ESA

N90-11040# Intespace, Toulouse (France).
TRANSIENT TESTS FOR SPACECRAFT STRUCTURES
L.-P. BUGEAT, A. GIRARD, and J. MERLET *In* ESA, Spacecraft Structures and Mechanical Testing p 401-405 Jan. 1989
Sponsored by ESA, CNES, and Aerospatiale
Copyright Avail: NTIS HC A99/MF E06

The use of transient tests in the dynamic qualification of spacecraft structures is outined. The technique uses a combination of spacecraft dynamic mass identification tests and open loop transient tests based on an impedance coupling and an equivalent force formulation. A closed loop transient vibration test theoretical formulation is presented as well as a prototype implementation. A comparison of the two techniques, transient tests and sine vibration tests, is given. Accuracy, monitoring, and control are given special attention. The closed loop driving procedure gives better results than the open loop driving method. ESA

N90-11042# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).
MULTI-AXIS TRANSIENT TESTING: EXPERIMENTAL INVESTIGATIONS
K. ECKHARDT and G. SCHMIDT (Hochtemperatur Reaktorbau, Juelich, Germany, F.R.) *In* ESA, Spacecraft Structures and Mechanical Testing p 413-419 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The technique of using multi-axis transient testing in obtaining correct stress distributed loading of spacecraft structure hardware is outlined. Test results from a pilot facility, located at the Hochtemperatur Reaktorbau in Julich (Federal Republic of Germany) are presented. The goal of the research is to determine the limits of load capacity and define specific facility constraints, e.g. noise level, cross talk, input reproducibility, resonances, control mode selection, and safety measures. Results are compared with existing requirements for a facility capable of carrying out spacecraft transient testing. Areas requiring improvement are identified. ESA

N90-11047# Rome Univ. (Italy). Dipt. Aerospaziale.
JOE: JORDAN OPTIMIZED EIGENSOLVER. A STEP TOWARD A NUMERICAL JORDAN FORM ANALYZER FOR CONTROL AND INTERACTIVE THERMO-STRUCTURAL-DYNAMIC APPLICATIONS
C. ARDUINI and D. MORTARI *In* ESA, Spacecraft Structures and Machanical Testing p 461-465 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The JOE (Jordan Optimized Eigensolver) software program is described. It differs from other software programs of its kind in using screening criteria on eigenvector parallelism and eigenvalue coalescence once they are generated on a standard eigenanalyzer. The screening is dependent on user selected parameters allowing for a flexible search for successful decompositions. Results of test cases show success for matrices as large as 100 by 100 and multiple roots up to 16. The results of this technique are shown and possible improvements discussed. ESA

N90-11049# Centre National d'Etudes Spatiales, Toulouse (France).
MATHEMATICAL MODEL AND PREDICTIONS FOR STATIC AND DYNAMIC BEHAVIOR OF SOLAR ARRAY STRUCTURE
D. GANGLOFF, F. MERCIER, N. PRIOU, and J. F. DAVID (Aerospatiale, Les Mureaux, France) *In* ESA, Spacecraft Structures and Mechanical Testing p 483-489 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The technical requirements, mathematical models and test correlation analysis used in the qualification procedure of new solar array structures are described. These criteria are applied to the mathematical models devised to predict performance in the following areas: quasi-static loads, stiffness, sine vibration, and acoustic noise. The pre-flight qualification philosophy takes into account the need for greater electrical power and reduced payload volume, mass, and cost in designing future satellites and solar arrays. ESA

N90-11067# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
THE LARGE EUROPEAN ACOUSTIC FACILITY AT ESTEC
W. E. GRUEN and W. A. SHICKLE *In its* Spacecraft Structures and Mechanical Testing p 619-627 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The design of the reverberant acoustic chamber of ESTEC (European Space Research and Technology Center) with respect to the acoustic noise field is described. Design aspects for the noise generation system comprising horns and acoustic modulators using gaseous nitrogen as a working medium are discussed. Special attention is given to the nitrogen evaporating system where design alternatives are mentioned. Instrumentation and control systems are described with respect to noise control, safety and data handling. Considerations of the conceptual safety design in order to protect personnel and equipment from hazardous situations are discussed. ESA

N90-11068# Commissariat a l'Energie Atomique, Saclay (France).
TAMARIS: A NEW EUROPEAN FACILITY FOR LOW FREQUENCY MULTI-AXIS VIBRATION SIMULATION
P. BULAND, C. BERRIAUD, and PH. JAMET *In* ESA, Spacecraft Structures and Mechanical Testing p 631-634 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The main features of the Tamaris vibration simulation facility are outlined. Special attention is given to the 6 m by 6 m shaking table named Azalee. This table is presently a three Degrees of Freedom (DOF) facility and will be upgraded in the near future to be a full six DOF system with accurate control of rotations. The main characteristics of three other mono or multiaxial shaking tables are presented as well as the geometry of a 15 m deep testing pit for slender structures. A brief description of the digital data acquisition and control system is presented. ESA

N90-11643 Colorado Univ., Boulder.
GUARANTEED COST CONTROL OF FLEXIBLE SPACE STRUCTURES Ph.D. Thesis
DONALD LEE MACKISON 1988 140 p
Avail: Univ. Microfilms Order No. DA8912205

The control of flexible space structures is complicated by the uncertain nature of the system to be controlled. The design of control laws which are intended to control both the inertial orientation (attitude) and shape (flexures) must be robust against anticipated variations in the system parameters (modal frequencies, shapes, locations of nodes of the flexures). The only control synthesis technique which includes a priori measures of the uncertainties of system parameters is guaranteed cost control (GCC). Guaranteed cost controllers are generated for a variety of flexible space structures. The stability robustness of the resulting closed loop systems is determined using singular value methods. The system dynamics are modeled as a linear system whose coefficients contain time varying parameters of bounded variation. Linear state feedback is used to minimize an integral quadratic cost function. Dissert. Abstr.

N90-13452*# General Research Corp., McLean, VA.
EXPERT SYSTEMS FOR ADAPTIVE CONTROL OF LARGE SPACE STRUCTURES
CHARLES F. GARTRELL *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 52-53 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

It is expected that space systems for the future will evolve to structures of unprecedented size with associated extreme control requirements. A method is necessary that is sufficiently general to initiate stable control of a vehicle and subsequently learn the true nature of the structure. It is suggested that a suitable constructed expert system (ES) would be capable of learning by appending observations to a knowledge base. To verify that an ES can control a large space structure, numerical simulations of a simple structure subjected to periodic vibrations and the performance of a classical controllers were performed. The ES was then exercised to show its ability to truthfully mimic nominal control and to demonstrate its superiority to the classical controller, given sensor failures. An ES generating software package, The Intelligent Machine Model, was employed. It uses the pattern matching technique. Results of this program are discussed. Author

N90-13453*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
POINTING CONTROL FOR LDR
Y. YAM and C. BRIGGS *In its* Report of the Asilomar 3 LDR Workshop p 54-55 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

One important aspect of the LDR control problem is the possible excitations of structural modes due to random disturbances, mirror

chopping, and slewing maneuvers. An analysis was performed to yield a first order estimate of the effects of such dynamic excitations. The analysis involved a study of slewing jitters, chopping jitters, disturbance responses, and pointing errors, making use of a simplified planar LDR model which describes the LDR dynamics on a plane perpendicular to the primary reflector. Briefly, the results indicate that the command slewing profile plays an important role in minimizing the resultant jitter, even to a level acceptable without any control action. An optimal profile should therefore be studied. Author

N90-13481*# TRW Space Technology Labs., Redondo Beach, CA.
EXPLICIT MODELING AND CONCURRENT PROCESSING IN THE SIMULATION OF MULTIBODY DYNAMIC SYSTEMS
R. GLUCK *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 120-121 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

The objective is to present the activities at TRW in developing the capability to simulate the behavior of large flexible multibody space structures. The features of the simulation tools are: (1) to accommodate all rigid/flexible body degrees-of-freedom which incorporate the control system models and external forces, (2) to provide the flexibility to incorporate engineering-defined models and to retain parameters of significance to the engineer, (3) to reduce the computation cost by one order of magnitude (two orders of magnitude compared to a CRAY 1S), and (4) to keep it versatile so that radical variations in anticipated space structures can be accommodated. The current computer tools to simulate multibody systems appear not only to be very costly and time consuming, but also do not produce the desired fidelity of the mathematical models. In summary, a multibody simulation tool will be developed in the near future which will allow solution of the dynamics and controls of the deployment of the LDR backup structure, or the problem associated with the robotic assembly of the structure. The tools will allow the engineer to define the modeling technique and solve problems in less time and at reduced cost. Author

N90-13484*# Air Force Systems Command, Kirtland AFB, NM.
CONTROL OF OPTICAL SYSTEMS
D. FOUNDS *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 126-127 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 13/9

Some of the current and planned activities at the Air Force Systems Command in structures and controls for optical-type systems are summarized. Many of the activities are contracted to industry; one task is an in-house program which includes a hardware test program. The objective of the in-house program, referred to as the Aluminum Beam Expander Structure (ABES), is to address issues involved in on-orbit system identification. The structure, which appears similar to the LDR backup structure, is about 35 feet tall. The activity to date has been limited to acquisition of about 250 hours of test data. About 30 hours of data per excitation force is gathered in order to obtain sufficient data for a good statistical estimate of the structural parameters. The development of an Integrated Structural Modeling (ISM) computer program is being done by Boeing Aerospace Company. The objective of the contracted effort is to develop a combined optics, structures, thermal, controls, and multibody dynamics simulation code. Author

N90-13487*# Martin Marietta Aerospace, Denver, CO.
PACOSS PROGRAM
K. E. RICHARDS, JR. *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 132-133 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

The objectives of the PACOSS program were to demonstrate the respective roles of passive and active control for structures that represented future Large Space Structures (LSS), to develop means to introduce passive vibration control, and to experimentally verify the damping predictions and the control algorithms. In order to meet the objectives, the program was divided into an analytical simulation phase to establish the respective roles of passive and active damping on a LSS-type structure, and a design, analysis, and test phase to validate the passive damping and the control algorithm performance for a structure. Predictable amounts of damping can be designed into a LSS structure, the best control strategy uses a combination of passive damping and active controls, and a more optimum system can be achieved by an early interaction between the structural designer, controls engineer, and the damping designer. Author

N90-13494*# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES - 12, SUPPLEMENT 11 Final Report
PETER M. BAINUM, A. S. S. R. REDDY, FEIYUE LI, and JIANKE XU Sep. 1989 67 p
(Contract NSG-1414)
(NASA-CR-185966; NAS 1.26:185966) Avail: NTIS HC A04/MF A01 CSCL 22/2

The rapid 2-D slewing and vibrational control of the unsymmetrical flexible SCOLE (Spacecraft Control Laboratory Experiment) with multi-bounded controls is considered. Pontryagin's Maximum Principle is applied to the nonlinear equations of the system to derive the necessary conditions for the optimal control. The resulting two point boundary value problem is then solved by using the quasilinearization technique, and the near minimum time is obtained by sequentially shortening the slewing time until the controls are near the bang-bang type. The tradeoff between the minimum time and the minimum flexible amplitude requirements is discussed. The numerical results show that the responses of the nonlinear system are significantly different from those of the linearized system for rapid slewing. The SCOLE station-keeping closed loop dynamics are re-examined by employing a slightly different method for developing the equations of motion in which higher order terms in the expressions for the mast modal shape functions are now included. A preliminary study on the effect of actuator mass on the closed loop dynamics of large space systems is conducted. A numerical example based on a coupled two-mass two-spring system illustrates the effect of changes caused in the mass and stiffness matrices on the closed loop system eigenvalues. In certain cases the need for redesigning control laws previously synthesized, but not accounting for actuator masses, is indicated. Author

N90-13579 Howard Univ., Washington, DC.
ATTITUDE AND SHAPE CONTROL OF OPTIMALLY DESIGNED LARGE SPACE STRUCTURES Ph.D. Thesis
SATYANARAYANA KOTARU 1989 187 p
Avail: Univ. Microfilms Order No. DA8921109

The equations of motion of flexible structures such as cantilever beams and free-free beams are taken as a basis to study the uncontrolled dynamics and to synthesize control laws using linear regulator theory. Such control laws must meet the design specification levels for shape and orientation control purposes. Point actuators that are used for control purposes are incorporated into the linear dynamic models of the beams. The focus is on the design of minimum weight structures for space applications satisfying mission requirements such as frequency and other constraints. The stepped configurations obtained by implementing the finite element method during the optimization process are considered as they represent a class of optimally designed structures. A comparison of the control system designs and requirement of control efforts is studied for the weight optimized stepped beams and the corresponding uniform beams. Examples of stepped configurations obtained by both rigorous optimization procedures and trial and error designs are examined. Control laws are also developed for both uniform and stepped structures with inherent structural damping which is additive to the control efforts in suppressing the vibrations of the cantilever beams. The use of optimality criteria methods for optimizing the combined cost function including the structural dynamicist's objective function and a form

of the control designer's objective function taken from the linear regulator theory is studied with a numerical example applied to a long orbiting beam. Dissert. Abstr.

N90-14269# Hydraulic Research Textron, Valencia, CA. Servocontrols Div.
OPTIMAL STOCHASTIC MODELING AND CONTROL OF FLEXIBLE STRUCTURES Final Report, Sep. 1986 - Sep. 1988
HAGOP V. PANOSSIAN Sep. 1988 321 p
(Contract F33615-85-C-3220)
(AD-A212347; AFWAL-TR-88-3066) Avail: NTIS HC A14/MF A02 CSCL 01/3

Modeling and control design of large flexible space structures under high uncertainty is considered. Linear stochastic system models with multiplicative and additive noises that are state -, control -, and measurement - dependent are treated extensively. Controllability, observability, and robustness issues are also discussed under various optimality considerations. An optimal stochastic controller is derived under perfect information and a sub-optimal compensator is formulated under partial and noisy information. The intent is to treat the modeling of uncertainties and to develop the appropriate stochastic control that is robust. GRA

N90-14270*# North Carolina Univ., Charlotte. Dept. of Electrical Engineering.
DYNAMICS AND CONTROL OF FLEXIBLE SPACECRAFT DURING AND AFTER SLEWING MANEUVERS Annual Report, 1 May - 31 Oct. 1989
YOGENDRA P. KAKAD 1989 40 p
(Contract NAG1-535)
(NASA-CR-186123; NAS 1.26:186123) Avail: NTIS HC A03/MF A01 CSCL 22/2

The dynamics and control of slewing maneuvers of NASA Spacecraft COntrol Laboratory Experiment (SCOLE) are analyzed. The control problem of slewing maneuvers of SCOLE is formulated in terms of an arbitrary maneuver about any given axis. The control system is developed for the combined problem of rigid-body slew maneuver and vibration suppression of the flexible appendage. The control problem formulation incorporates the nonlinear dynamical equations derived previously, and is expressed in terms of a two-point boundary value problem utilizing a quadratic type of performance index. The two-point boundary value problem is solved as a hierarchical control problem with the overall system being split in terms of two subsystems, namely the slewing of the entire assembly and the vibration suppression of the flexible antenna. The coupling variables between the two dynamical subsystems are identified and these two subsystems for control purposes are treated independently in parallel at the first level. Then the state-space trajectory of the combined problem is optimized at the second level. Author

N90-14639# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
NON-LINEAR VIBRATIONS, STABILITY, AND DYNAMICS OF STRUCTURES AND MECHANISMS Final Report, 1 Mar. 1988 - 31 May 1989
A. H. NAYFEH and D. T. MOOK Aug. 1989 288 p
(Contract DAAL03-88-G-0013)
(AD-A212152; ARO-25614.1-EG-CF) Avail: NTIS HC A13/MF A02 CSCL 01/2

The topics addressed include: Chaotic Oscillations in Mechanical Systems, On Understanding Chaos in Nonlinear Oscillators Having a Single Equilibrium Position, Bifurcations in a Forced Softening Duffing Oscillator, Suppression of Chaos by Nonlinear Damping, Modal Interaction in the Response of Shells to a Subharmonic Excitation, Response of a Single-Degree-of-Freedom System to a Nonstationary Parametric Excitation Dynamic Snap-Buckling Under Stochastic Loads, A New Approach to Stochastic Flap-Lag Stability of a Rotor Blade in Hover, On the Adaptive Control of Dynamic Systems with Flexible Structures, On the Stabilization of Tethered Satellite Systems, A Mathematical Formulation and Control Expressions for Compliant Control of Constrained Robot Manipulators, Fractals and Chaos in Elastic Systems, Nonlinear Nonlinear Oscillation of a Flexible Cantilever Nonlinear Oscillations in a Rotating Shaft System, Nonlinear Effects in the Static and Dynamic Behavior of Beams and Rotor Blades, Dynamics of Beams with Tip Masses and Attached to a Moving Base, Non-Linear Oscillations of an Inextensible, Air-Inflated, Cylindrical Membrane, A Finite Element Method for Nonlinear Panel Flutter of Composite Laminates, Planar Response of Elastic Cables to a Subharmonic or Superharmonic Excitation, Nonlinear Large Rotational Structural Dynamics, and Joint Damping and Joint Nonlinearity Effects in Dynamics of Space Structures. GRA

N90-16851*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.
SCREENING ACTUATOR LOCATIONS FOR STATIC SHAPE CONTROL Progress Report, 1989
RAPHAEL T. HAFTKA Jan. 1990 19 p
(Contract NAG1-224)
(NASA-CR-181970; NAS 1.26:181970) Avail: NTIS HC A03/MF A01 CSCL 22/2

Correction of shape distortion due to zero-mean normally distributed errors in structural sizes which are random variables is examined. A bound on the maximum improvement in the expected value of the root-mean-square shape error is obtained. The shape correction associated with the optimal actuators is also characterized. An actuator effectiveness index is developed and shown to be helpful in screening actuator locations in the structure. The results are specialized to a simple form for truss structures composed of nominally identical members. The bound and effectiveness index are tested on a 55-m radiometer antenna truss structure. It is found that previously obtained results for optimum actuators had a performance close to the bound obtained here. Furthermore, the actuators associated with the optimum design are shown to have high effectiveness indices. Since only a small fraction of truss elements tend to have high effectiveness indices, the proposed screening procedure can greatly reduce the number of truss members that need to be considered as actuator sites. Author

N90-16859# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
ROBUSTNESS OF A MOVING-BANK MULTIPLE MODEL ADAPTIVE CONTROLLER FOR A LARGE SPACE STRUCTURE M.S. Thesis
MICHAEL R. SCHORE Dec. 1989 182 p
(AD-A215670; AFIT/GE/ENG/89D-46) Avail: NTIS HC A09/MF A01 CSCL 22/2

The robustness of moving-bank multiple model adaptive estimation (MMAE) and control (MMAC) algorithms is analyzed. The mismatch of a 24-state truth model and a 6-state filter model are evaluated on the basis of MMAE/MMAC performance. A model developed using finite element analysis is used to approximate a large space structure which has a large central hub with appendages radiating out from it. The mass of the hub is considered to be much larger than the mass of the flexible structure. The model is developed in physical coordinates and then transformed into modal coordinates. To obtain a reduced order filter model, the method of singular perturbations is used. The actual positions and velocities of various physical points on the structure are used in the evaluation of the MMAE/MMAC algorithm performance. The results of model mismatching indicates that the MMAE provides accurate position and velocity estimates even in the face of a 6-state to 24-state model mismatch. When a non-adaptive filter is used with a mismatched parameter location, the performance suffers slightly. The use of an adaptive estimator does provide improved performance in the face of uncertain parameter location. Stable control was obtained with the use of MMAC. For the case of nonadaptive filter and mismatched parameter location, the control algorithm behaved in a possible destructive manner. By allowing the filter to adapt to the initial parameter location, the MMAC algorithm provided stable control of the structure, even in the face of lagre disturbances. GRA

N90-17134 Michigan Univ., Ann Arbor.
DYNAMIC MODELING OF FLEXIBLE BODIES IN MULTIBODY SYSTEMS Ph.D. Thesis
HONG HEE YOO 1989 152 p
Avail: Univ. Microfilms Order No. DA8920642

The objective of this research is the development of analytical and computational methods for analyzing the effects of motion-induced stiffness variations on the dynamic behavior of mechanical multibody system composed of structural components undergoing arbitrarily large, unrestrained, overall motions as well as small elastic deformations. The importance of the subject is indicated by the fact that components of dynamic multibody mechanical systems are often assumed to possess nearly constant stiffness properties, even though rather benign overall motions can, in some important applications, cause enough variation in stiffness to have dramatic effects on dynamic behavior. Thus, incomplete accounting for such variations can yield completely erroneous analysis results. As newer designs for spacecraft, robotic manipulators, and mechanisms call for lighter weight and faster operational speeds, the topic assumes even greater importance as characteristic stiffness vary significantly for these extremely flexible systems. The focus of the present research is the study of structural stiffness variations caused by inertia forces and torques, a main goal being to formulate an efficient and effective technique for accounting for all such stiffness changes in a general multibody simulation theory which incorporate flexible body control schemes and arbitrary forcing functions. Dissert. Abstr.

N90-17136*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
REMOTE MANIPULATOR SYSTEM (RMS)-BASED CONTROLS-STRUCTURES INTERACTION (CSI) FLIGHT EXPERIMENT FEASIBILITY STUDY Final Report, Oct. 1988 - Jul. 1989
MARTHA E. DEMEO 1 1990 84 p
(Contract NAS9-17560; NAS9-18147)
(NASA-CR-181952; NAS 1.26:181952; CSDL-R-2186) Avail: NTIS HC A05/MF A01 CSCL 13/9

The feasibility of an experiment which will provide an on-orbit validation of Controls-Structures Interaction (CSI) technology, was investigated. The experiment will demonstrate the on-orbit characterization and flexible-body control of large flexible structure dynamics using the shuttle Remote Manipulator System (RMS) with an attached payload as a test article. By utilizing existing hardware as well as establishing integration, operation and safety algorithms, techniques and procedures, the experiment will minimize the costs and risks of implementing a flight experiment. The experiment will also offer spin-off enhancement to both the Shuttle RMS (SRMS) and the Space Station RMS (SSRMS).
Author

N90-17172 North Carolina State Univ., Raleigh.
DYNAMIC INTERACTIONS AND GLOBALLY OPTIMAL MANEUVER OF DISTRIBUTED SYSTEMS Ph.D. Thesis
SUNGTAE PARK 1989 108 p
Avail: Univ. Microfilms Order No. DA8918985

Significant interactions between rigid body and flexible-body motions, and the globally optimal maneuver of distributed spacecraft undergoing large overall rigid-body maneuvers and small relative elastic motion are described. One distinguishes between the rigid-body and flexible-body motions by introducing a tracking coordinate system that coincides with the rigid-body component of the motion and by enforcing the motion relative to the tracking coordinate system (the elastic motion) to be orthogonal to the rigid-body motion. This leads to an infinite set of second-order weakly coupled modal differential equations describing the elastic motion. It is shown that the elastic motion is excited by the rigid body motion through Coriolis terms, angular acceleration terms and centrifugal terms. The Coriolis terms represent a linear time-varying gyroscopic effect, the angular acceleration terms represent a linear time varying circulatory effect and the centrifugal terms represent a linear time-varying stiffness effect. For unidirectional elastic motions, the Coriolis terms and the angular acceleration terms are shown to vanish. For uniform unidirectional elastic motion the centrifugal terms are diagonal and the modal equations become decoupled. Dissert. Abstr.

N90-17184# Sandia National Labs., Albuquerque, NM.
THE 59TH SHOCK AND VIBRATION SYMPOSIUM, VOLUME 4
HENRY C. PUSEY, comp. and SALLIE C. PUSEY, comp. Dec. 1988 292 p Symposium held in Albuquerque, NM, 18-20 Oct. 1988; sponsored by DOD
(Contract DE-AC04-76DP-00789)
(AD-A214581; SAND-88-2473C-VOL-4; UC-13-VOL-4) Avail: NTIS HC A13/MF A02 CSCL 20/11

The proceeding of the conference is presented. Some of the areas of discussion are: Validation testing of nuclear survivable systems; Vibroacoustic Payload Environment Prediction System (VAPEPS) (Using the VAPEPS program to support TOPEX spacecraft design); Statistical energy analysis modeling of nonstructural mass on lightweight equipment panels using VAPEPS, and stress estimation and statistical energy analysis of the Magellan spacecraft solar array using VAPEPS; Dynamic measurement (An automated vibration transducer calibration system using advanced FFT techniques); Dynamic criteria avionics environmental reliability; Modal applications -- Structural verification using modal frequency testing (A nondestructive evaluation); Model validation using substructure modal-testing applied to a large and very flexible wind turbine; and Analytical estimation of earth penetrator structural response and comparison with laboratory shock and modal test data; Shock -- Vertical launching system modeling techniques for shadow side effect during ship shock trials, and dynamic response of pipe subjected to high impact loads; Dynamic analysis -- Bubble jet calculations using the DYSMAS/E finite difference code, Convergence of finite element frequency analysis for a thin walled cylinder, and integral method for free edge plates with stiffeners; Vibration control -- Shock isolation using an active magnetostrictive element; and Prediction of modal characteristics and harmonic response of viscoelastically damped structures. GRA

N90-17371*# Catholic Univ. of America, Washington, DC. Dept. of Mechanical Engineering.
ACTIVE CONTROL OF A FLEXIBLE STRUCTURE USING A MODAL POSITIVE POSITION FEEDBACK CONTROLLER
S. POH and A. BAZ 1990 31 p
(Contract NAG5-749)
(NASA-CR-186336; NAS 1.26:186336) Avail: NTIS HC A03/MF A01 CSCL 09/2

The feasibility of a new Modal Positive Position Feedback (MPPF) strategy in controlling the vibration of a complex flexible structure using a single piezo-electric active structural member is demonstrated. The control strategy generates its control forces by manipulating only the modal position signals of the structure to provide a damping action to undamped modes. This is in contrast to conventional modal controllers that rely in their operation on negative feedback of both the modal position and velocity. The proposed strategy is very simple to design and implement as it designs the controller at the uncoupled modal level and utilizes simple first order filters to achieve the Positive Position Feedback effect. The performance of the new strategy is enhanced by augmenting it with a time sharing strategy to share a small number of actuators between larger number of modes. The effectiveness of the new strategy is validated experimentally on a flexible box-type structure that has four bays and its first two bending modes are 2.015 and 6.535 Hz respectively. A single piezo-electric actuator is utilized as an active structural member to control several transverse bending modes of the structure. The performance of the active control system is determined in the time and the frequency domains. The results are compared with those obtained when using the Independent Modal Space Control (IMSC) of Meirovitch. The experimental results suggest the potential of the proposed strategy as a viable means for controlling the vibration of large flexible structures in real time. Author

N90-18076# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
BASELINE EXPERIMENT FOR ACTIVE CONTROL OF STRUCTURAL VIBRATIONS M.S. Thesis
DAVID R. JACQUES Dec. 1989 121 p
(AD-A216194; AFIT/GAE/ENY/89D-15) Avail: NTIS HC A06/MF A01 CSCL 20/11

A baseline experiment is developed which can be used to evaluate control systems for large space structures. The experiment consists of an inverted cantilever beam. Proof mass actuators and a structural dynamics shaker provide the control forces, and integrated output of beam-mounted accelerometers provides velocity feedback. A programmable controller allows different control algorithms to be evaluated. System damping and frequency response are determined with and without the controller engaged, and experimental results are compared to analytical predictions. Modal suppression techniques are attempted in order to demonstrate active control of selected modes while maintaining overall system stability. GRA

N90-18450# Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).
OPTIMIZATION OF SENSORS AND ACTUATORS POSITIONING AIMED AT OBTAINING REDUCED MODELS FOR THE SYNTHESIS OF OPTIMAL CONTROL REGULATORS OF FLEXIBLE STRUCTURES Ph.D. Thesis [OTIMIZACAO DO POSICIONAMENTO DE SENSO RES E ATUADORES VISANDO A OBTENCAO DE MODELOS REDUZIDOS PARA A SINTESE DE REGULADORES OTIMOS EM CONTROLE DE ESTRUTURAS FLEXIVEIS]
PAULO TADEU DEMELLOLOURENCAO Dec. 1988 138 p In PORTUGUESE; ENGLISH summary
(INPE-4760-TDL/348) Avail: NTIS HC A07/MF A01

Two approaches are presented which are proposed to obtain reduced order models for the active control of flexible structures, specifically considering the problem of positioning actuators and sensors. The first method consists in truncating the original model to the dominant modes only, the actuators and sensors placed according to a criterion that minimizes the spillover (interaction between controller and nondominant modes). In the second approach, the matrices of the reduced order model and the positions of actuators and sensors are determined to minimize the difference between the outputs of the original and reduced models. Based on these reduced models, two optimal controllers are synthesized assuming direct output feedback. These controllers are finally validated against the original model and their performances are compared: the closed-loop eigenvalues and eigenvectors, and limit values of a quadratic performance index. Author

N90-18751*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEVELOPMENT OF AN EXPERIMENTAL SPACE STATION MODEL FOR STRUCTURAL DYNAMICS RESEARCH
PAUL E. MCGOWAN, HAROLD E. EDIGHOFFER (AS&M, Inc., Hampton, VA.), and JOHN W. WALLACE Jan. 1990 19 p Presented at the 60th Shock and Vibration Symposium, Virginia Beach, VA, 14-16 Nov. 1989
(NASA-TM-102601; NAS 1.15:102601) Avail: NTIS HC A03/MF A01 CSCL 20/11

Design, analysis, and testing of an experimental space station scale model is presented. The model contains hardware components with dynamic characteristics similar to those expected for other large space structures. Validation of analysis models is achieved through correlation with dynamic tests of hardware components and representative assembly configurations. A component mode synthesis analysis method is examined through comparisons with results from fully mated system models. Selection of input requirements for accurate component synthesis analysis predictions are assessed. Author

N90-19061# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Product Assurance and Safety Dept.
CONFIGURATION MANAGEMENT AND CONTROL FOR ESA SPACE SYSTEMS
Mar. 1989 18 p
(ESA-PSS-01-11-ISSUE-1; ISSN-0379-4059; ETN-90-96300)
Copyright Avail: NTIS HC A03/MF A01

A specification containing the configuration data management and control program requirements that are associated with and complementary to every other ESA discipline is presented. Policies and procedures for the initialization, preparation, review, approval, release, control and status accounting of all design definition and configuration identification data for spacecraft and associated equipment and software are included. ESA

N90-19272*# Jet Propulsion Lab., California Inst. of Tech., Pasadena. Optical Sciences and Application Section 385.
PRECISION SEGMENTED REFLECTOR, FIGURE VERIFICATION SENSOR
PAUL K. MANHART and STEVE A. MACENKA *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 369-374 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 14/2

The Precision Segmented Reflector (PSR) program currently under way at the Jet Propulsion Laboratory is a test bed and technology demonstration program designed to develop and study the structural and material technologies required for lightweight, precision segmented reflectors. A Figure Verification Sensor (FVS) which is designed to monitor the active control system of the segments is described, a best fit surface is defined, and an image or wavefront quality of the assembled array of reflecting panels is assessed Author

N90-19274 North Carolina State Univ., Raleigh.
ADVANCED TOPICS IN STRUCTURAL DYNAMICS: THE MANEUVER OF FLEXIBLE SPACECRAFT, AND ON-OFF DECENTRALIZED CONTROL OF FLEXIBLE STRUCTURES Ph.D. Thesis
LESTER ANDERSON FOSTER 1989 100 p
Avail: Univ. Microfilms Order No. DA8918091

Two approaches to maneuver flexible spacecraft and an approach to suppress vibration of flexible structures using decentralized feedback on-off control are described. The first maneuver method suppresses spacecraft motion relative to the motion of a fictitious shadow spacecraft using a decentralized feedback control. The second maneuver method is equivalent to the first method but it applies open-loop control with a decentralized feedback control suppressing motion relative to the open-loop path. First, the dynamics of maneuvering flexible spacecraft are reviewed in general and then specifically for a non-dimensional free-free beam with well separated dimensions. For the first maneuver method, several in-plane rest-to-spin maneuvers are investigated for different choices of shadow coordinates including the maneuver corresponding to minimum fuel. In order to prescribe actual spacecraft motion, lag compensation of the shadow coordinates is introduced to account for feedback lag between the shadow and actual spacecraft coordinates. Also in-plane and out-of-plane maneuvers are investigated. Next, on-off decentralized control is presented. Fuel minimization is achieved by turning on actuators when local kinetic energy is at a maximum and local potential energy is at a minimum. Dissert. Abstr.

N90-19280*# Texas Univ., Austin. Center for Aeronautical Research.
APPLICATION OF ATTACHMENT MODES IN THE CONTROL OF LARGE SPACE STRUCTURES
ROY R. CRAIG, JR. Sep. 1989 56 p
(Contract NAS9-17254)
(NASA-CR-185604; NAS 1.26:185604; CAR-89-3) Avail: NTIS HC A04/MF A01 CSCL 22/2

Various ways are examined to obtain reduced order mathematical models of structures for use in dynamic response

analyses and in controller design studies. Attachment modes are deflection shapes of a structure subjected to specified unit load distributions. Attachment modes are frequently employed to supplement free-interface normal modes to improve the modeling of components (structures) employed in component mode synthesis analyses. Deflection shapes of structures subjected to generalized loads of some specified distribution and of unit magnitude can also be considered to be attachment modes. Several papers which were written under this contract are summarized herein. Author

N90-19406*# Ohio Univ., Athens. Dept. of Electrical and Computer Engineering.
INVESTIGATIONS INTO A NEW ALGORITHM FOR CALCULATING H INFINITY OPTIMAL CONTROLLERS
R. DENNIS IRWIN *In* Alabama Univ., Research Reports: 1989 NASA/ASEE Summer Faculty Fellowship Program 28 p Dec. 1989
(Contract NGT-01-008-021)
Avail: NTIS HC A99/MF E06 CSCL 09/2

A new algorithm for calculating H (sup infinity) optimal controllers is investigated. The algorithm is significantly simpler than existing approaches and yields much simpler controllers. The design equations are first presented. Special system transformations required to apply the algorithm are then presented. The use of the algorithm with sampled-data systems is outlined in detail. Several constraints on the characteristics of the problem formulation are required for the application of the design equations. The consequences of these constraints are investigated by applying the algorithm to a simplified design for a subsystem of a large space structure ground test facility. The investigation of these constraints is continued by application of the design equations and constraints to an extremely simple tracking problem. The result of these investigations is the development of a frequency dependent weighting strategy that allows realistic control problems to be cast in a form compatible with the new algorithm. Further work is indicated in the area of developing strategies for choosing frequency-dependent weights to achieve specific design goals. The use of the freedom in problem formulation to achieve robustness/performance tradeoffs should also be investigated. It is not clear that the algorithm always leads to simpler controllers. The more restrictive formulation may dictate that frequency-dependent weighting adds to the controller order disproportionately. This effect must also be investigated. Author

N90-19597 Catholic Univ. of America, Washington, DC.
MODIFIED INDEPENDENT MODAL SPACE CONTROL OF FLEXIBLE STRUCTURES Ph.D. Thesis
SOON-NEO POH 1989 89 p
Avail: Univ. Microfilms Order No. DA8925990

A Modified Independent Modal Space Control (MIMSC) method is developed for designing active vibration control systems for large flexible structures. The method modified the well known Independent Modal Space Control (IMSC) method by accounts for the interaction between the controlled and residual modes. It incorporates also optimal placement procedures for selecting the optimal locations of the actuators in the structure in order to minimize the structural vibrations as well as the actuation effort. The MIMSC method relies on an important feature which is based on time sharing of a small number of actuators, in the modal space, to control effectively a large number of modes. Numerical examples as well as an experiment employing flexible cantilever beams were presented to demonstrate the effectiveness of MIMSC method. The results obtained indicate that the MIMSC with maximum modal energy ranking is more effective in damping the vibration than the IMSC, the PI (pseudo-inverse), and the MIMSC with sequential time sharing. The MIMSC requires, however, higher control energy than the IMSC and PI method. Dissert. Abstr.

08

ASSEMBLY, MAINTENANCE, and EXTRAVEHICULAR ACTIVITY

Description of on-orbit deployment or assembly including tools. Includes space suits and other EVA equipment or support.

A90-13318#
THE FEATURES OF INVESTIGATIONS PERFORMED ONBOARD THE 'MIR' ORBITAL COMPLEX WHEN PUTTING INTO OPERATION ADDITIONAL SCIENTIFIC MODULES
M. IU. BELIAEV, S. G. ZHUKOV, V. V. RIUMIN, V. A. SOLOV'EV, and V. M. STAZHKOV (Nauchno-Proizvodstvennoe Ob'edinenie Energiia, USSR) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-111) Copyright

The studies that may be performed on the Mir orbital station are examined, including the possibility of adding scientific modules to the station. Software developed to solve problems associated with the addition of scientific modules is described, noting configuration complications due to putting additional modules into operation. Results are presented from mathematical simulations of Mir flight with additional module. Recommendations are made for experiments to be conducted on multimodular complexes.
R.B.

A90-16684* Martin Marietta Corp., Denver, CO.
TOOL AND EQUIPMENT REQUIREMENTS FOR HUMAN HABITATION OF MARS
MICHAEL G. THORNTON (Martin Marietta Corp., Denver, CO) IN: The case for Mars III: Strategies for exploration - General interest and overview. San Diego, CA, Univelt, Inc., 1989, p. 607-616.
(Contract NAS8-37126)
(AAS PAPER 87-219) Copyright

This paper presents an examination of requirements and design considerations for tools and equipment to establish a continuous human presence on Mars. Specific problems addressed include; manufacturing in zero gravity conditions, with or without an atmosphere, temperature considerations, and use of tools by astronauts on Mars or while traveling to or from Mars. A design for a salvage concept for equipment landed on Mars is presented. Author

A90-18031
A SITUATED REASONING ARCHITECTURE FOR SPACE-BASED REPAIR AND REPLACE TASKS
JIM SANBORN, BEN BLOOM (Mitre Artificial Intelligence Technical Center, McLean, VA), and DEBRA MCGRATH (Mitre Corp., Space Systems Div., Houston, TX) (NASA, Bendix Field Engineering Corp., Computer Sciences Corp., et al., Annual Goddard Conference on Space Applications of Artificial Intelligence, Greenbelt, MD, May 16, 17, 1989) Telematics and Informatics (ISSN 0736-5853), vol. 6, no. 3-4, 1989, p. 133-143. Research supported by Mitre Corp. Previously announced in STAR as N89-26583. refs
Copyright

Space-based robots need low level control for collision detection and avoidance, short-term load management, fine-grained motion, and other physical tasks. In addition, higher level control is required to focus strategic decision making as missions are assigned and carried out. Reasoning and control must be responsive to ongoing changes in the environment. Research aimed at bridging the gap between high level artificial intelligence (AI) planning techniques and task-level robot programming for telerobotic systems is described. Situated reasoning is incorporated into AI and Robotics systems in order to coordinate a robot's activity within its environment. An integrated system under development in a component maintenance domain is described. It is geared toward replacing worn and/or failed Orbital Replacement

Units (ORUs) designed for use aboard NASA's Space Station Freedom based on the collection of components available at a given time. High level control reasons in component space in order to maximize the number operational component cells over time, while the task-level controls sensors and effectors, detects collisions, and carries out pick and place tasks in physical space. Situated reasoning is used throughout the system to cope with component failures, imperfect information, and unexpected events. Author

A90-19726#
SPACE CONSTRUCTION - MICRO-GRAVITY AND THE HUMAN ELEMENT
RICHARD JOHNSON (Colorado, University, Boulder) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 7 p. refs
(AIAA PAPER 90-0184) Copyright

Future space construction missions will involve both human and machine constructors. Selection of the optimum constructor mix requires a model of constructor capabilities and requirements. Obtaining data on the capabilities and requirements of humans in microgravity is a major part of that effort. Data searches have resulted in first-cut estimates of human constructor micro-g stay durations and work effectiveness. The current best stay duration limit is 180 days, while work effectiveness is approximately 20 percent less than on the earth's surface. Author

A90-20004*# Planning Research Corp., Hampton, VA.
STRUCTURAL DYNAMIC CHARACTERISTICS OF A SPACE STATION FREEDOM FIRST ASSEMBLY FLIGHT CONCEPT
MARTIN J. KASZUBOWSKI (Planning Research Corp., Hampton, VA), ZORAN N. MARTINOVIC (Analytical Mechanics Associates, Inc., Hampton, VA), and PAUL A. COOPER (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p.
(AIAA PAPER 90-0748) Copyright

A study has been conducted of the dynamic characteristics of the first flight of NASA's Space Station Freedom and its response to a typical preboost excitation; the FEM model of the structure used encompasses 88 flexible modes below 5 Hz. The low frequency modes of the system are noted to have been dominated by the relatively low stiffness of such components as the photovoltaic arrays, thermal radiators, and alpha joint. The spacecraft backbone-forming truss was stiffer, exhibiting no deformation below 3 Hz. Reboost forcing-function response was moderate. O.C.

A90-23898#
CONCEPT DESIGN OF THE SPECIAL PURPOSE DEXTEROUS MANIPULATOR FOR THE SPACE STATION MOBILE SERVICING SYSTEM
H. BORDUAS, D. GOSSAIN, A. KONG, E. QUITTNER, and D. SHAFFER (Spar Aerospace, Ltd., Mississauga, Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 35, Dec. 1989, p. 197-204.

The Special Purpose Dexterous Manipulator (SPDM), Canada's contribution to the International Space Station, is discussed, emphasizing its mechanical aspects. The principal SPDM requirement pertaining to functions, design driving subtasks, reach, force/moment application, handling capabilities, and control modes are examined. The control design for the overall configuration, base, central body, arms, mounting structure, tool change out-mechanisms, tools, and thermal protection system is described. Special features pertaining to the joint drives, commonality items, multiple functions, maintainability, and fault tolerance are addressed. C.D.

A90-24793#
FURTHER DEVELOPMENTS IN VERY LARGE TRUSS CONSTRUCTION IN SPACE
ANTHONY P. COPPA (General Electric Co., Astro-Space Div., Philadelphia, PA) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 162-169. refs
Copyright

Developments of the Coppatruss system for the construction of very large truss foundations in space are presented. The geometrical basis of the system is described in terms of zero-order structural and higher-order architectural grids. Several characteristic structures are discussed including a 5 GW solar power satellite platform. The paper concludes with an argument for establishing a worldwide standard for very large truss construction in space. Author

A90-25183* Massachusetts Inst. of Tech., Cambridge.
MOMENTS APPLIED IN THE MANUAL ASSEMBLY OF SPACE STRUCTURES - EASE BIOMECHANICS RESULTS FROM STS-61B
D. COUSINS and D. L. AKIN (MIT, Cambridge, MA) Acta Astronautica (ISSN 0094-5765), vol. 19, Dec. 1989, p. 973-979. refs
(Contract NAS8-35996; NAS9-17266)
Copyright

Measurements of the level and pattern of moments applied in the manual assembly of a space structure were made in extravehicular activity (EVA) and neutral buoyancy simulation (NBS). The Experimental Assembly of Structures in EVA program included the repeated assembly of a 3.6 m tetrahedral truss structure in EVA on STS-61B after extensive neutral buoyancy crew training. The flight and training structures were of equivalent mass and geometry to allow a direct correlation between EVA and NBS performance. A stereo photographic motion camera system was used to reconstruct in three dimensions rotational movements of structural beams during assembly. Moments applied in these manual handling tasks were calculated on the basis of the reconstructed movements taking into account effects of inertia, drag and virtual mass. Applied moments of 2.0 Nm were typical for beam rotations in EVA. Corresponding applied moments in NBS were typically up to five times greater. Moments were applied as impulses separated by several seconds of coasting in both EVA and NBS. Decelerating impulses were only infrequently observed in NBS. Author

A90-26819#
ON THE DEPLOYMENT OF A FLEXIBLE BEAM FROM AN OSCILLATING BASE
NELSON G. CREAMER (Bendix Field Engineering Corp., Oxon Hill, MD) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 459-468. refs
(AIAA PAPER 90-1239) Copyright

The transverse and torsional equations of motion for the deployment of a Timoshenko beam from an oscillating base are derived. The equations are general in that arbitrary shape functions (including finite-element functions) can be used and an arbitrary time-varying base motion is assumed (as a result of small freeplay and jitter within the deployment canister). It is shown, that resonant-type interactions between the current beam natural frequencies and the driving frequency of the base may result in potentially large displacements and loads during deployment. If deemed necessary, these resonance effects can be actively suppressed by either marching through the resonance region in a stepwise manner or using output feedback control to maintain beam health. Author

A90-26972#
TECHNICAL APPROACH FOR DEFINING A SYSTEM FOR SERVICEABILITY
FRANK G. GALLO (Fairchild Space Co., Germantown, MD) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 6 p.
(AIAA PAPER 90-0613) Copyright

Future systems such as spacecraft and attached payloads to SS Freedom will be designed for serviceability. These systems

can be designed to be serviced by several methods including astronaut EVA, robotic (teleoperated and autonomous), and/or a combination of both astronaut EVA and robotics. The methods selected will play an important role in defining the overall design of both the servicing system and system being serviced. As a result, an approach to servicing needs to be defined at a systems level. This approach must incorporate considerations which will drive the design of all systems designed to be serviced. Without proper consideration of these factors, the serviceability of the system may be severely limited. This paper presents a generic approach applicable to defining a system which is to be serviced. it addresses those factors which need to be considered in order to define a system which integrates the design of the equipment to be serviced with the design of the system for servicing the equipment. Author

A90-27468
A SPACE STATION EXTRAVEHICULAR MOBILITY UNIT COMPUTER SIMULATION
STEPHEN A. GIANGRANDE, JR., EDWARD H. TEPPER, and JAMES L. YANOSY (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 11 p. refs
(SAE PAPER 891501) Copyright

A computer simulation model developed to evaluate the performance of a Space Station Extravehicular Mobility Unit (SSEMU) is briefly described. The model has been demonstrated to be a useful tool in performing steady state and transient simulations of an entire extravehicular activity, from suit depressurization to repressurization. Some planned applications of the model include evaluation of candidate subsystem performance when integrated into the SSEMU system, evaluation of the effects of subsystem plumbing arrangements on the overall system, examination of candidate control schemes, analysis of system failure modes and effects, and evaluation of actual hardware performance. V.L.

A90-27492* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PAYLOAD ACCOMMODATION AND DEVELOPMENT PLANNING TOOLS - A DESKTOP RESOURCE LEVELING MODEL (DRLM)
JOHN D. HILCHEY (NASA, Marshall Space Flight Center, Huntsville, AL), BOBBY LEDBETTER, and RICHARD C. WILLIAMS (Planning Research Corp., McLean, VA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 26 p. refs
(SAE PAPER 891528) Copyright

The Desktop Resource Leveling Model (DRLM) has been developed as a tool to rapidly structure and manipulate accommodation, schedule, and funding profiles for any kind of experiments, payloads, facilities, and flight systems or other project hardware. The model creates detailed databases describing 'end item' parameters, such as mass, volume, power requirements or costs and schedules for payload, subsystem, or flight system elements. It automatically spreads costs by calendar quarters and sums costs or accommodation parameters by total project, payload, facility, payload launch, or program phase. Final results can be saved or printed out, automatically documenting all assumptions, inputs, and defaults. V.L.

A90-27508
DEVELOPMENT ACTIVITIES FOR THE EUROPEAN EVA SPACE SUIT SYSTEM (ESSS)
NIKOLAUS HERBER (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 18 p.
(SAE PAPER 891544) Copyright

A development status evaluation is presented for the ESA EVA Space Suit System (ESSS) being designed for Hermes spacecraft servicing of the Columbus Free Flying Laboratory in LEO. An 'EVA Suit Enclosure Module' (ESEM) has been defined which, as the anthropomorphic, pressure-retentive enclosure of the crewmember, must facilitate the operationally required mobility and dexterity. An EVA Life Support Module attached to the ESEM provides respiration gases, metabolic cooling, nutrition, and waste collection, while the EVA Information and Communication Module provides control and data-processing functions. EVA Support and Verification Equipment is also incorporated by the ESSS system. O.C.

A90-27540
ADVANCED PORTABLE LIFE SUPPORT SYSTEM COMPONENT INTEGRATION AND SYSTEM TESTING
WESLEY COLEMAN and DAN REYNOLDS (Rockwell International Corp., El Segundo, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 19 p.
(SAE PAPER 891580) Copyright

A facility has been designed and built to perform the first integrated testing of Space Station Freedom Extravehicular Mobility Unit Portable Life Support System. The test articles are a non-venting thermal sink, a metal oxide CO2 absorber, a quaternary amine CO2 absorber, and a fast response CO2 sensor. The water loop and vent loop of the EMU are simulated using facility fluid movers. Minimum volume and thermal mass were also drivers. Difficulties in system design and the resolution of each are discussed. Author

A90-27541
THERMAL SINK FOR THE ADVANCED EXTRAVEHICULAR MOBILITY UNIT PORTABLE LIFE SUPPORT SYSTEM
HAL J. STRUMPF (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., Torrance, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(SAE PAPER 891581) Copyright

A study is being conducted to design, develop, fabricate, integrate, and test a preprototype coolant loop subsystem for an advanced extravehicular mobility unit portable life support system for Space Station Freedom. The overall function of the coolant loop is to remove metabolic and equipment heat loads and provide a comfortable thermal environment for a crewperson during extravehicular activity. The heat loads are transported by water circulating through a liquid-cooled ventilation garment. The thermal environment is regulated using thermal capacitive and/or radiative control. After use, the system must be capable of regenerating relatively rapidly. The key component in the coolant loop is the thermal sink, which is a completely nonventing unit comprising cold-plate heat exchangers, a radiator to reject a fraction of the generated heat load, and a regenerable thermal storage unit to absorb the remaining heat load. No embedded thermoelectric devices are required. Author

A90-27543* United Technologies Corp., Windsor Locks, CT.
A HELMET MOUNTED DISPLAY DEMONSTRATION UNIT FOR A SPACE STATION APPLICATION
CAROLYN G. GERNUX, ROBERT W. BLASER (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT), and JOSE MARMOLEJO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p.
(Contract NAS9-17543)
(SAE PAPER 891583) Copyright

Under NASA guidance an advanced development helmet mounted display (HMD) has been designed and fabricated. Delivery has been made of an extravehicular mobility unit (EMU) HMD demonstration unit as an alternative to the current low-resolution, chest-mounted display, and cuff-mounted checklists. Important design goals achieved with this HMD include the use of transmissive liquid display image sources with fairly high resolution (text, graphics, and video compatible), binocular viewing with total image overlap, virtual image projection, low profile packaging, low power design, and demonstration of voice control of the HMD data. Test

results showed that the HMD program successfully demonstrated the feasibility of the concept and operated as designed, meeting the necessary program requirements. R.E.P.

A90-27549* Grumman Aerospace Corp., Bethpage, NY.
AUTOMATIC SEQUENCING AND CONTROL OF SPACE STATION AIRLOCK OPERATIONS
VICTOR HIMEL, FRED J. ABELES (Grumman Corp., Grumman Space Systems Div., Bethpage, NY), JAMES AUMAN (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT), and TERRY O. TQI (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p.
(SAE PAPER 891590) Copyright

Procedures that have been developed as part of the NASA JSC-sponsored pre-prototype Checkout, Servicing and Maintenance (COSM) program for pre- and post-EVA airlock operations are described. This paper addresses the accompanying pressure changes in the airlock and in the Advanced Extravehicular Mobility Unit (EMU). Additionally, the paper focuses on the components that are checked out, and includes the step-by-step sequences to be followed by the crew, the required screen displays and prompts that accompany each step, and a description of the automated processes that occur. Author

A90-27550* Barrios Technology, Inc., Houston, TX.
PERFORMANCE EVALUATION OF ADVANCED SPACE SUIT CONCEPTS FOR SPACE STATION
DAVID M. KLAUS (Barrios Technology, Inc., Houston, TX) and PHILIP R. WEST (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. refs
(SAE PAPER 891591) Copyright

The requirements for an advanced space suit for Space Station EVA and the methods used to evaluate candidate suit concepts are examined. Two candidate Space Station suits, the AX-5 and the Mk. III, are described and illustrated. The methods to test these suits are discussed, including, tests at the NASA/Johnson Space Center Weightless Environment Training Facility, tests in the microgravity environment of the KC-135 aircraft, CO2 washout evaluations, component torque measurements, environmental hazards protection evaluations, and component cycle life verification. R.B.

A90-27551* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
RESULTS AND APPLICATIONS OF A SPACE SUIT RANGE-OF-MOTION STUDY
AL REINHARDT (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 15 p. Previously announced in STAR as N89-26398. refs
(SAE PAPER 891592) Copyright

The range of motion of space suits has traditionally been described using limited 2-D mapping of limb, torso, or arm movements performed in front of an orthogonal grid. A new technique for recovering extra-vehicular (EVA) space suit range-of-motion data during underwater testing was described in a paper presented by the author at the 1988 conference. The new technique uses digitized data which is automatically acquired from video images of the subject. Three-dimensional trajectories are recovered from these data, and can be displayed using 2-D computer graphics. Results of using this technique for the current shuttle EVA suit during underwater simulated weightlessness testing are discussed. Application of the data for use in animating anthropometric computer models is highlighted. Author

A90-27552
DETECTION OF EXTRAVEHICULAR ACTIVITY GENERATED CONTAMINATION
RICHARD A. HEPPNER (Perkin-Elmer Corp., Applied Science Div., Pomona, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p.
(SAE PAPER 891593) Copyright

An External Contaminant Monitor (ECM) system is proposed as a means of preventing toxic contaminants from entering the Space Station after EVA. The proposed ECM unit occupies about 0.5 cubic ft, weighs 22 pounds, and requires 16 W of power. The ECM is based on a small mass analyzer and is able to pinpoint the source of contaminants such as ammonia, nitrogen tetroxide, and hydrazine propellants. The characteristics of the ECM are described, focusing on the quadrupole mass filter and support electrons, the sample inlet and vacuum systems, and a dual microprocessor system for data acquisition and processing and instrument control. R.B.

A90-27553* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DEVELOPMENT OF AN EXTRAVEHICULAR ACTIVITY SELF RESCUE TECHNIQUE FOR SPACE STATION
ADAM BRODY (NASA, Ames Research Center; Sterling Software, Moffett Field, CA) and CURTIS LOMAX (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p. refs
(SAE PAPER 891594) Copyright

A design study was conducted to delineate potential failure modes and to evaluate various solutions to the many risks to which an astronaut is exposed while performing EVA activities. Among these are suit depressurization as a result of micrometeoroid impact and portable life system failure. There is also a risk of prolonged separation from the vehicle should a tether break or a manned maneuvering unit run out of fuel. In order to simplify contingency operations and to prepare for the situation when no other means are available, a self-rescue capability must be determined. Rescue options are detailed and a number of possible approaches and solutions are presented. R.E.P.

A90-28572
THE EUROPEAN EVA SUIT ENCLOSURE - CHALLENGES IN THE DEVELOPMENT AND DESIGN OF A NEW SPACESUIT
Y. OLLIVIER, D. HORNET (AMDBA, S.A., Vaucresson, France), O. DROMARD (Aerazur, Issy-les-Moulineaux, France), and G. ALBERTINI (ESTEC, Noordwijk, Netherlands) Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p. Research supported by ESA.
(SAE PAPER 891545) Copyright

The paper describes the results of the efforts carried out in Europe for the definition, design and development of an EVA Suit Enclosure Module (ESEM) operating at 500 hPa, within the frame of the development studies for the Hermes Spaceplane EVA System. The assessment of the main performance requirements of the ESEM has been supported by the results of previous EVA System Studies and by experimental activities. These activities included: tests with an ergonomic test bench for the definition of the entry concept and the main geometrical parameters of the Hard Upper Torso (HUT), soft materials thermal and mechanical characteristics evaluation, preliminary components tests. Following the results of the experimentation and knowing the lessons learned from the U.S. and USSR EVA experience, a preliminary design concept for the future ESEM was established. The main features of such concept are: hybrid suit (HUT and soft limbs) with rear entry, a lower torso with hip and thigh bearings, rolling convolute joints for the shoulder articulations. Author

A90-29273*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
MECHANICAL JOINTS AND LARGE COMPONENTS FOR PATHFINDER IN-SPACE ASSEMBLY AND CONSTRUCTION
JEFF FINCKENOR and FRANK THOMAS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and

Astronautics, 1990, p. 476-490. refs
(AIAA PAPER 90-1001) Copyright

This paper summarizes the background of the Pathfinder Project, In-Space Assembly, and Construction activity for fiscal year 1989. Work is presented on high strength mechanical truss joints and the definition of typical large components that might be required for assembly on-orbit and use on interplanetary space missions. Several mechanical joints were designed, and the most promising early design is presented in detail. The primary design drivers were the ability for robot assembly, the correction of up to a + or - 0.020 inch axial misalignment, and an axial load in the vicinity of + or - 100,000 lb. The most promising joint uses axisymmetric grooves to correct the misalignment and to transfer the load in a smooth path. Author

A90-29277*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A MOBILE TRANSPORTER CONCEPT FOR EVA ASSEMBLY OF FUTURE SPACECRAFT
JUDITH J. WATSON, HAROLD G. BUSH, WALTER L. HEARD, JR., MARK S. LAKE (NASA, Langley Research Center, Hampton, VA), J. KERMIT JENSEN (Lockheed Engineering and Sciences Co., Hampton, VA) et al. IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 524-532. refs
(AIAA PAPER 90-1049) Copyright

This paper details the ground test program for the NASA Langley Research Center Mobile Transporter concept. The Mobile Transporter would assist EVA astronauts in the assembly of the Space Station Freedom. 1-g and simulated O-g (neutral buoyancy) tests were conducted to evaluate the use of the Mobile Transporter. A three-bay (44 struts) orthogonal tetrahedral truss configuration with a 15-foot-square cross section was repeatedly assembled by a single pair of pressure suited test subjects working from the Mobile Transporter astronaut positioning devices. The average unit assembly time was 28 seconds/strut. The results of these tests indicate that the use of a Mobile Transporter for EVA assembly of Space Station size structure is viable and practical. Additionally, the Mobile Transporter could be used to construct other spacecraft such as the submillimeter astronomical laboratory, space crane, and interplanetary (i.e., Mars and lunar) spacecraft. Author

A90-29679
HOT KNIFE IN ORBIT
IAN PARKER Space (ISSN 0267-954X), vol. 6, Mar.-Apr. 1990, p. 4-6.
Copyright

A thermal knife system has been developed to cut kevlar cables to release elements such as solar panels or antennas. The system consists of ceramic knives which contin a resistance pattern heated by the passage of an electrical current. The thermal knife system is described and illustrated. The system design may be altered for various applications, with the diameter of the cables chosen to suit the required hold-down tension. The system was developed for a solar array application as part of the Fokker Advanced Rigid Array program. The use of the thermal knife system in this application is discussed and additional applications of the system are noted, including deployment of the ERA structure from Mir and on the solar panels of Inmarsat 2. R.B.

A90-30739
TRADEOFF OF EVA AND FTS FOR SPACE STATION SERVICING
THOMAS B. MALONE and KATHRYN E. PERMENTER (Carlow Associates, Inc., Fairfax, VA) IN: NAECON 89; Proceedings of the IEEE National Aerospace and Electronics Conference, Dayton, OH, May 22-26, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 811-815.
Copyright

This paper describes a function allocation decision aid consisting of requirements and criteria for conducting tradeoffs between EVA and FTSs (flight telerobotic systems) for Space Station servicing. The function allocation decision aid has four major components: (1) data bases of capability data on current EVA and FTS systems and Space Station components; (2) a time-line simulation to compare time to perform and workloads associated with servicing missions; (3) an expert system for integration of task requirements and servicing capabilities, identification of incompatabilities of a mode for a mission, determination of the optimal mode for a mission, determination of design requirements for a mode, identification of the implications of selecting a mode for a mission, and identification of R&D requirements for a mode; and (4) the user interface. Requirements for the decision aid are described, and the results of the application of a prototype of the aid are discussed. I.E.

A90-31356* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
NEUTRAL BUOYANCY METHODOLOGY FOR STUDYING SATELLITE SERVICING EVA CREWMEMBER INTERFACES
MARY E. BARNBY, THOMAS J. GRIFFIN (CTA, Inc., Greenbelt, MD), and RUTHAN LEWIS (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Human Factors Society, Annual Meeting, 33rd, Denver, CO, Oct. 16-20, 1989, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1989, p. 149-153. refs
Copyright

Current economic constraints indicate the need for incorporating the satellite servicing philosophy of commonality within the design of spacecraft subsytems. This philosophy is essential for conserving resources including hardware/software development and implementation costs, on-orbit and ground-based manpower, crew training/testing time, and documentation. In addition, spacecraft subsystem commonality may be coupled with standardization of operation procedures, and test and verification techniques for spacecraft design. Several spacecraft have adopted this practice, including Hubble Space Telescope, Space Station Freedom, and the Explorer Platform. As these and other programs continue and if effective crew interfaces and procedures are clearly and consistently defined, crew retraining for similar spacecraft subsystems will lessen, and procurement efforts will diminish. A relatively high fidelity zero-gravity simulation using water immersion is available to establish crew interfaces economically. The flexibility and utility of this space simulation medium for planning and assisting on-orbit operations was exemplified by astronaut evaluations of potential EVA electrical connectors. The testing was conducted at a NASA underwater neutral buoyancy training facility. Author

N90-10937*# McDonnell-Douglas Astronautics Co., Houston, TX.
INDEPENDENT ORBITER ASSESSMENT (IOA): ANALYSIS OF THE EXTRAVEHICULAR MOBILITY UNIT
GARY G. RAFFAELLI 15 Dec. 1986 558 p
(Contract NAS9-17650)
(NASA-CR-185540; NAS 1.26:185540; REPT-1.0-WP-VA86001-15)
Avail: NTIS HC A24/MF A03 CSCL 22/2

The results of the Independent Orbiter Assessment (IOA) of the Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL) are presented. The IOA approach features a top-down analysis of the hardware to determine failure modes, criticality, and potential critical items (PCIs). To preserve independence, this analysis was accomplished without reliance upon the results contained within the NASA FMEA/CIL documentation. This report documents the independent analysis results corresponding to the Extravehicular Mobility Unit (EMU) hardware. The EMU is an independent anthropomorphic system that provides environmental protection, mobility, life support, and communications for the Shuttle crewmember to perform Extravehicular Activity (EVA) in Earth orbit. Two EMUs are included on each baseline Orbiter mission, and consumables are provided for three two-man EVAs. The EMU consists of the Life Support System (LSS), Caution and Warning System (CWS), and the Space Suit Assembly (SSA). Each level of hardware was evaluated and analyzed for possible failure modes and effects. The majority of these PCIs are resultant from failures

which cause loss of one or more primary functions: pressurization, oxygen delivery, environmental maintenance, and thermal maintenance. It should also be noted that the quantity of PCIs would significantly increase if the SOP were to be treated as an emergency system rather than as an unlike redundant element.
Author

N90-11038# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
A HIGH PRECISION GRAVITY COMPENSATION SYSTEM FOR THE DEPLOYMENT TEST OF THE ERS-1 SAR ANTENNA
R. SIPPEL *In* ESA, Spacecraft Structures and Mechanical Testing p 389-394 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The gravity compensation system used for the deployment tests of a foldable 10 m by 1 m planar array antenna made of Carbon Fiber Reinforced Plastics (CFRP) used on the ERS-1 (environmental research satellite) is described. After the satellite is launched, the antenna will be deployed by means of an electric motor and spring drives. The complete deployment sequence was successfully tested under terrestrial conditions on the antenna engineering model. Limitations in the allowable latching shocks allowed only small driving forces which made the use of a high quality gravity compensation system necessary. The gravity compensation system used, maintains each antenna wing at one point with the help of two cranes which passively follow the antenna motion during deployment. The gravity induced driving forces were reduced to very small values without introducing significant additional friction. The manufactured system geometry, stiffness, and suspension force magnitude, were adjusted following problem oriented adjustment methods. ESA

N90-11074# Aerospatiale, Cannes (France).
DEPLOYMENT SIMULATION FOR 3RD GENERATION SOLAR ARRAY GSR3
C. VERNE and M. ROUCHON *In* ESA, Spacecraft Structures and Mechanical Testing p 681-684 Jan. 1989 Sponsored by ESA
Copyright Avail: NTIS HC A99/MF E06

Deployment tests for different solar arrays are described. The Spacebus solar array deployment is tested in two dimensions. The Spot 4 array deployment is tested in three dimensions. A mock-up deployment test on an air cushion is compared to results obtained using simulation software. The third generation solar array concept equipped with Adele hinges is compared to previous solar array models. The need for greater accuracy and reliability in the deployment analysis of these third generation solar arrays is stressed. ESA

N90-12025# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
COMPUTER-AIDED DESIGN OF FLEXIBLE ASSEMBLY SYSTEMS Final Report, 15 Aug. 1986 - 31 Jan. 1988
DANIEL E. WHITNEY, THOMAS L. DEFAZIO, RICHARD E. GUSTAVSON, STEPHEN C. GRAVES, KURT COOPRIDER, CAROL A. HOLMES, CHARLES J. KLEIN, MANCHEUNG LUI, and SUGUNA PAPPU (Massachusetts Inst. of Tech., Cambridge.) 1988 107 p
(Contract NSF DMC-84-17949)
(PB89-216253; CSDL-R-2033; NSF/ENG-88038) Avail: NTIS HC A06/MF A01 CSCL 13/8

The goal of the project is to better understand product and system design issues associated with flexible assembly. As a result of prior research and extensive work with industry on these topics, researchers identified the following knowledge gaps for study: (1) development of a systematic methodology for coordinated design of products and processes, especially assembly; (2) determination, enumeration, and evaluation of alternate assembly sequences; (3) economic analysis methods for assembly systems and processes, including the effects of inspection and rework; and (4) assembly system design methods, especially those which can create designs for systems that must handle model mix. Author

N90-13480*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ASSEMBLY CONSIDERATIONS FOR LARGE REFLECTORS
H. BUSH *In* Jet Propulsion Lab., California Inst. of Tech., Report of the Asilomar 3 LDR Workshop p 118-119 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

The technologies developed at LaRC in the area of erectable instructures are discussed. The information is of direct value to the Large Deployable Reflector (LDR) because an option for the LDR backup structure is to assemble it in space. The efforts in this area, which include development of joints, underwater assembly simulation tests, flight assembly/disassembly tests, and fabrication of 5-meter trusses, led to the use of the LaRC concept as the baseline configuration for the Space Station Structure. The Space Station joint is linear in the load and displacement range of interest to Space Station; the ability to manually assemble and disassemble a 45-foot truss structure was demonstrated by astronauts in space as part of the ACCESS Shuttle Flight Experiment. The structure was built in 26 minutes 46 seconds, and involved a total of 500 manipulations of untethered hardware. Also, the correlation of the space experience with the neutral buoyancy simulation was very good. Sections of the proposed 5-meter bay Space Station truss have been built on the ground. Activities at LaRC have included the development of mobile remote manipulator systems (which can traverse the Space Station 5-meter structure), preliminary LDR sun shield concepts, LDR construction scenarios, and activities in robotic assembly of truss-type structures. Author

N90-14608*# Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.
EXTRAVEHICULAR ACTIVITY WELDING EXPERIMENT Final Report
J. KEVIN WATSON 21 Aug. 1989 158 p Original contains color illustrations
(Contract NAS8-37753)
(NASA-CR-183848; NAS 1.26:183848; RI/RD89-216) Avail: NTIS HC A08/MF A01 CSCL 13/9

The In-Space Technology Experiments Program (INSTEP) provides an opportunity to explore the many critical questions which can only be answered by experimentation in space. The objective of the Extravehicular Activity Welding Experiment definition project was to define the requirements for a spaceflight experiment to evaluate the feasibility of performing manual welding tasks during EVA. Consideration was given to experiment design, work station design, welding hardware design, payload integration requirements, and human factors (including safety). The results of this effort are presented. Included are the specific objectives of the flight test, details of the tasks which will generate the required data, and a description of the equipment which will be needed to support the tasks. Work station requirements are addressed as are human factors, STS integration procedures and, most importantly, safety considerations. A preliminary estimate of the cost and the schedule for completion of the experiment through flight and postflight analysis are given. Author

N90-15120*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SHUTTLE-C UTILIZATION FOR ASSEMBLY OF THE REPHASED FREEDOM CONFIGURATION
LEONARD J. DERYDER, WASHITO A. SASAMOTO, and PATRICK A. TROUTMAN Aug. 1989 57 p
(NASA-TM-101658; NAS 1.15:101658) Avail: NTIS HC A04/MF A01 CSCL 22/2

The utilization of the Shuttle-C Heavy Lift Launch Vehicle (HLLV) to augment the Shuttle orbiter to deliver to earth orbit elements for assembly of a rephased definition of Space Station Freedom is assessed. A past history of previous HLLV studies performed with respect to Freedom launch and assembly is reviewed and conclusions extrapolated that are appropriate to consider for the new rephased Freedom definition. The rephased Freedom definition is explained, two utilization scenarios are developed and related assessments are provided for Shuttle-C utilization early in the

assembly sequence or utilization later in theon-orbit build up phase. Author

N90-15431*# Martin Marietta Corp., New Orleans, LA. Michoud Assembly Facility.
ONORBIT ELECTRON BEAM WELDING EXPERIMENT DEFINITION Final Report
27 Sep. 1989 60 p
(Contract NAS8-37756)
(NASA-CR-183847; NAS 1.26:183847) Avail: NTIS HC A04/MF A01 CSCL 13/8

The proposed experiment design calls for six panels to be welded, each having unique characteristics selected to yield specific results and information. The experiment is completely automated and the concept necessitated the design of a new, miniaturized, self-contained electron beam (EB) welding system, for which purpose a separate IR and D was funded by the contractor, Martin Marietta Corporation. Since future tasks beyond the proposed experiment might call for astronauts to perform hand-held EB gun repairs or for the gun to be interfaced with a dexterous robot such as the planned flight telerobotic servicer (FTS), the EB gun is designed to be dismountable from the automated system. In the experiment design, two separate, identical sets of weld panels will be welded, one on earth in a vacuum chamber and the other onorbit in the aft cargo bay of an orbiter. Since the main objective of the experiment is to demonstrate that high quality welds can be achieved under onorbit conditions, the welds produced will be subjected to a wide range of discriminating non-destructive Q.C. procedures and destructive physical tests. However, advantage will be taken of the availability of a fairly large quantity of welded material in the two series of welded specimens to widen the circle of investigative talent by providing material to academic and scientific institutions for examination. Author

N90-15976# Glavkosmos, Moscow (USSR).
EVA SPACE SUIT. GENERAL CONCEPTS OF DESIGN AND ARRANGEMENT
G. I. SEVERIN, V. I. SVERTSHEK, and I. P. ABRAMOV *In* ESA, Crew Safety and Rescue in Space: An International Approach p 13-17 Aug. 1989
Copyright Avail: NTIS HC A04/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 30 Dutch guilders

The Extra Vehicular Activities (EVA) space suit, used by the Soviets, is presented. It is a semi-rigid type of suit. High reliability of a space suit and its subsystems and an adequate cosmonaut mobility are considered in the space suit development process. Space suit system design concepts and associated study results are reviewed. Methods to provide space suit reliability are presented. ESA

N90-16786# European Space Agency, Paris (France).
ESA'S SPACE TRANSPORTATION PROGRAMME
JOERG FEUSTEL-BUEECHL *In its* Progress in Space Transportation p 23-37 Aug. 1989
Copyright Avail: NTIS HC A22/MF A03

The Ariane 5 development program is described. Its technical data sheet and component parts are presented. The Ariane 5 launch complex in Kourou, French Guiana, is described and illustrated. The schedule and cost of the Ariane 5 development scheme is given in detail. The objectives of the program are listed. Illustrations of the Hermes spaceplane and of the Hermes space suit for extra-vehicular activities are provided. A timetable for the different developmental projects is presented. Future plans beyond Ariane 5 and Hermes are presented. ESA

N90-16860* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SUITPORT EXTRA-VEHICULAR ACCESS FACILITY Patent
MARC M. COHEN, inventor (to NASA) 27 Jun. 1989 19 p Filed Oct. 20, 1987
(NASA-CASE-ARC-11635-1; US-PATENT-4,842,224; US-PATENT-APPL-SN-110388; US-PATENT-CLASS-244-159; US-PATENT-CLASS-2-2.1A) Avail: US Patent and Trademark Office CSCL 22/2

In a system for entering and leaving a space station, a bulkhead divides the module into an antechamber and an airlock. A space suit has a portable life support system (PLSS) interface on its back. The suit is removably attached to the bulkhead by the interface at a hatch in the bulkhead. A PLSS is detachably mounted in the hatch cover, which is pivotally mounted to move away from the hatch to allow an astronaut to enter the suit through the open hatch and the PLSS interface. After entering the suit, the astronaut closes the hatch and attaches the PLSS to the suit by the operating control to which the glove portion of the suit is attached. The astronaut initiates pumpdown of the airlock with the control. When the pumpdown is complete, the astronaut opens the hatch, disconnects the PLSS from the hatch cover, pivots the pressure vessels of the control to one side on their supports, disconnects the glove portions from the pressure vessels and goes EVA.
Official Gazette of the U.S. Patent and Trademark Office

N90-17762# Centre National d'Etudes Spatiales, Toulouse (France).
THE GSR3: A NEW APPROACH FOR SOLAR ARRAY DEPLOYMENTS
A. MAMODE, D. GANGLOFF, and J. L. BASTARD (Aerospatiale, Cannes, France) *In* ESA, European Space Power, Volume 2 p 563-567 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

The GSR3 solar array concept, designed to provide a high performance to cost ratio and good reliability, is presented. Results of qualification tests on two development models are presented. Deployment analysis refinements are described. The GSR3 development plan is presented. Frictionless hinges used in the deployment of the arm are described. ESA

N90-17763# Centre National d'Etudes Spatiales, Toulouse (France).
DEPLOYMENT SIMULATION FOR THE THIRD GENERATION SOLAR ARRAYS GSR3
A. MAMODE, E. CONDE, C. VERNE, M. ROUCHON, and J. L. BASTARD (Aerospatiale, Cannes, France) *In* ESA, European Space Power, Volume 2 p 569-572 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

Deployment analysis of the Amede concept solar array is described. This concept does away with regulation and synchronization devices. This makes high reliability simulation necessary in order to ensure that there be no interference with the satellite, no stop during deployment, and limited latching shocks. The deployment analysis is carried out using dynamics analysis of mechanism software, the validity of which is checked on the deployment of a moke-up on air cushions. The results of the Spacebus solar array deployment in two dimensions, and the moke-up deployment test and simulation are presented. ESA

N90-19945*# Texas Univ., Austin. Dept. of Physics.
THE PREGALACTIC COSMIC GRAVITATIONAL WAVE BACKGROUND
RICHARD A. MATZNER *In* NASA, Relativistic Gravitational Experiments in Space p 25-37 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 03/2

An outline is given that estimates the expected gravitational wave background, based on plausible pregalactic sources. Some cosmologically significant limits can be put on incoherent gravitational wave background arising from pregalactic cosmic evolution. The spectral region of cosmically generated and cosmically limited radiation is, at long periods, P greater than 1 year, in contrast to more recent cosmological sources, which have P approx. 10 to 10(exp -3). Author

09

ROBOTICS & REMOTE OPERATIONS

Simulations, models, analytical techniques, and requirements for remote, automated or robotic mechanical systems. Includes remote control of experiments.

A90-10351
SPACE STATION AUTOMATION IV; PROCEEDINGS OF THE MEETING, CAMBRIDGE, MA, NOV. 7-9, 1988
WUN C. CHIOU, SR., ED. Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 1006), 1988, 241 p. For individual items see A90-10352 to A90-10374.
(SPIE-1006) Copyright

Papers are presented on such topics as system autonomy, artificial intelligence, and telerobotics and space applications (with emphasis on system design, data management, and core technologies). Particular attention is given to the autonomous control of spacecraft nuclear reactors, teleoperation and autonomy in Space Station robotic systems, knowledge-based systems for the Hubble Space Telescope, a multisensor robotic system for autonomous space maintenance and repair, spatial operator algebra for manipulator modeling and control, and the System Autonomy Demonstration Project, a catalyst for Space Station advanced automation. B.J.

A90-10352* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AI, AUTOMATION AND THE FLIGHT TELEROBOTIC SERVICER
ANDRE GOFORTH (NASA, Ames Research Center, Moffett Field, CA) and ROBERT DOMINY (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 2-11. refs
Copyright

A NASA study for the preliminary definition of a teleoperated robotic device has been recently completed. The Fligt Telerobotic Servicer (FTS) will be used to assist astronauts in many of the on-board tasks of assembly, maintenance, servicing, and inspection of the Space Station. The role of artificial intelligence (AI) in furthering the FTS automation capabilities and, hence, extending its capacity for growth and evolution is discussed. Relevant system engineering issues are identified, and an approach for insertion of AI technology is presented in terms of the NASA/NBS Standard Reference Model control architecture NASREM. C.E.

A90-10353* California Univ., La Jolla.
AN EXAMINATION OF AUTOMATION AND ROBOTICS IN THE CONTEXT OF SPACE STATION OPERATIONS
DAVID R. CRISWELL (California, University, La Jolla), DOUGLAS S. LEE (DOT, Cambridge, MA), JAMES RAGUSA (Central Florida, University, Titusville, FL), SCOTT A. STARKS (East Texas State University, Commerce, TX), JOHN WOODRUFF (Lawrence Livermore National Laboratory, Livermore, CA), GRANVILLE PAULES (NASA, Space Station Systems Applications Branch, Washington, DC) et al. IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 12-19. refs
Copyright

A NASA-sponsored review of Space Station automation and robotics (A&R) applications from an operations and utilization perspective is presented. The goals of the A&R panel and this report are to identify major suggestions for advanced A&R operations application in Space Station as well as key technologies that have emerged or gained prominence since the completion of previous reports; to review and incorporate the range of possible Space Station A&R applications into a framework for evaluation of A&R opportunities; and to propose incentives for the government, work packages, and subcontractors to more aggressively identify, evaluate, and incorporate advanced A&R in Space Station Operations. The suggestions for A&R focused on narrow objectives using a conservative approach tuned to Space Station at IOC and limiting the Station's growth capabilities. A more aggressive stance is to identify functional needs over the Program's life, exploit and leverage available technology, and develop the key advanced technologies permitting effective use of A&R. The challenge is to systematically identify candidate functions to be automated, provide ways to create solutions resulting in savings or increased capabilities, and offer incentives that will promote the automation. C.E.

A90-10354* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN INTELLIGENT, FREE-FLYING ROBOT
G. J. REUTER, C. W. HESS, D. E. RHOADES, L. W. MCFADIN, K. J. HEALEY, and J. D. ERICKSON (NASA, Johnson Space Center, Houston, TX) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 20-27. refs
Copyright

The ground-based demonstration of EVA Retriever, a voice-supervised, intelligent, free-flying robot, is designed to evaluate the capability to retrieve objects (astronauts, equipment, and tools) which have accidentally separated from the Space Station. The major objective of the EVA Retriever Project is to design, develop, and evaluate an integrated robotic hardware and on-board software system which autonomously: (1) performs system activation and check-out, (2) searches for and acquires the target, (3) plans and executes a rendezvous while continuously tracking the target, (4) avoids stationary and moving obstacles, (5) reaches for and grapples the target, (6) returns to transfer the object, and (7) returns to base. Author

A90-10357
TELEOPERATION AND AUTONOMY IN SPACE STATION ROBOTIC SYSTEMS
PAUL D. CAMPBELL (Rockwell International Corp., Space Transportation Systems Div., Houston, TX) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 56-62.
Copyright

The control methods and corresponding crew interfaces for robotic systems in conjunction with crewmember extravehicular activity (EVA) in the U.S. Space Station planned for on-orbit assembly in the 1990's are investigated. Both teleoperation and autonomous operation are being pursued to provide either low-level control or high-level supervision of robotic tasks. The Flight Telerobotic Servicer (FTS) will be teleoperated to perform a variety of assembly, maintenance, and servicing tasks, while the EVA retriever is a free-flying autonomous robot designed for retrieval of a drifting crewmember or piece of equipment inadvertently detached from the Station. Teleoperation and autonomy are the ends of a spectrum of possible control modes. For a design selection along this dimension as well as safety considerations, the complexity of the robotic task must be considered together with the technologies required to support either teleoperation or autonomous performance of the task. Space Station operations will be enhanced by optimization of each robot's control method with respect to its mission. C.E.

A90-10358
TASK DECOMPOSITION MODULE FOR TELEROBOT TRAJECTORY GENERATION
ALBERT J. WAVERING and RON LUMIA (NIST, Robot Systems Div., Gaithersburg, MD) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988.

Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 63-70. refs
Copyright

A task decomposition module which plans and executes manipulator trajectories for a manipulator controlled by a hierarchical control system is described. The module consists of three concurrently executing submodules which manage the input command queue and coordinate operator interaction, plan trajectory functions or motion profiles, and execute planned trajectories while evaluating sensor and other world model information. An interface is suggested for the module which allows the specification of a number types of motions in a time-independent manner. Finally, some examples illustrating how different types of trajectory generation techniques are accommodated by the module structure and interfaces are presented. C.E.

A90-10359
TASK PLANNING ISSUES FOR AN IN-ORBIT SERVICE MANIPULATOR
RICHARD E. SMITH (FMC Advanced Systems Center, Minneapolis, MN) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 71-78. Research supported by ESA. refs
Copyright

Goals and concerns surrounding the development of intelligent robotics software for the Service Manipulator System (SMS) being developed for the European Space Agency are discussed. The principal goal of the SMS task software is to automate the mundane details of operating the manipulator as much as possible. The astronaut or other operator would only need to identify a task and the SMS would automatically plan and execute the appropriate motions and grasping operations needed to carry it out. The technical problems underlying these activities have been studied closely by robotics researchers; the effectiveness of available techniques often depends on the complexity of the in-orbit service environment. Reliability and testability requirements as well as uncertainties introduced in component geometries by the stress of launch and deployment are also important. These problems are currently being explored through software experiments and the development of an intelligent robotic testbed. C.E.

A90-10362
MAN-ROBOT SYMBIOSIS - A FRAMEWORK FOR COOPERATIVE INTELLIGENCE AND CONTROL
LYNNE E. PARKER and FRANCOIS G. PIN (Oak Ridge National Laboratory, TN) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 94-103. refs
(Contract DE-AC05-84OR-21400)
Copyright

The man-robot symbiosis concept has the fundamental objective of bridging the gap between fully human-controlled and fully autonomous systems to achieve true man-robot cooperative control and intelligence. A robotic system framework facilitating the symbiotic integration of teleoperative and automated modes of task execution is presented. The proposed architecture reflects a blend of many disciplines of artificial intelligence into a working system, including job or mission planning, dynamic task allocation, man-robot communication, automated monitoring, and machine learning. The five major components embodying these disciplines include the job planner, the dynamic task allocator, the presenter/interpreter, the automated monitor, and the learning system. A demonstration example illustrating the coalescence of the modules to achieve true human/robot cooperation is also discussed. Although this architecture is presented in terms of man-robot symbiosis, it is also designed to be applicable to man-machine symbiosis. C.E.

A90-10363* Tennessee Univ., Knoxville.
MULTISENSOR ROBOTIC SYSTEM FOR AUTONOMOUS SPACE MAINTENANCE AND REPAIR
M. A. ABIDI, W. L. GREEN, T. CHANDRA, and J. SPEARS (Tennessee, University, Knoxville) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 104-114. refs
(Contract NAG8-630)
Copyright

The feasibility of realistic autonomous space manipulation tasks using multisensory information is demonstrated. The system is capable of acquiring, integrating, and interpreting multisensory data to locate, mate, and demate a Fluid Interchange System (FIS) and a Module Interchange System (MIS). In both cases, autonomous location of a guiding light target, mating, and demating of the system are performed. Implemented visio-driven techniques are used to determine the arbitrary two-dimensional position and orientation of the mating elements as well as the arbitrary three-dimensional position and orientation of the light targets. A force/torque sensor continuously monitors the six components of force and torque exerted on the end-effector. Both FIS and MIS experiments were successfully accomplished on mock-ups built for this purpose. The method is immune to variations in the ambient light, in particular because of the 90-minute day-night shift in space. C.E.

A90-10364* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
GEOMETRIC DATABASE MAINTENANCE USING CCTV CAMERAS AND OVERLAY GRAPHICS
SHELDON C. OXENBERG, B. PATRICK LANDELL (GE Advanced Technology Laboratories, Moorestown, NJ), and EDWIN KAN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 115-123. refs
Copyright

An interactive graphics system using closed circuit television (CCTV) cameras for remote verification and maintenance of a geometric world model database has been demonstrated in GE's telerobotics testbed. The database provides geometric models and locations of objects viewed by CCTV cameras and manipulated by telerobots. To update the database, an operator uses the interactive graphics system to superimpose a wireframe line drawing of an object with known dimensions on a live video scene containing that object. The methodology used is multipoint positioning to easily superimpose a wireframe graphic on the CCTV image of an object in the work scene. An enhanced version of GE's interactive graphics system will provide the object designation function for the operator control station of the Jet Propulsion Laboratory's telerobot demonstration system. C.E.

A90-10365* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
NASA TELEROBOT TESTBED DEVELOPMENT AND CORE TECHNOLOGY DEMONSTRATION
PAUL S. SCHENKER, ROBERT L. FRENCH, and DAVID B. SMITH (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 132-150. refs
Copyright

In 1985, NASA initiated a major program of technology development and demonstration for robotics applications to space servicing, assembly, repair, and remote exploration. A ground-based telerobot testbed at the Jet Propulsion Laboratory has been the focal point within this program. Designed to prove technology concepts for supervised automation of increasingly unstructured and complex tasks, the testbed has reached an initial stage of integration. Several significant testbed experiments have been performed, including visual tracking and grapple of a satellite, dual-arm spatial coordination and manipulator control, force-reflecting teleoperations, and simulated task planning for a

satellite servicing scenario. The current NASA plans for continuing testbed development and demonstration are also described. C.E.

A90-10366
TELE-PERCEPTION
FRANCIS QUEK, RAMESH JAIN (Michigan, University, Ann Arbor), and BRIAN MITCHELL (Michigan, Environmental Research Institute, Ann Arbor) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 152-162. refs
Copyright

A concept called tele-perception has been developed by the NASA Center for Autonomous and Man-Controlled Robotics and Sensing Systems (CAMRSS). The tele-perception concept deals with various computer perception and human interface problems; according to this concept the distinction between computer perception and human perception need not be absolute. Tele-perception is the technology of man-machine interaction which permits the augmentation of machine perception technique with the considerable intangibilities of human cognition and which exploits the facility of machine perception to handle vast amounts of data to distill and enhance information for selective presentation to human agents. The paper illustrates the tele-perception concept along with all related projects undertaken at the CAMRSS laboratories. C.E.

A90-10367
EDGE DETECTION FOR TACTILE SENSING
ALAN D. BERGER and PRADEEP K. KHOSIA (Carnegie-Mellon University, Pittsburgh, PA) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 163-172. refs
Copyright

An edge detection algorithm for use with tactile sensors is presented in this paper. The algorithm is based on the physical properties of the tactile sensor and tactile data. In addition, the algorithm is computationally efficient, and is thus suitable for real-time data processing. Experimental results from the application of this algorithm to a Lord LTS-210 tactile array sensor are presented. Further observations about the use of a tactile sensor in a system are discussed. The proposed algorithm is a part of a real-time controller, implemented on CMU DD Arm II, that uses a tactile sensor in the feedback loop. Author

A90-10369
REAL-TIME CONTROL OF MANIPULATORS
G. V. S. RAJU (Ohio University, Athens) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 179-185. refs
Copyright

The Adaptive Model Following Control (AMFC) method is used in the design of a manipulator controller to take care of variations in payload and spatial configuration and some of the effects of unmodeled dynamics. The paper addresses the real-time implementation of the adaptive controller of PUMA 560 manipulator. The experimental results have shown that the manipulator closely follows the behavior of the reference model regardless of the load it is carrying. Author

A90-10370* McGill Univ., Montreal (Quebec).
MODEL BASED TRAJECTORY PLANNING USING PREVIEW
VINCENT HAYWARD, LAEEQUE DANESHMEND, and AJIT NILAKANTAN (McGill University, Montreal, Canada) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 186-193. Research supported by NASA and NSERC. refs
Copyright

The control of manipulators is seen here as a two-level process. A method is described to convert information available at the programming level into trajectories suitable to be tracked by a servo control system. The goal of the servo is to absorb the unmodeled dynamics. Tracking accuracy will depend mainly on the acceleration demand of the nominal trajectory setpoint, in particular, the actuator output demand must remain bounded. Our scheme adaptively takes into consideration at the trajectory computation level the dynamics of the underlying system, dynamically available information acquired through sensors, various types of constraints, such as path accuracy, and manipulator optimization. This scheme is meant to be implemented on-line, to drive mechanical systems such as manipulators. It is developed in the context of a multi-manipulator programming and control environment for space applications developed as part of a collaborative effort between McGill University and the Jet Propulsion Laboratory. Author

A90-10374* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MOBILE TRANSPORTER PATH PLANNING USING A GENETIC ALGORITHM APPROACH
PAUL BAFFES and LUI WANG (NASA, Johnson Space Center, Houston, TX) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 226-234. refs
Copyright

The use of an optimization technique known as a genetic algorithm for solving the mobile transporter path planning problem is investigated. The mobile transporter is a traveling robotic vehicle proposed for the Space Station which must be able to reach any point of the structure autonomously. Specific elements of the genetic algorithm are explored in both a theoretical and experimental sense. Recent developments in genetic algorithm theory are shown to be particularly effective in a path planning problem domain, though problem areas can be cited which require more research. However, trajectory planning problems are common in space systems and the genetic algorithm provides an attractive alternative to the classical techniques used to solve these problems. Author

A90-10525*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A TESTBED ARCHITECTURE FOR EVALUATING SPACE STATION TELESCIENCE OPERATIONS
ARSHAD MIAN (NASA, Ames Research Center; GE Government Services, Moffett Field, CA) and DARYL RASMUSSEN (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 395-401. refs
(AIAA PAPER 89-3024) Copyright

The telescience and testbedding concepts to be implemented using the Space Station are briefly reviewed. In particular, attention is given to the conceptual view of the hardware and software elements of the testbeds, their relationship to the Space Station end-to-end architecture, and the methodologies for telescience operations. It is shown that properly used testbedding mechanisms can be used to gain sufficient experience to define requirements and concepts for science experiments, payload development, design of information system elements, and engineering considerations for Space Station hardware and operations. V.L.

A90-11075
VIBRATIONLESS STARTING AND STOPPING CONTROL FOR A FLEXIBLE ARM
HIROSHI YAMAURA and KYOSUKE ONO (Tokyo Institute of Technology, Japan) JSME International Journal, Series III (ISSN 0914-8825), vol. 32, Sept. 1989, p. 413-420. refs
Copyright

An efficient vibrationless starting and stopping control method for a multidegrees-of-vibration-freedom flexible mechanical system is proposed. The procedure used to derive an optimal vibrationless

motion and input force are generally formulated using the modal equations of motion for a multidegrees-of-vibration-freedom flexible mechanical system. Combined control of control point velocity tracking feedback together with the vibrationless feedforward input is described. Then this method is applied to the starting and stopping control for a rotational flexible arm positioning system. It is shown from the experiment that transient vibrations can be suppressed well using the combined control of collocation velocity tracking feedback and vibrationless feedforward input. Author

A90-11680* Rice Univ., Houston, TX.
MICROWAVE AND CAMERA SENSOR FUSION FOR THE SHAPE EXTRACTION OF METALLIC 3D SPACE OBJECTS
SCOTT W. SHAW, RUI J. P. DEFIGUEIREDO (Rice University, Houston, TX), and KUMAR KRISHEN (NASA, Johnson Space Center, Houston, TX) IN: Sensor fusion: Spatial reasoning and scene interpretation; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 28-37. refs
(Contract NGT-44-006-806)
Copyright

The vacuum of space presents special problems for optical image sensors. Metallic objects in this environment can produce intense specular reflections and deep shadows. By combining the polarized RCS with an incomplete camera image, it has become possible to better determine the shape of some simple three-dimensional objects. The radar data are used in an iterative procedure that generates successive approximations to the target shape by minimizing the error between computed scattering cross-sections and the observed radar returns. Favorable results have been obtained for simulations and experiments reconstructing plates, ellipsoids, and arbitrary surfaces. Author

A90-13265*# National Aeronautics and Space Administration, Washington, DC.
NASA TELESCIENCE TESTBED PILOT PROGRAM
B. M. LEINER (NASA, Ames Research Center, Moffett Field, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. Previously announced in STAR as N88-3039.
(IAF PAPER 89-032) Copyright

The Universities Space Research Association (USRA), under sponsorship from the NASA Office of Space Science and Applications, is conducting a Telescience Testbed Pilot Program. Fifteen universities, under subcontract to USRA, are conducting a variety of scientific experiments using advanced technology to determine the requirements and evaluate the tradeoffs for the information system of the Space Station era. An interim set of recommendations based on the experiences of the first six months of the pilot program is presented. Author

A90-13268#
TELESCIENCE - TEST BED FIRST RESULTS
C. RICAUD, J. TAILHADES, C. GRAULLE (Matra Espace, Toulouse, France), and J. C. DEGAVRE (ESTEC, Noordwijk, Netherlands) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-035)

Telescience will provide on-ground investigators with a 'transparent' and interactive access to their payloads in orbit. It is essential to evaluate these new operation modes, their impact on system requirements and on operation management. The Test Bed developed by MATRA and now installed in ESTEC helps answering these questions by giving potential users an efficient tool to test their procedures. The paper, after recalling what is European Telescience concept, first shows how an experimenter operates Telescience Test Bed and gives the preliminary results of a few months of experimentation. It is then shown how the Test Bed is evolving, taking advantage of its highly modular structure. Finally, an overview of how these test bed facilities are going to be used in next year is presented. Author

A90-13269#
MODULAR A&R SYSTEM TESTBED FOR DEVELOPMENT AND IMPLEMENTATION OF AUTOMATION AND ROBOTICS ELEMENTS WITHIN FUTURE ORBITAL SYSTEMS
E. SCHMIDT and K.-P. LUDWIG (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p. refs
(IAF PAPER 89-036)

A study has been made of the automation and robotics (A&R) elements needed to operate the experiment facilities of the Columbus Free Flying Laboratory during the free flying mode and to support the astronaut in the Columbus Attached Laboratory. A potential A&R concept alternative for the payload operation within the Attached Laboratory is described, and the system definition of a modular A&R testbed as a tool for developing, optimizing, and verifying automation concepts in realistic simulations and tests is outlined. V.L.

A90-13270#
TELETEXUS - THE TECHNICAL AND OPERATIONAL ASPECTS OF A MICROGRAVITY EXPERIMENT IN TELESCIENCE
R. MONTI (Napoli, Universita, Naples, Italy) and R. FORTEZZA (Microgravity Advanced Research and Support Centre, Naples, Italy) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 13 p.
(IAF PAPER 89-037) Copyright

The technical and operational details of the Texus 23 Mission, which will include fluid dynamics experiments on critical Marangoni flow, are discussed with particular reference to telescience capabilities in performing microgravity experiments. The discussion covers a description of the flight hardware and the required hardware modifications, the control workstation, links, the experimental sequence, experiment control modes, and test beds. V.L.

A90-13271#
COMMERCIAL TELESCIENCE TESTBED OPERATIONS USING THE OUTPOST PLATFORM IN ORBIT - A CONCURRENT ENGINEERING APPROACH
JAMES R. GRADY, MICHAEL J. WISKERCHEN (Stanford University, CA), THOMAS C. TAYLOR, and WILLIAM A. GOOD (Global Outpost, Inc., Alexandria, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(IAF PAPER 89-039) Copyright

The Discovery Space Technology Center and Global Outpost, Inc. are participants in a program to define and develop prototypes of advanced integrated space operations technology applicable to wide variety of space systems. This cooperative research program will incorporate concurrent engineering methodology to develop advanced telescience capabilities with the goal of providing a more effective environment for space systems engineering and operations. Author

A90-13276#
THE HEALTH AND FAULT MANAGEMENT EXPERT SYSTEM FOR THE ROTEX ROBOT
H.-J. HOTOP and C.-D. STRUBE (DLR, Institut fuer Flugfuehrung, Brunswick, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-048) Copyright

The fault detection and diagnosis system for the robot of the robotic technology experiment (Rotex) within the German D2-Spacelab mission is presented. The experiment itself as well as the components of the Health and Fault Management (HFM) system are described. The HFM is built using methods of artificial intelligence and conventional techniques. The expert system of the HFM processes BITEs and other signals generated by the hardware and software of Rotex. The implementation of the object

structure, analog to the physical relations, is outlined together with the results of the reasoning system for the power supervision. Author

A90-13277#
THE FLIGHT TELEROBOTIC SERVICER - NASA'S FIRST OPERATIONAL SPACE ROBOT
RONALD K. BROWNING, HARRY G. MCCAIN, and RUTH I. WHITMAN (McDonnell Douglas Space Systems Co., Huntington Beach, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-050)

The Flight Telerobotic Servicer (FTS) is a NASA development of an operational space telerobot and supporting systems to be used in the assembly and maintenance of the international Space Station Freedom. The functional capabilities of the FTS and some of the unique technical challenges faced in developing the system are discussed. The architectural approach taken with FTS is described. C.D.

A90-13278#
DEVELOPMENT OF THE 2ND GENERATION SPACE ROBOT IN NASDA
TSUTOMU IWATA, MITSUSHIGE ODA, and TAICHI NAKAMURA (National Space Development Agency of Japan, Tsukuba Space Center, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-051) Copyright

The research and development on space Automation and Robotics at the National Space Development Agency of Japan (NASDA) covers a range of projects, from the Remote Manipulator System of the Japanese Experimental Module of the International Space Station to the advanced space robotics, that are utilized in the future space activities. The research effort is now concentrated on the second generation space robotics which will be used for the Orbital Servicing Vehicle and other unmanned vehicles. The characteristics of the second generation space robotics is teleoperation with semiautonomous control, or shared autonomy. The role sharing between human operator and the robot will be the key issue of this advanced space robotics. In this paper, NASDA's scenario for achieving semiautonomous/teleoperational space robotics is presented. Author

A90-13279*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADVANCES IN SPACE ROBOTICS
GIULIO VARSI (JPL, Pasadena, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p. refs
(IAF PAPER 89-052)

The problem of the remote control of space operations is addressed by identifying the key technical challenge: the management of contact forces and the principal performance parameters. Three principal classes of devices for remote operation are identified: anthropomorphic exoskeletons, computer aided teleoperators, and supervised telerobots. Their fields of application are described, and areas in which progress has reached the level of system or subsystem laboratory demonstrations are indicated. Key test results, indicating performance at a level useful for design tradeoffs, are reported. Author

A90-13289#
REQUIREMENTS AND CONCEPTS FOR THE SPACE STATION REMOTE MANIPULATOR SYSTEM
J. H. DUECKMAN, D. M. GOSSAIN, S. S. SACHDEV, and J. A. MIDDLETON (Spar Aerospace, Ltd., Remote Manipulator Systems Div., Toronto, Canada) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p.
(IAF PAPER 89-069) Copyright

The Mobile Servicing System (MSS) that is Canada's contribution to the NASA Space Station Freedom will be used for station assembly, maintenance, and servicing; the MSS's Remote Manipulator System (RMS) is a large robotic system derived from the Space Shuttle's RMS, which will be operated by astronauts aboard the station. The Freedom RMS is a seven degree-of-freedom manipulator with a central elbow joint as well as a three-joint cluster and an end-effector at either end. This configuration allows the RMS to be relocated by using each end effector alternately as the base or as the tip of the arm. O.C.

A90-13300#
DESIGN GUIDELINES FOR ACCOMMODATION OF ROBOTIC AND MANIPULATIVE DEVICES ON SPACE STATION FREEDOM
JOHN BOUVIER, DANIEL POL, CURT NEWPORT, JOHN O'DONNELL, and JOSEPH PARRISH (Ocean Systems Engineering, Falls Church, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(IAF PAPER 89-084)

The purpose of this paper is to address the issues related to the development of the design guidelines necessary for the accommodation of robotic and manipulative devices used for the assembly, maintenance and servicing of Space Station Freedom. Analogies and lessons learned will be drawn from the sub-sea and related industries and comparisons will be made to Space Station planned tasks and phased configurations. Criteria will be discussed in the consideration of human/machine compatibility, standardization, commonality, kinematics, operational constraints and task/resource matching. Present Space Station robotic technology will be compared to future space activity requirements. Author

A90-13302#
SIMULATION BY PERSONAL WORKSTATION FOR MAN-MACHINE INTERFACE DESIGN
S. BERTHIER, R. MIGINIAC (AMDBA, Saint-Cloud, France), and W. FREI (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-089) Copyright

This paper presents a simulation tool which has been developed for Man-Machine Interface design study, in the context of the European EVA Space Suit System development, under contract of ESA/ESTEC. The main new point is that this simulation is based on a personal workstation, and not on a heavy real-time computer, as in most simulation centers. It will be used in ESTEC to perform low cost simulations of the front part of a manned system, to improve and develop MMI with efficiency. Author

A90-13303#
DESIGN AND EVALUATION OF MAN-IN-THE-LOOP CONTROL SYSTEM OF JAPANESE EXPERIMENTAL MODULE REMOTE MANIPULATOR SYSTEM
K. YAMAWAKI, K. KURAOKA (National Space Development Agency of Japan, Tokyo), M. SHIGEHARA, K. GOMA, T. SUMI (Toshiba Corp., Space Programs Div., Kawasaki, Japan) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-090) Copyright

The Japanese Experimental Module Remote Manipulator System (JEMRMS) has two manipulator arms, the main arm (MA) and the small fine arm (SFA). The MA provides the capability of transferring, retrieving, and berthing user payload in the vicinity of the servicing bays. Attached to the MA, the SFA performs dexterous tasks, such as antenna assembly and replacement of test samples. Both arms are controlled by a single operator in the Pressurized Module (PM). The JEMRMS operation console is equipped with various man-machine interface equipments such as display and TV monitors, control panels, a keyboard, and a six-degree-of-freedom hand controller. The vision subsystem provides the RMS operator with an indirect image of the work monitored by TV cameras mounted on the MA/SFA arms, the exposed facility, and the PM. A stereoscopic image monitored by a stereoscopic TV camera mounted on the SFA's shoulder provides the human operator with three-dimensional visual information considered as the center of the man-in-the-loop control system.

Several man-in-the-loop experiments were conducted to evaluate the algorithm of the control system and the design of the man-machine interface. A set of significant data have been obtained for the phase C development of the JEMRMS program. C.E.

A90-13522#
A REMOTE MICROSCOPE FOR EXAMINING PROTEIN CRYSTALS - AN EXAMPLE OF A MICROGRAVITY EXPERIMENT USING TELESCIENCE
C. L. PINCHES (Imperial College of Science and Technology, London, England) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-417) Copyright

'Telescience' involves the interactive control of an experiment in the presence of significant control loop delays and limited transmission bandwidth, with a view to the achievement of a flexible and efficient environment for microgravity investigations without constant assistance from onboard crews. Attention is presently given to the 'bottom-up' development of a remote microscope for the examination of protein crystals. Microscope requirements encompass an object-recognition algorithm, autofocussing, and user-friendly man-machine interface. The crystal recognition algorithm's development results are presented. O.C.

A90-13523#
EXPERT SYSTEM FOR MICROGRAVITY IN TELESCIENCE
DAOAN DA, RISHENG XI (Ministry of Aeronautics and Astronautics, Lanzhou Institute of Physics, People's Republic of China), and G. OTTO (DLR, Cologne, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-418) Copyright

The ideal concept of telescience and the scope of application and state of development of telescience are reviewed. The roles that expert systems in telescience can fulfill under conditions of microgravity are described. The development and construction of such expert systems are discussed in terms of a series of abstract stages. C.D.

A90-13526#
USER REQUIREMENTS STUDY ON TELESCIENCE OPERATION IN THE SPACE STATION
K. MATSUMOTO (National Aerospace Laboratory, Chofu, Japan), K. HIGUCHI, K. YANAGAWA, N. TAKEDA (National Space Development Agency of Japan, Tokyo), S. MATSUBARA (Japan Space Utilization Promotion Center, Tokyo) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-421) Copyright

The telescience activities which will be used on the JEM are described. The key technologies to be developed are addressed and the user communications requirements for 22 typical space experiments are clarified and classified into seven levels. The design and demonstration of the first telescience testbed using three engineering models is discussed. The necessity and effectiveness of testbeds is addressed and the importance of bilateral video links using image compressions is considered. C.D.

A90-13623#
THE ASTRONAUT'S FUZZY CONTROL MODEL AND PROSPECT FOR ITS APPLICATION
SHENGZHAO LONG (Institute of Space Medico-Engineering, Beijing, People's Republic of China) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. refs
(IAF PAPER 89-589) Copyright

This paper proposes a Fuzzy Control Model (FCM) for the astronaut by means of fuzzy sets theory on the basis of astronaut's thinking activities. In order to demonstrate the efficiency of the model, the experiment results are given of an astronaut's control of a spacecraft. The FCM can be used to describe the control behavior of the astronaut controlling a manned vehicle. This model can show a new way for the study of spaceman-machine-environment systems, and also provide a new approach for the design of fuzzy control systems. Author

A90-14998*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE ROBOTICS IN THE '90S
CARL F. RUOFF (JPL, Pasadena, CA) Aerospace America (ISSN 0740-722X), vol. 27, Aug. 1989, p. 38-41, 46.
Copyright

The use of telerobots and rovers in space missions is examined. The functioning of the telerobots and rovers and their proposed applications are described. Research developments needed to design robots for specific environments and functions are described. Examples of NASA robotics projects are presented. I.F.

A90-14999#
WEST GERMANY'S FIRST SPACE ROBOT
GERD HIRZINGER (DLR, Cologne, Federal Republic of Germany) Aerospace America (ISSN 0740-722X), vol. 27, Aug. 1989, p. 42-46.
Copyright

The proposed telerobotic technology experiment, Rotex, is described. Rotex is a six-axis robot in a spacelab rack; it has force and torque sensors, range finders, and a stereo camera. Rotex capabilities include assembly and servicing tasks and grasping of floating objects. Also the robot has slow and fast modes of operation. The design and operation of the robot's gripper and laser range finders are examined; a diagram of the Rotex's gripper is presented. Teleoperation from the ground is discussed. I.F.

A90-16352
ROBOTICS AND TELEOPERATION
IAN PARKER Space (ISSN 0267-954X), vol. 5, Nov.-Dec. 1989, p. 10-12.
Copyright

The use of telepresence and teleoperation for EVA is examined. The application of robotic technology to microgravity experiments, risk reduction for astronauts, and docking procedures is discussed. Current advances in robotics and the advantages they provide for space exploration and research are considered. I.F.

A90-16518
GRAPHICAL VERIFICATION OF COMPLEX MULTIBODY MOTION IN SPACE APPLICATIONS
P. PUTZ (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Dynamics of controlled mechanical systems; Proceedings of the IUTAM/IFAC Symposium, Zurich, Switzerland, May 30-June 3, 1988. Berlin and New York, Springer-Verlag, 1989, p. 91-104. refs
Copyright

Recent advances in the development of CAE tools for complex multibody dynamical systems are surveyed. The advantages of graphical computer simulations for the design process are discussed; the current capabilities of (1) nonlinear dynamic simulation programs and (2) three-dimensional solid-model-based CAD packages with kinematic features are reviewed; and their applicability to space structures is considered. Integrated packages combining (1) and (2) are briefly characterized, and applications to simulations of controlled dynamic robot motion and a robot filament-winding motion are shown in drawings. T.K.

A90-16522
ACTIVE VIBRATION CONTROL FOR FLEXIBLE SPACE ENVIRONMENT USE MANIPULATORS
T. KOMATSU, M. UENOHARA, S. IIKURA (Toshiba Corp., Mechanical Engineering Laboratory, Kawasaki, Japan), H. MIURA, and I. SHIMOYAMA (Tokyo, University, Japan) IN: Dynamics of controlled mechanical systems; Proceedings of the IUTAM/IFAC Symposium, Zurich, Switzerland, May 30-June 3, 1988. Berlin and

New York, Springer-Verlag, 1989, p. 181-192. refs
Copyright

A new dynamic control system for flexible space manipulators has been developed from the practical viewpoint. The key concept is that the local position and torque PD feedback loop at each joint should be used for position and structural-vibration control. The manipulator dynamics is derived, and then feedback control is developed using an appropriate potential function. An experimental setup using an air-suspended SCARA flexible manipulator is described. The effectiveness of this method has been verified by experimental results, adapting it to automatic payload handling. Author

A90-17038
ANALYSIS AND TEST ON THE DIGITAL OPTIMAL CONTROL OF A FLEXIBLE ROBOT ARM VIBRATION
YOUNG-PIL PARK, HYEOK-SUNG PARK, YOUNG-KYUN HA (Yonsei University, Seoul, Republic of Korea), and SEUNG-HO KIM (Korea Advanced Energy Research Institute, Seoul, Republic of Korea) IN: International Modal Analysis Conference, 7th, Las Vegas, NV, Jan. 30-Feb. 2, 1989, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1989, p. 1489-1495. refs
Copyright

A flexible robot arm carrying a payload is modeled as a cantilever beam with a tip mass subjected to a high-speed rotation. Equations of motion, for modal control, are represented as state variable form using Galerkin's mode summation method. Digital optimal control law with observer is developed to suppress the arm vibration and control the position of the joint angle. Two types of control schemes: (1) single actuator control by servo motor (SIMO system); and (2) dual actuator control by the motor and specially-designed linear actuator (MIMO system) are considered. The effects of weighting factors of the performance index (PI), sampling time, and the number of controlled modes on the control performance are analyzed by computer simulations and experiments. Author

A90-21606#
DIAGNOSIS SYSTEMS FOR SPACE PAYLOADS
JOHANNES ROGG, ULRICH SCHWAN, and HANS REFFEL Dornier Post (ISSN 0012-5563), no. 3, 1989, p. 23-25.
Copyright

Such next-generation manned space systems as the Columbus Space Station's MTFF and APM will need to employ an AI systems-diagnosis approach as well as advanced man/machine interfaces due to their complexity. The diagnostic expert systems to be developed must detect and locate system errors, generate error-correction procedures, and run test routines upon correction of the error in order to verify the systems's return to functioning order. The bases for system reconfigurations and payload integrations should also be furnished by the AI diagnostic system. O.C.

A90-21633
INVASION OF THE SPACEBOTS
GREG FREIHERR Air and Space (ISSN 0886-2257), vol. 4, Feb.-Mar. 1990, p. 72-81.
Copyright

NASA-Goddard is the lead development center for robotic devices that will help assemble, service, and repair the planned NASA Space Station. Goddard's efforts currently extend to what may be the first practical space robot, the Flight Telerobotic Servicer. The EVA Retriever, under construction at the Johnson Space Center, will be able to fetch either tools or astronauts that come to be unsafely separated from the Station. Trully pathbreaking robotic systems are exemplified by the 15 ft-tall, six-legged 'Ambler' planetary terrain-walker, and the 'DataSuit' and 'DataGlove' garments with integrated fiber-optic sensors; when the data they generate are connected to a visual representation of a three-dimensional space, the wearer can interact with the simulated environment. O.C.

A90-22691
NONLINEAR STRUCTURAL DYNAMICS OF SPACE MANIPULATORS WITH ELASTIC JOINTS
H. S. TZOU (Kentucky, University, Lexington) International Journal of Analytical and Experimental Modal Analysis (ISSN 0886-9367), vol. 4, Oct. 1989, p. 117-123. Research supported by the University of Kentucky. refs
Copyright

Joint dynamic characteristics in flexible space manipulators affect the manipulators' high-demanding operational performance and accuracy. In this paper, the structural dynamics of a flexible robotic manipulator with elastic joints is studied using nonlinear theoretical and finite-element methods. Dynamic equations of a discretized multi-degree of freedom system with initial joint gaps are derived. Dynamic contacts in an elastic joint are simulated by a nonlinear joint model represented by a set of nonlinear springs and dampers. A pseudoforce approximation method is used in nonlinear finite-element analyses. Nonlinear dynamic contacts resulting from internal joint gap between two links in the manipulator systems are studied. Effect of joint gap size and surface rigidity are evaluated in this paper. Author

A90-23672* California Univ., Los Angeles.
INTERACTION DYNAMICS OF MULTIPLE AUTONOMOUS MOBILE ROBOTS IN BOUNDED SPATIAL DOMAINS
P. K. C. WANG (California, University, Los Angeles) International Journal of Control (ISSN 0020-7179), vol. 50, Dec. 1989, p. 2109-2124. Research supported by NASA. refs
(Contract NSF ECS-87-18473)
Copyright

A general navigation strategy for multiple autonomous robots in a bounded domain is developed analytically. Each robot is modeled as a spherical particle (i.e., an effective spatial domain about the center of mass); its interactions with other robots or with obstacles and domain boundaries are described in terms of the classical many-body problem; and a collision-avoidance strategy is derived and combined with homing, robot-robot, and robot-obstacle collision-avoidance strategies. Results from homing simulations involving (1) a single robot in a circular domain, (2) two robots in a circular domain, and (3) one robot in a domain with an obstacle are presented in graphs and briefly characterized. T.K.

A90-23676
ROBOTS IN SPACE - A CHECKLIST FOR SAFE DESIGN AND OPERATION
L. KEN LAUDERBAUGH (Rensselaer Polytechnic Institute, Troy, NY) and T. DAVETTA MONTGOMERY Society of Manufacturing Engineers, Robots in Aerospace Manufacturing Conference, Irvine, CA, Feb. 20-23, 1989. 22 p. refs
(SME PAPER MS89-128) Copyright

The prospective use of robots in space has prompted consideration of such autonomous robotic systems' potential safety risks in light of their most comparable terrestrial counterparts' role in industrial accidents and fatalities. Illustrative examples are presented for the three essential frameworks of space robot design safeguarding practices: (1) intrinsic safety of robot system design, (2) intrinsic safety of robot system operation, and (3) add-on safety systems. Also, a space robot hazard-identification chechlist is developed on the basis of a systematic identification of hazard sources, their associated risks, and the determination of necessary safeguards. O.C.

A90-23692
CRITICAL DESIGN CRITERIA OF END OF ARM TOOLING FOR SPACE ROBOT SERVICER
SUREN N. DWIVEDI (West Virginia University, Morgantown) Society of Manufacturing Engineers, Conference on Robots 13, Gaithersburg, MD, May 7-11, 1989. 12 p. refs
(SME PAPER MS89-305) Copyright

NASA's semiautonomous Flight Telerobotic Services device requires a 'gripping' component which will share in the robot's level of intelligence and be fully applicable to EVA operations. A

study has accordingly been conducted into the design features of an intelligent, general-purpose gripper with six-DOF force/torque sensor, and the implementation of a wrist-actuated autochange mechanism allowing the robot to switch end-effectors automatically for more specialized tasks than the general-purpose apparatus can accomplish. O.C.

A90-23741
STEREO VISION TECHNIQUES FOR TELESCIENCE
S. HEWETT (Logica Space and Defence Systems, Ltd., London, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Feb. 1990, p. 57-67. Research supported by ESA. refs
Copyright

The Botanic Experiment is one of the pilot experiments in the Telescience Test Bed program at the ESTEC research and technology center of the European Space Agency. The aim of the Telescience Test Bed is to develop the techniques required by an experimenter using a ground based work station for remote control, monitoring, and modification of an experiment operating on a space platform. The purpose of the Botanic Experiment is to examine the growth of seedlings under various illumination conditions with a video camera from a number of viewpoints throughout the duration of the experiment. This paper describes the Botanic Experiment and the points addressed in developing a stereo vision software package to extract quantitative information about the seedlings from the recorded video images. Author

A90-23911*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
NASA'S FIRST DEXTEROUS SPACE ROBOT
HARRY G. MCCAIN (NASA, Goddard Space Flight Center, Greenbelt, MD) Aerospace America (ISSN 0740-722X), vol. 28, Feb. 1990, p. 12-15.
Copyright

NASA is developing the Flight Telerobotic Servicer (FTS), a robotic device that can be teleoperated under constant command of a human operator or run by itself under human supervision. Plans call for the FTS to assist the astronauts in the assembly, maintenance, servicing, and inspection of Space Station Freedom. The FTS project is driven by five major objectives: to reduce Space Station dependence on crew EVA, improve crew safety, enhance crew utilization, promote remote servicing capabilities for platforms, and accelerate technology transfer from research to U.S. industry. Another part of the FTS project is a ground system that will support operations and system evolution. Not only will the FTS provide a needed operational capability during the assembly and operation of Space Station Freedom, it will also provide an expanding foundation for proving more advanced robotic and telepresence concepts in space. R.E.P.

A90-23912#
DESIGN OVERVIEW
JAMES W. LOWRIE (Martin Marietta Corp., Astronautics Group, Denver, CO) Aerospace America (ISSN 0740-722X), vol. 28, Feb. 1990, p. 15, 16, 18, 20.
Copyright

A design overview of the Flight Telerobotic System (FTS) is presented. The FTS has two manipulators, each with seven degrees of freedom (DOF). It also has one five-DOF attachment stabilization and positioning system. The manipulators are teleoperator-controlled in seven DOF. Safety software associated with avoiding collisions is separated onto a redundant controller and two data processors, providing two-fault tolerance. Simulators will provide a real-time graphic display of simulated telerobot operations. The telerobot promises to be a useful, reliable, and safe tool to assist the astronauts in performing assembly, maintenance, servicing, and inspection tasks on Space Station Freedom and the Space Shuttle. R.E.P.

A90-23913*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
FTS OPERATIONS
JAMES F. ANDARY, SANFORD W. HINKAL, and DENNIS HEWITT (NASA, Goddard Space Flight Center, Greenbelt, MD) Aerospace America (ISSN 0740-722X), vol. 28, Feb. 1990, p. 20, 21.
Copyright

The first planned use of the Flight Telerobotic Servicer (FTS) in the Space Station Freedom program is for the initial assembly of the station. Before the station is permanently manned, the FTS will operate out of the Shuttle bay. After initial assembly is complete, the 60-ft-long arm of the Canadian Mobile Servicing Center (MSC) will transport the FTS to the worksites. The FTS has three operating modes: dependent, transporter attached, and independent. Further details are given for each of these modes. In analyzing assembly operations, potential tasks were examined for their similarity to the six baseline FTS tasks. Operations will also include ground support for the servicer. Future tasks are being analyzed and verified by hardware performance in the lab. R.E.P.

A90-23914#
NASA/NBS REFERENCE MODEL
JAMES S. ALBUS and RONALD LUMIA (NIST, Robot Systems Div., Gaithersburg, MD) Aerospace America (ISSN 0740-722X), vol. 28, Feb. 1990, p. 21-23.
Copyright

The NASA/NBS Standard Reference Model (NASREM) Telerobot Control System Architecture defines the basic architecture for a robot control system capable of teleoperation and autonomous operation. The goal is to make it the standard for all robotic systems. The control system architecture is a three-legged hierarchy of computing models, serviced by a communications system and a global memory. Details are provided for the three legs of the system. The control architecture allows human operators, at any location, to supervise the telerobot and assume control at any level of the hierarchy. NASREM is being implemented in support of the Flight Telerobotic Servicer (FTS) project. It provides a framework for controlling the telerobot's manipulators, cameras, end effectors, and tools. Some details of the proposed FTS test flight program are also provided. R.E.P.

A90-23915*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
EVOLUTION AND ADVANCED TECHNOLOGY
STANFORD OLLENDORF (NASA, Goddard Space Flight Center, Greenbelt, MD), JACK E. PENNINGTON (NASA, Langley Research Center, Hampton, VA), and BERT HANSEN, III (JPL, Pasadena, CA) Aerospace America (ISSN 0740-722X), vol. 28, Feb. 1990, p. 23, 24, 30.
Copyright

The NASREM architecture with its standard interfaces permits development and evolution of the Flight Telerobotic Servicer to greater autonomy. Technologies in control strategies for an arm with seven DOF, including a safety system containing skin sensors for obstacle avoidance, are being developed. Planning and robotic execution software includes symbolic task planning, world model data bases, and path planning algorithms. Research over the last five years has led to the development of laser scanning and ranging systems, which use coherent semiconductor laser diodes for short range sensing. The possibility of using a robot to autonomously assemble space structures is being investigated. A control framework compatible with NASREM is being developed that allows direct global control of the manipulator. Researchers are developing systems that permit an operator to quickly reconfigure the telerobot to do new tasks safely. R.E.P.

A90-24022*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MANUAL CONTROL OF THE LANGLEY LABORATORY TELEROBOTIC MANIPULATOR
WALTER W. HANKINS, III and RANDOLPH W. MIXON (NASA, Langley Research Center, Hampton, VA) IEEE, International Conference on Systems, Man, and Cybernetics, Cambridge, MA, Nov. 14-17, 1989, Paper. 7 p.

Langley's new Laboratory Teleoperator Manipulator (LTM) provides manual control of seven-degree-of-freedom, replica, force-reflecting, master/slave manipulator arms in two arms

simultaneously. This paper describes the LTM, its installation, and plans for a comparable evaluation study of various control input devices to the system. The comparison includes control using the system's master arms, six-degree-of-freedom hand controllers, minimasters, and a force-reflecting hand controller. C.D.

A90-27506* Krug International, Houston, TX.
TELEMYCOLOGY - A NOVEL APPROACH TO MONITORING ENVIRONMENTAL MICROBIAL LOAD IN SPACE STATION FREEDOM
S. K. MISHRA, H. D. BROWN, R. D. TAYLOR (Krug International Corp., Houston, TX), and D. L. PIERSON (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p. refs
(SAE PAPER 891542) Copyright

The currently available methods for monitoring environmental microbial load call for the cultivation of microbes on laboratory media, a time- and material-consuming task that is potentially hazardous. Telemycology proposed in this communication is designed to eliminate the need for growing microbes, especially fungi, on board the spacecraft and to shift the bulk of the work-load to the ground-based Microbiology Laboratory. The system is based on the principle of trapping microbial propagules on a membrane filter, treating it with a microbe-enhancing reagent, and examining under a microscope down-linked to the central laboratory equipped with a synchronized televideo, telerobotics, and image banking system. Author

A90-29230#
THE TWO-WAY SHAPE MEMORY EFFECT FOR MECHANICAL HANDS
K. ESCHER, E. HORNBOGEN (Bochum, Ruhr-Universitaet, Federal Republic of Germany), A. H. EXNER, and H. SCHMIDT (Deutsche Agentur fuer Raumfahrt-Angelegenheiten GmbH, Bonn, Federal Republic of Germany) IN: AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 29-37. refs
(Contract BMFT-01-EAS-88292)
(AIAA PAPER 90-1028) Copyright

The use of mechanical hands and grippers based on shape memory alloys is proposed to be employed in particular in space operations. Versatile and dexterous motions can be carried out by the materials only and therefore lubrication becomes unnecessary. The origin of the shape memory effect is a martensitic phase transformation occurring at specific temperatures. In the case of the two-way effect the transformation results in a shape change effected by heating and, in a reverse shape change, effected by cooling. The effect can be trained in by thermomechanical treatments which are presented, also investigations have been made on polycristalline NiTi-alloys, and the results are discussed. Author

A90-29359
AIAA/ASME/ASCE/AHS/ASC STRUCTURES, STRUCTURAL DYNAMICS AND MATERIALS CONFERENCE, 31ST, LONG BEACH, CA, APR. 2-4, 1990, TECHNICAL PAPERS. PART 3 - STRUCTURAL DYNAMICS I
Washington, DC, American Institute of Aeronautics and Astronautics, 1990, 602 p. For individual items see A90-29360 to A90-29408.
Copyright

Papers are presented on the prediction of unsteady transonic flow around missile configurations; unsteady flow computation of oscillating flexible wings; time-domain simulations of a flexible wing in subsonic compressible flow; and a reduced-cost rational-function approximation for unsteady aerodynamics. Topics discussed include flutter, aeroelasticity, aeroservoelasticity, and acoustic radiation. Consideration is given to computational prediction of stall flutter in cascaded airfoils; aeroelastic analysis of helicopter rotor blades; aeroelastic problems in turbomachines; aeroelastic tailoring analysis; shock testing using rapid frequency sweep; and the application of distributed piezoelectric film sensors to space robotics. I.F.

N90-10124*# Alabama Univ., Huntsville. Dept. of Computer Science.
KNOWLEDGE-BASED MACHINE VISION SYSTEMS FOR SPACE STATION AUTOMATION Annual Report, 1 Aug. 1988 - 31 Jul. 1989
HEGGERE S. RANGANATH and LAURE J. CHIPMAN 23 Aug. 1989 46 p
(Contract NCC8-016)
(NASA-CR-185710; NAS 1.26:185710) Avail: NTIS HC A03/MF A01 CSCL 22/2

Computer vision techniques which have the potential for use on the space station and related applications are assessed. A knowledge-based vision system (expert vision system) and the development of a demonstration system for it are described. This system implements some of the capabilities that would be necessary in a machine vision system for the robot arm of the laboratory module in the space station. A Perceptics 9200e image processor, on a host VAXstation, was used to develop the demonstration system. In order to use realistic test images, photographs of actual space shuttle simulator panels were used. The system's capabilities of scene identification and scene matching are discussed. K.C.D.

N90-10447*# Spectra Research Systems, Inc., Huntsville, AL. Systems Technology Div.
INTERCHANGEABLE END EFFECTOR TOOLS UTILIZED ON THE PROTOFLIGHT MANIPULATOR ARM Final Report
May 1987 153 p
(Contract NAS8-36307)
(NASA-CR-179374; NAS 1.26:179374; SRS/STD-TR86-011-549)
Avail: NTIS HC A08/MF A01 CSCL 13/9

A subset of teleoperator and effector tools was designed, fabricated, delivered and successfully demonstrated on the Marshall Space Flight Center (MSFC) protoflight manipulator arm (PFMA). The tools delivered included a rotary power tool with interchangeable collets and two fluid coupling mate/demate tools; one for a Fairchild coupling and the other for a Purolator coupling. An electrical interface connector was also provided for the rotary power tool. A tool set, from which the subset was selected, for performing on-orbit satellite maintenance was identified and conceptionally designed. Maintenance requirements were synthesized, evaluated and prioritized to develop design requirements for a set of end effector tools representative of those needed to provide on-orbit maintenance of satellites to be flown in the 1986 to 2000 timeframe. Author

N90-10577*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCING AUTOMATION AND ROBOTICS TECHNOLOGY FOR THE SPACE STATION FREEDOM AND FOR THE US ECONOMY Progress Report No. 8, Aug. 1988 - Feb. 1989
JEREMIAH F. CREEDON Apr. 1989 25 p
(NASA-TM-101561; NAS 1.15:101561) Avail: NTIS HC A03/MF A01 CSCL 12/1

In April 1985, as required by Public Law 98-371, the NASA Advanced Technology Advisory Committee (ATAC) reported to Congress the results of its studies on advanced automation and robotics technology for use on the Freedom space station. This material was documented in the initial report (NASA Technical Memorandum 87566). A further requirement of the law was that ATAC follow NASA's progress in this area and report to Congress semiannually. This report is the eighth in a series of progress updates and covers the period between October 1, 1988, and March 31, 1989. NASA has accepted the basic recommendations of ATAC for its Space Station Freedom efforts. ATAC and NASA agree that the thrust of Congress is to build an advanced automation and robotics technology base that will support an evolutionary Space Station Freedom program and serve as a highly visible stimulator, affecting the U.S. long-term economy. The

progress report identifies the work of NASA and the Freedom study contractors. It also describes research in progress, and it makes assessments of the advancement of automation and robotics technology on the Freedom space station. Author

N90-11310*# National Inst. of Standards and Technology, Gaithersburg, MD. Robot System Div.
NASA/NBS (NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/NATIONAL BUREAU OF STANDARDS) STANDARD REFERENCE MODEL FOR TELEROBOT CONTROL SYSTEM ARCHITECTURE (NASREM) Final Report
JAMES S. ALBUS, HARRY G. MCCAIN, and RONALD LUMIA Apr. 1989 85 p Sponsored by NASA, Goddard Space Flight Center, Greenbelt, Md
(NASA-CR-185078; NAS 1.26:185078; PB89-193940; NIST/TN-1235-89) Avail: NTIS HC A05/MF A01; SOD HC $4.25 as 003-003-02928-9 CSCL 13/9

The document describes the NASA Standard Reference Model (NASREM) Architecture for the Space Station Telerobot Control System. It defines the functional requirements and high level specifications of the control system for the NASA space Station document for the functional specification, and a guideline for the development of the control system architecture, of the 10C Flight Telerobot Servicer. The NASREM telerobot control system architecture defines a set of standard modules and interfaces which facilitates software design, development, validation, and test, and make possible the integration of telerobotics software from a wide variety of sources. Standard interfaces also provide the software hooks necessary to incrementally upgrade future Flight Telerobot Systems as new capabilities develop in computer science, robotics, and autonomous system control. GRA

N90-11455*# Research Inst. for Advanced Computer Science, Moffett Field, CA.
TELESCIENCE TESTBED PILOT PROGRAM Quarterly Report No. 5, 1 Jun. - 31 Aug. 1988
MARIA L. GALLAGHER, ed. and BARRY M. LEINER, ed. 1 Sep. 1988 80 p
(Contract NASW-4234)
(NASA-CR-184594; NAS 1.26:184594; RIACS-M88.5) Avail: NTIS HC A05/MF A01 CSCL 09/2

The Telescience Testbed Pilot Program is developing initial recommendations for requirements and design approaches for the information systems of the Space Station era. During this quarter, drafting of the final reports of the various participants was initiated. Several drafts are included in this report as the University technical reports. K.C.D.

N90-13047*# Research Inst. for Advanced Computer Science, Moffett Field, CA.
TELESCIENCE TESTBED PILOT PROGRAM Quarterly Report No. 4, 1 Mar. 1988 - 31 Aug. 1988
MARIA L. GALLAGHER, ed. and BARRY M. LEINER, ed. 1 Jun. 1988 74 p
(Contract NASW-4234)
(NASA-CR-184997; NAS 1.26:184997; RIACS-M88.4) Avail: NTIS HC A04/MF A01 CSCL 09/2

The Telescience Testbed Pilot Program (TTPP) is intended to develop initial recommendations for requirements and design approaches for the information system of the Space Station era. Multiple scientific experiments are being performed, each exploring advanced technologies and technical approaches and each emulating some aspect of Space Station era science. The aggregate results of the program will serve to guide the development of future NASA information systems. Author

N90-13794*# Teledyne Brown Engineering, Huntsville, AL.
USER NEEDS, BENEFITS, AND INTEGRATION OF ROBOTIC SYSTEMS IN A SPACE STATION LABORATORY Final Report, Oct. 1987 - Oct. 1989
W. R. DODD, M. B. BADGLEY, and C. R. KONKEL Oct. 1989 78 p
(Contract NAS3-25278)
(NASA-CR-185150; NAS 1.26:185150; TBE-SSD-P601-89-191)
Avail: NTIS HC A05/MF A01 CSCL 13/9

The methodology, results and conclusions of all tasks of the User Needs, Benefits, and Integration Study (UNBIS) of Robotic Systems in a Space Station Laboratory are summarized. Study goals included the determination of user requirements for robotics within the Space Station, United States Laboratory. In Task 1, three experiments were selected to determine user needs and to allow detailed investigation of microgravity requirements. In Task 2, a NASTRAN analysis of Space Station response to robotic disturbances, and acceleration measurement of a standard industrial robot (Intelledex Model 660) resulted in selection of two ranges of microgravity manipulation: Level 1 (10-3 to 10-5 G at greater than 1 Hz) and Level 2 (less than equal 10-6 G at 0.1 Hz). This task included an evaluation of microstepping methods for controlling stepper motors and concluded that an industrial robot actuator can perform milli-G motion without modification. Relative merits of end-effectors and manipulators were studied in Task 3 in order to determine their ability to perform a range of tasks related to the three microgravity experiments. An Effectivity Rating was established for evaluating these robotic system capabilities. Preliminary interface requirements for an orbital flight demonstration were determined in Task 4. Task 5 assessed the impact of robotics. Author

N90-13991*# Alabama Univ., Huntsville.
APPLICATIONS OF ARTIFICIAL INTELLIGENCE TO SPACE STATION AND AUTOMATED SOFTWARE TECHNIQUES: HIGH LEVEL ROBOT COMMAND LANGUAGE Final Report, 1 Jun. 1988 - 31 May 1989
JAMES W. MCKEE Jun. 1989 116 p
(Contract NCC8-13)
(NASA-CR-182997; NAS 1.26:182997; UAH-RR-803) Avail: NTIS HC A06/MF A01 CSCL 09/2

The objective is to develop a system that will allow a person not necessarily skilled in the art of programming robots to quickly and naturally create the necessary data and commands to enable a robot to perform a desired task. The system will use a menu driven graphical user interface. This interface will allow the user to input data to select objects to be moved. There will be an imbedded expert system to process the knowledge about objects and the robot to determine how they are to be moved. There will be automatic path planning to avoid obstacles in the work space and to create a near optimum path. The system will contain the software to generate the required robot instructions. Author

N90-14247*# Georgia Inst. of Tech., Atlanta. School of Mechanical Engineering.
MANIPULATION STRATEGIES FOR MASSIVE SPACE PAYLOADS Semiannual Progress Report, 16 May - 15 Nov. 1989
WAYNE J. BOOK 1989 138 p
(Contract NAG1-623)
(NASA-CR-186081; NAS 1.26:186081) Avail: NTIS HC A07/MF A01 CSCL 22/1

Control for the bracing strategy is being examined. It was concluded earlier that trajectory planning must be improved to best achieve the bracing motion. Very interesting results were achieved which enable the inverse dynamics of flexible arms to be calculated for linearized motion in a more efficient manner than previously published. The desired motion of the end point beginning at t=0 and ending at t=t sub f is used to calculate the required torque at the joint. The solution is separated into a causal function that is zero for t is less than 0 and an accusal function which is zero for t is greater than t sub f. A number of alternative end point trajectories were explored in terms of the peak torque required, the amount of anticipatory action, and other issues. The single link case is the immediate subject and an experimental verification of that case is being performed. Modeling with experimental verification of closed chain dynamics continues. Modeling effort has pointed out inaccuracies that result from the choice of numerical techniques used to incorporate the closed

chain constraints when modeling our experimental prototype RALF (Robotic Arm Large and Flexible). Results were compared to TREETOPS, a multi body code. The experimental verification work is suggesting new ways to make comparisons with systems having structural linearity and joint and geometric nonlinearity. The generation of inertial forces was studied with a small arm that will damp the large arm's vibration. Author

N90-15433 Rutgers - The State Univ., New Brunswick, NJ.
ON THE ANALYSIS AND OPTIMIZATION OF A PLATFORM MANIPULATOR Ph.D. Thesis
MARTIN CWIAKALA 1988 115 p
Avail: Univ. Microfilms Order No. DA8914201

A platform manipulator (closed-loop manipulator) is a spatial mechanism used to position and orient a platform. In consulting literature concerning open- and closed-loop manipulators, the topic of statis analysis was found to be missing for the closed-loop manipulator. By combining static analysis and workspace evaluation, a design of optimum geometry for a closed-loop manipulator is developed. Based on application, this research has two distinct parts: analysis and workspace optimization with regard to actuator load; and a feasibility study concerning the use of cables for legs of the manipulator. The work presented is based on a special configuration of an applied static load which is restricted to a plane. This load configuration results in the polar plots of actuator loads to be circled when plotted against load direction. Extending this concept for the general loads, work volume in which the actuators remained below a specified force for a specified platform orientation was found. A search is performed on the geometric parameters to maximize this work volume. The cable leg feasibility study also utilized the special form of the applied load. Two configurations are investigated: inverting the manipulator and using the force of gravity to keep all legs in tension, and using an additional leg mounted between the centers of the platforms. A method is presented to determine the range of force orientations that result in all legs being in tension, a necessary condition if cables are used. For specified platform orientation and disturbance/tension-force ratio, workspace shape and volume is determined in which all legs remain in tension. Again, a search is performed on the geometric parameters of the manipulator to maximize the workspace volume for each configuration. Dissert. Abstr.

N90-15447*# Carnegie-Mellon Univ., Pittsburgh, PA. The Robotics Inst.
BASE REACTION OPTIMIZATION OF REDUNDANT MANIPULATORS FOR SPACE APPLICATIONS
C. L. CHUNG, S. DESA, and C. W. DESILVA (British Columbia Univ., Vancouver.) 1988 32 p
(Contract NAG3-811)
(NASA-CR-186274; NAS 1.26:186274; CMU-RI-TR-88-17)
Copyright Avail: NTIS HC A03/MF A01 CSCL 13/9

One of the problems associated with redundant manipulators which were proposed for space applications is that the reactions transmitted to the base of the manipulator as a result of the motion of the manipulator will cause undesirable effects on the dynamic behavior of the supporting space structure. It is therefore necessary to minimize the magnitudes of the forces and moments transmitted to the base. It is shown that kinematic redundancy can be used to solve the dynamic problem of minimizing the magnitude of the base reactions. The methodology described is applied to a four degree-of-freedom spatial manipulator with one redundant degree-of-freedom. Author

N90-16221*# Alabama Univ., Huntsville. Dept. of Computer Science.
A KNOWLEDGE-BASED MACHINE VISION SYSTEM FOR SPACE STATION AUTOMATION
LAURE J. CHIPMAN and H. S. RANGANATH *In* NASA, Langley Research Center, Visual Information Processing for Television and Telerobotics p 231-241 Nov. 1989
(Contract NCC8-16)
Avail: NTIS HC A12/MF A02 CSCL 14/2

A simple knowledge-based approach to the recognition of objects in man-made scenes is being developed. Specifically, the system under development is a proposed enhancement to a robot arm for use in the space station laboratory module. The system will take a request from a user to find a specific object, and locate that object by using its camera input and information from a knowledge base describing the scene layout and attributes of the object types included in the scene. In order to use realistic test images in developing the system, researchers are using photographs of actual NASA simulator panels, which provide similar types of scenes to those expected in the space station environment. Figure 1 shows one of these photographs. In traditional approaches to image analysis, the image is transformed step by step into a symbolic representation of the scene. Often the first steps of the transformation are done without any reference to knowledge of the scene or objects. Segmentation of an image into regions generally produces a counterintuitive result in which regions do not correspond to objects in the image. After segmentation, a merging procedure attempts to group regions into meaningful units that will more nearly correspond to objects. Here, researchers avoid segmenting the image as a whole, and instead use a knowledge-directed approach to locate objects in the scene. The knowledge-based approach to scene analysis is described and the categories of knowledge used in the system are discussed. Author

N90-18151*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ADVANCING AUTOMATION AND ROBOTICS TECHNOLOGY FOR THE SPACE STATION FREEDOM AND FOR THE US ECONOMY Progress Report No. 7, Apr. 1988 - Sep. 1988
Sep. 1988 37 p
(NASA-TM-101691; NAS 1.15:101691) Avail: NTIS HC A03/MF A01 CSCL 05/8

In April 1985, as required by Public Law 98-371, the NASA Advanced Technology Advisory Committee (ATAC) reported to Congress the results of its studies on advanced automation and robotics technology for use on the Freedom space station. This material was documented in the initial report (NASA Technical Memorandum 87566). A further requirement of the law was that ATAC follow NASA's progress in this area and report to Congress semiannually. This report is the seventh in a series of progress updates and covers the period between April 1, 1988 and September 30, 1988. NASA has accepted the basic recommendations of ATAC for its Space Station Freedom efforts. ATAC and NASA agree that the thrust of Congress is to build an advanced automation and robotics technology base that will support an evolutionary Space Station Freedom program and serve as a highly visible stimulator, affecting the U.S. long-term economy. The progress report identifies the work of NASA and the Freedom study contractors. It also describes research in progress, and it makes assessments of the advancement of automation and robotics technology on the Freedom space station. Author

N90-19279*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCING AUTOMATION AND ROBOTICS TECHNOLOGY FOR THE SPACE STATION FREEDOM AND FOR THE US ECONOMY: SUBMITTED TO THE UNITED STATES CONGRESS Progress Report No. 9, Mar. - Jul. 1989
Mar. 1990 39 p
(NASA-TM-101647; NAS 1.15:101647) Avail: NTIS HC A03/MF A01 CSCL 22/2

In April 1985, as required by Public Law 98-371, the NASA Advanced Technology Advisory Committee (ATAC) reported to Congress the results of its studies on advanced automation and robotics technology for use on the Space Station Freedom. This material was documented in the initial report (NASA Technical Memorandum 87566). A further requirement of the law was that ATAC follow NASA's progress in this area and report to Congress semiannually. This report is the ninth in a series of progress updates and covers the period between February 24, 1989, and July 12, 1989. NASA has accepted the basic recommendation of ATAC

for its Space Station Freedom efforts. ATAC and NASA agree that the thrust of Congress is to build an advanced automation and robotics technology base that will support an evolutionary Space Station program and serve as a highly visible stimulator, affecting the U.S. long-term economy. The work of NASA and the Freedom contractors, e.g., Work Packages, as well as the Flight Telerobotic Servicer is identified. Research in progress is also described and assessments of the advancement of automation and robotics technology on the Space Station Freedom are given. Author

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MECHANICAL SYSTEMS

Design and operation of mechanical equipment, including gyroscopes and pointing mechanisms. Includes lubrication and lubricants.

A90-13248#
SOFA - SOFT ORIENTATION FOR ANTENNAE
PIERRE BRUNET (Aerospatiale, Cannes, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p.
(IAF PAPER 89-008) Copyright
Requirements for the antenna pointing mechanism of large spacecraft are formulated, and the design of a SOFA system is described. Results of functional, reliability, and flight testing of SOFA devices are presented, demonstrating a pointing accuracy of few millidegrees. The reliability of the electronic and mechanical parts of the SOFA mechanism is estimated at 0.995 (over 7 years) and 0.9996, respectively. V.L.

A90-14017
NEW MATERIALS APPROACHES TO TRIBOLOGY: THEORY AND APPLICATIONS; PROCEEDINGS OF THE SYMPOSIUM, BOSTON, MA, NOV. 29-DEC. 2, 1988
LARRY E. POPE, ED. (Sandia National Laboratories, Albuquerque, NM), LARRY L. FEHRENBACHER, ED. (Technology Assessment and Transfer, Inc., Annapolis, MD), and WARD O. WINER, ED. (Georgia Institute of Technology, Atlanta) Symposium supported by the U.S. Army, USAF, and NSF,. Pittsburgh, PA, Materials Research Society (MRS Symposium Proceedings. Volume 140), 1989, 540 p. For individual items see A90-14018 to A90-14035.
(Contract DAAL03-88-G-0027; AF-AFOSR-88-0210; NSF MSM-88-15746)
Copyright
The present conference discusses topics in low-friction engineering systems requirements, atomic and molecular scale tribobehavior, ion- and laser-modified surfaces, solid lubricants, ceramic lubrication, tribotesting methods and material evaluation techniques, and wear-resistant coatings. Attention is given to the tribological requirements of advanced spacecraft, molecular contact pressure in tribology, the tribology of amorphous alloys formed with ion beams, the friction and wear of ion beam-assisted nitride coatings, sputter-deposited MoS2 solid lubricant films, and solid lubricant films for extreme environments. Also discussed are tribological applications for advanced ceramics, fluorinated diamond films, the binding of lubricating films to refractories and ceramics, fretting damage in electrical connectors, and thin diamond films for tribological applications. O.C.

A90-14018
ASSESSMENT OF THE TRIBOLOGICAL REQUIREMENTS OF ADVANCED SPACECRAFT MECHANISMS
PAUL D. FLEISCHAUER and MICHAEL R. HILTON (Aerospace Corp., Los Angeles, CA) IN: New materials approaches to tribology: Theory and applications; Proceedings of the Symposium, Boston, MA, Nov. 29-Dec. 2, 1988. Pittsburgh, PA, Materials Research Society, 1989, p. 9-20. Research supported by SDIO. refs
(Contract F04701-85-C-0086-P00019)
Copyright
A survey was conducted of existing technologies for moving mechanical assemblies used in spacecraft applications. The purpose was to identify areas where future requirements for lifetimes in excess of ten years with anticipated speeds, loads, and temperatures might not be satisfied. Some specific mechanisms, such as momentum/reaction wheels, high-speed turbines, pointing and tracking mechanisms, despin mechanisms, and gimbal mechanisms, were identified as areas for potential application of existing but unused technologies. Two major problem areas identified involve boundary-regime lubrication and lubricant supply (active or passive) for long life. Areas where substantial, near-term improvements appear practical include the use of hybrid bearings, new synthetic fluid lubricants, new bearing retainer materials, and properly designed solid-film lubricants. Author

A90-14019
A REVIEW OF EUROPEAN TRENDS IN SPACE TRIBOLOGY AND ITS APPLICATION TO SPACECRAFT MECHANISM DESIGN
ROBERT A. ROWNTREE and MICHAEL J. TODD (U.K. Atomic Energy Authority, National Centre of Tribology, Risley, England) IN: New materials approaches to tribology: Theory and applications; Proceedings of the Symposium, Boston, MA, Nov. 29-Dec. 2, 1988. Pittsburgh, PA, Materials Research Society, 1989, p. 21-34. Research supported by USAF. refs
Copyright
The development of spacecraft moving mechanical assemblies (MMAs) in Europe has been primarily directed toward their use aboard three-axis stabilized satellites in stationary orbit; the need to achieve operational lifetimes of 7 years or more, and the prelaunch qualification and service life testing of these MMAs, are reflected in the approach taken to lubrication design. An account is given of design practices associated with PFPE fluid lubricants, such solid lubricants as soft metal films, lamellar solids, and polymers, and polymer/lamellar solid lubricant mixes. Applications for these encompass attitude-control mechanisms, antenna-pointing mechanisms, despin devices, solar array drives, and scanning mechanisms. O.C.

A90-21121*# Aerojet Electrosystems Co., Azusa, CA.
WEAR CONSIDERATION IN GEAR DESIGN FOR SPACE APPLICATIONS
L. S. AKIN (Aerojet ElectroSystems Co., Azusa, CA) and D. P. TOWNSEND (NASA, Lewis Research Center, Cleveland, OH) IN: 1989 International Power Transmission and Gearing Conference, 5th, Chicago, IL, Apr. 25-28, 1989, Proceedings. Volume 1. New York, American Society of Mechanical Engineers, 1989, p. 361-365. Previously announced in STAR as N89-15414. refs
Copyright
A procedure is described that was developed for evaluating the wear in a set of gears in mesh under high load and low rotational speed. The method can be used for any low-speed gear application, with nearly negligible oil film thickness, and is especially useful in space stepping mechanism applications where determination of pointing error due to wear is important, such as in long life sensor antenna drives. A method is developed for total wear depth at the ends of the line of action using a very simple formula with the slide to roll ratio V sub s/V sub r. A method is also developed that uses the wear results to calculate the transmission error also known as pointing error of a gear mesh. Author

A90-21543* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE CIRCUMSTELLAR IMAGING TELESCOPE IMAGE MOTION COMPENSATION SYSTEM - ULTRA-PRECISE CONTROL ON THE SPACE STATION PLATFORM
G. E. SEVASTON, M. M. SOCHA, and A. EISENMAN (JPL, Pasadena, CA) IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference,

Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989, p. 291-310. refs
(AAS PAPER 89-033) Copyright

The Circumstellar Imaging Telescope (CIT) is a 1.9 m visible wavelength Cassegrain instrument whose primary mission is to locate extra-solar planets by direct imaging. The current reference concept calls for it to be deployed as a Space Station attached payload some time in the late 1990s. Mission and signal processing demands impose the following attitude control requirements: pointing accuracy - 250 nrad RMS, pointing stability - 50 nrad RMS over 30 minutes, roll accuracy - 1 mrad RMS, roll stability 1 mrad RMS over 30 minutes. This paper reports on the results of a recent design study in which it was determined that these requirements can be met on the Space Station by a three tiered control system consisting of a two degree of freedom mechanical gimbal for course pointing, a magnetically suspended roll bearing for roll accommodation, translational isolation and intermediate pointing control, and articulation of the secondary mirror for fine pointing. Author

A90-27561
A GAS-BEARING COMPRESSOR SYSTEM FOR SPACE STATION AIRLOCK GAS RECOVERY
ROGER P. MURRAY (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., Torrance, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p.
(SAE PAPER 891605) Copyright

A gas-bearing compressor system designed for Space Station airlock gas recovery is described, whose elements include a high-speed permanent magnet brushless dc motor, high-tip-speed shrouded compressor impellers, contamination-free compliant foil air bearings, and FET-based chopper-inverter power electronics. The designs of each of these elements are examined, and the operation and performance of the overall system are discussed. Tests showed that the two-stage compressor is capable of evacuating a 215 cu ft airlock to 0.90 psia in 7.0 min, consuming 1030 kj of energy. Schematic diagrams of the compressor system are presented. I.S.

N90-13416*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
PERIODIC-DISTURBANCE ACCOMMODATING CONTROL OF THE SPACE STATION FOR ASYMPTOTIC MOMENTUM MANAGEMENT
WAYNE WARREN, BONG WIE (Texas Univ., Austin.), and DAVID GELLER *In* NASA, Goddard Space Flight Center, Flight Mechanics/Estimation Theory Symposium, 1989 p 39-50 Oct. 1989 Previously announced in IAA as A89-52570
Avail: NTIS HC A20/MF A03 CSCL 22/2

Periodic-disturbance accommodating control is investigated for asymptotic momentum management of control moment gyros used as primary actuating devices for the Space Station. The proposed controller utilizes the concepts of quaternion feedback control and periodic-disturbance accommodation to achieve oscillations about the constant torque equilibrium attitude, while minimizing the control effort required. Three-axis coupled equations of motion, written in terms of quaternions, are derived for roll/yaw controller design and stability analysis. The quaternion feedback controller designed using the linear-quadratic regulator synthesis technique is shown to be robust for a wide range of pitch angles. It is also shown that the proposed controller tunes the open-loop unstable vehicle to a stable oscillatory motion which minimizes the control effort needed for steady-state operations. Author

N90-13491*# Allied-Signal Aerospace Co., Torrance, CA. AiResearch Div.
SPACE STATION GAS COMPRESSOR TECHNOLOGY STUDY PROGRAM, PHASE 1 Final Report
B. W. HAFELE and R. R. RAPOZO 16 Jun. 1989 76 p
(Contract NAS8-37747)
(NASA-CR-183758; NAS 1.26:183758; REPT-89-62104(5)) Avail: NTIS HC A05/MF A01 CSCL 22/2

The objectives were to identify the space station waste gases and their characteristics, and to investigate compressor and dryer types, as well as transport and storage requirements with tradeoffs leading to a preliminary system definition. Author

N90-17675*# Honeywell, Inc., Glendale, AZ. Satellite Systems Div.
ASTROMETRIC TELESCOPE FACILITY ISOLATION AND POINTING STUDY Final Report
WILLIAM HIBBLE, TERRY ALLEN, LOUIS JACKSON, JAMES MEDBERY, and RICHARD SELF Jan. 1988 102 p
(Contract NAS2-32815)
(NASA-CR-177473; NAS 1.26:177473) Avail: NTIS HC A06/MF A01 CSCL 22/2

The Astrometric Telescope Facility (ATF), an optical telescope designed to detect extrasolar planetary systems, is scheduled to be a major user of the Space Station's Payload Pointing System (PPS). However, because the ATF has such a stringent pointing stability specification and requires + or - 180 deg roll about its line of sight, mechanisms to enhance the basic PPS capability are required. The ATF pointing performance achievable by the addition of a magnetic isolation and pointing system (MIPS) between the PPS upper gimbal and the ATF, and separately, by the addition of a passive isolation system between the Space Station and the PPS base was investigated. The candidate MIPS can meet the ATF requirements in the presence of a 0.01 g disturbance. It fits within the available annular region between the PPS and the ATF while meeting power and weight limitations and providing the required roll motion, payload data and power services. By contrast, the passive base isolator system must have an unrealistically low isolation bandwidth on all axes to meet ATF pointing requirements and does not provide roll about the line of sight. Author

N90-18488*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SUPERFLUID HELIUM ORBITAL RESUPPLY COUPLING
M. O. RYDER, D. H. MORASH (Moog, Inc., East Aurora, NY.), and R. J. SCHOENBERG *In* Johns Hopkins Univ., The 1989 JANNAF Propulsion Meeting, Volume 1 p 529-539 May 1989
(Contract NAS9-17872)
Avail: NTIS HC A25/MF A04 CSCL 22/2

The resupply of superfluid helium to satellites and other space-based experiment packages can increase the useful longevity of these devices far beyond their present life expectancies which are many times determined by the supply of helium coolant. The transfer of superfluid helium to spacecraft in space will require a reusable coupling that functions at 1.8 Kelvin with little heat leak and low pressure drop. Moog has designed the Helium Resupply Coupling to meet these operational requirements. Initially, the coupling manual mode operation will be demonstrated on orbit by an EVA crew member during the Space Shuttle borne Superfluid Helium On-Orbit Transfer (SHOOT) experiment. The ultimate application will use robotic (automatic) coupling operation to which the present design readily adapts. The utilization of Moog's exclusive Rotary Shut-Off (RSO) technology in the development of the Superfluid Helium Resupply Coupling is described. The coupling not only performs the function of a flow control valve and disconnect but also provides adequate safety features for a shuttle launched man-rated payload. In addition, the coupling incorporates the necessary features to provide the high thermal isolation of the internal flow path from the external environment. Author

N90-18489*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SMALL DISPLACEMENT, LONG LIFE ON-ORBIT COMPRESSOR DESIGN AND FABRICATION
C. R. GERLACH, E. C. SCHROEDER, D. D. DEFFENBAUGH (Southwest Research Inst., San Antonio, TX.), and J. P. MASETTA *In* Johns Hopkins Univ., The 1989 JANNAF Propulsion Meeting, Volume 1 p 541-550 May 1989

(Contract NAS9-18051)
Avail: NTIS HC A25/MF A04 CSCL 13/2

The focus is the generation of technology and fabrication of prototype hardware applicable to seven Space Station compressor system applications. The compressors are of the single acting reciprocating piston type and, in general, may be termed miniature in size compared with normal commercially available equipment. The initial technology development is focused on improved valve designs, and the control of pulsations and heating effects in order to increase compressor efficiency and reduce cycle temperatures, thus permitting significantly increased stage pressure ratios. The initial test compressor was successfully operated at pressure ratios of up to 50:1, and this significant extension of allowable pressure ratio will result in a reduction of the number of required stages and, hence, total hardware thereby reducing system weight and volume. These experiments have also identified the need to employ low shaft speeds, on the order of 250 to 500 rpm, to enhance heat transfer and increase life. The prototype compressor currently being designed, is to be driven by a low-speed brushless dc motor sealed in a case common to the compressor drive mechanism case. The compressor and motor case will communicate with stage suction pressure so that any minor gas leakage past the piston rings will be returned to the suction. Emphasis in this prototype design is being placed on simplicity, durability, commonality of components, and high efficiency. Author

N90-19261*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SYNTHETIC APERTURE INTERFEROMETRIC RADIOMETER (SAIR)
C. S. RUF *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 179-189 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 14/2

The aperture size requirements of imaging microwave radiometers in geosynchronous orbit ruled out filled aperture antenna systems below 10 GHz. In the regions 10 to 30 GHz, filled apertures are only marginally practical. The size requirements in turn aggravate the problems with a mechanically steered antenna beam. Both the aperture size and steering problems are resolved with a synthetic aperture interferometric radiometer (SAIR). The SAIR imaging is discussed, along with the requirements of the two-dimensional antenna elements. B.G.

11

THERMAL ENVIRONMENTS & CONTROL

Descriptions of analysis for passive or active thermal control techniques. External and internal thermal experiments and analyses. Trade studies of thermal requirements.

A90-11011#
THERMAL CONTROL OF SPACE X-RAY EXPERIMENT
R. L. AKAU and D. W. LARSON (Sandia National Laboratories, Albuquerque, NM) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Sept.-Oct. 1989, p. 297-302. Previously cited in issue 19, p. 2958, Accession no. A87-43083. refs
(Contract DE-AC02-76DP-00789)

A90-11108*# California Univ., Los Angeles.
SPACE CRYOGENICS COMPONENTS BASED ON THE THERMOMECHANICAL EFFECT - VAPOR-LIQUID PHASE SEPARATION
S. W. K. YUAN and T. H. K. FREDERKING (California, University, Los Angeles) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 3, Oct. 1989, p. 406-415. Research supported by NASA. refs
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Applications of the thermomechanical effect has been qualified including incorporation in large-scale space systems in the area of vapor-liquid phase separation (VLPS). The theory of the porous-plug phase separator is developed for the limit of a high thermal impedance of the solid-state grains. Extensions of the theory of nonlinear turbulent flow are presented based on experimental results. Author

A90-12020#
FUNDAMENTAL STUDY ON TWO PHASE FLUID LOOP FOR THERMAL CONTROL SYSTEM IN SPACE PLATFORMS. I - EXPERIMENTAL CHARACTERISTICS OF FIRST TRIAL PRODUCTION
KOICHI CHIBA, KOUKI SAIGA, SHIN-YA SUGURI, RYO AKIYOSHI, HIDEAKI TOKUTOMI et al. *Ishikawajima-Harima Engineering* Review (ISSN 0578-7904), vol. 29, March 1989, p. 115-119. In Japanese, with abstract in English.

Two-phase thermal control systems are expected to be used instead of single-phase ones in large space platforms after JEM (Japan Equipment Module). For these technical trends, since 1985, liquid gas two-phase flow using a deep tower, a capillary pump, and a two-phase fluid loop have been studied. In this paper, an outline of the first trial production of the two-phase fluid loop, evaporators, and condensers is presented, and static characteristics of evaporators and dynamic characteristics of the loop are given. It is shown that the loop and heat exchangers are sufficiently available in static characteristics, and some areas that need improvement are pointed out. C.D.

A90-17230
OPTIMIZATION OF A CLOSED-TYPE AUTONOMOUS THERMOSTATTING SYSTEM [OPTIMIZATIIA AVTONOMNOI SISTEMY TERMOSTATIROVANIIA ZAMKNUTNOGO TIPA]
M. A. KUZ'MIN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 27, Sept.-Oct. 1989, p. 674-681. In Russian.
Copyright

The paper develops a method for determining the optimal parameters of a closed-type autonomous thermostatting system for spacecraft use, consisting of a refrigerator-radiator, refrigerating machinery, and a power source. Minimum mass of the system and the upper cycle temperature of the refrigerating machinery are taken as the optimality and control criterion. A specific optimization example is used to illustrate the application of the proposed method. B.J.

A90-17824#
HEAT LOADS DUE TO SPACE PARTICLE ENVIRONMENT
A. L. VAMPOLA, R. D. JIMENEZ, and J. E. COX (Aerospace Corp., Los Angeles, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Dec. 1989, p. 474-476. Research supported by Aerospace Corp.
(Contract F04071-85-C-0086)
Copyright

A tabulation of average and peak heat inputs to spacecraft is presented for a number of orbits, together with a plot of the heat input as a function of time for a 24-hour period to indicate the type of profile foreseeable for a particular orbit. The accuracy of the heat calculations and of the particle models, as well as the variability of the enegetic particle environment itself, are discussed. The calculations yield the total energy flux through a surface without regard to the material depth of energy deposition. O.C.

A90-19654#
ADVANCED HEAT PIPE COMPONENTS FOR HIGH POWER SPACECRAFT THERMAL MANAGEMENT
G. L. FLEISCHMAN, A. BASIULIS (Hughes Aircraft Co., Electron Dynamics Div., Torrance, CA), and J. M. GOTTSCHLICH (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs
(Contract F33615-85-C-2557)
(AIAA PAPER 90-0058) Copyright

Conceptual design, fabrication considerations, and test results are presented for various heat pipe components for advanced spacecraft thermal control. The subcooled artery sideflow heat

pipe with ammonia as the working fluid is described for high transport capacity. Other components include high density heat acquisition baseplates with acetone as the working fluid, and a stainless steel honeycomb panel thermal diode, which uses methanol as the working fluid. Author

A90-19655*# Grumman Aerospace Corp., Bethpage, NY.
SPACE STATION HEAT PIPE ADVANCED RADIATOR ELEMENT (SHARE) FLIGHT TEST RESULTS AND ANALYSIS
ROBERT KOSSON, RICHARD BROWN (Grumman Aerospace Corp., Bethpage, NY), and EUGENE UNGAR (NASA, Johnson Space Center, Houston, TX) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. refs
(AIAA PAPER 90-0059) Copyright

The SHARE experiment, which consisted of a single 51 ft long by 1 ft wide prototypical Space Station heat pipe radiator panel, was flown aboard STS-29 in March 1989. Several problems were uncovered during the flight which limited performance. Extensive post-flight analysis has revealed that the manifold connecting the evaporator and condenser sections did not prime properly in 0-g, and that a mismatch in hydraulic diameters between the evaporator and condenser caused large bubbles to be present in the liquid channel at startup. These bubbles subsequently became trapped at the evaporator entrance, halting liquid flow and causing premature dryout of the evaporator wall grooves. The experiment did demonstrate heat pipe transport capability of up to 1572 W with near isothermality in both the evaporator and condenser for short periods of time. Author

A90-19901#
HEAT TRANSFER ENHANCEMENT TECHNIQUES FOR SPACE STATION COLD PLATES
G. P. PETERSON and L. S. FLETCHER (Texas A & M University, College Station) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 8 p. refs
(AIAA PAPER 90-0541) Copyright

Two attachment techniques for mounting electronic equipment to Space Station cold plates were analyzed and compared using thin foils of lead, tin, aluminum, and copper to enhance the thermal contact conductance. The two techniques evaluated included a 70 mm x 70 mm bolted attachment technique and an attachment scheme using an inflatable bladder. The results indicate that, even in the presence of the metallic foils, the bolted technique results in large variations in the local thermal contact conductance over the surface of the cold plate, while the pressurized bladder yields more uniform local contact conductance values. In addition, the results indicated that the lead foil provided an enhancement factor of approximately 3, the tin foil an enhancement factor of approximately 1.5, the aluminum an enhancement factor of approximately 1.0, and the copper an enhancement factor of approximately 0.9. Author

A90-21227#
STUDY OF THE SP-100 RADIATOR HEAT PIPES RESPONSE TO EXTERNAL THERMAL EXPOSURE
MOHAMED S. EL-GENK and JONG T. SEO (New Mexico, University, Albuquerque) (1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3, p. 673-680) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, Jan.-Feb. 1990, p. 69-77. Research supported by the University of New Mexico. Previously cited in issue 04, p. 489, Accession no. A89-15393. refs
Copyright

A90-26908#
THERMAL DESIGN CONSIDERATIONS FOR THE CRYOGENIC ON-ORBIT LIQUID DEPOT STORAGE, ACQUISITION AND TRANSFER SATELLITE (COLD-SAT)
GRANT E. WILLIAMS and JOHN R. SCHUSTER (General Dynamics Corp., Space Systems Div., San Diego, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs
(AIAA PAPER 90-0057) Copyright

An overview of the thermal analysis tasks performed for the Cryogenic On-orbit Liquid Depot Storage Transfer and Acquisition and Transfer (COLD-SAT) satellite is presented. Analysis methods that include both analytical and computer modeling techniques are detailed. The heat loads entering cryogenic experiment tanks during all phases of the mission are calculated, and the results of parametric studies performed as part of the analysis are presented. Significant heat leaks are found to occur through tank penetrations, and methods for reducing them are briefly mentioned. Two methods that proved effective in reducing calculated heat loads are careful material selection and development of more refined, less conservative thermal models. Author

A90-27427
SPACE STATION FREEDOM ACTIVE INTERNAL THERMAL CONTROL SYSTEM - A DESCRIPTIVE OVERVIEW
R. A. HEISING and J. E. HORNER (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p.
(SAE PAPER 891458) Copyright

The active internal thermal control system (ITCS) for Space Station Freedom will consist of multiple closed-cycle heat transport water loops that acquire, transport, and reject heat to the exterior central thermal bus. Heat loads to be cooled by the ITCS include the environmental control and life support systems (ECLSS), avionics racks, and user experiments (located in the laboratory module). The ITCS is an advanced single-phase pumped water loop that incorporates on-orbit repair features and enhanced components, such as high-efficiency, long-life centrifugal pumps and digital valves that allow step-wise precision control of valve position for modulating the water flow rate. Commonality is emphasized throughout the ITCS, and was a design driver during the selection of the ITCS components. Cold plate and heat exchanger designs are standardized to accommodate a variety of users. This paper describes the overall system, the subsystems, and the components within the ITCS from an operational viewpoint. Author

A90-27428
AVIONICS AIR COOLING FOR SPACE STATION FREEDOM
ROSS CUSHMAN (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) and HARLAN BURKE (Boeing Aerospace and Electronics, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 11 p.
(SAE PAPER 891459) Copyright

The paper provides a comparison of two possible approaches to avionics air cooling for Space Station modules, using requirements and ground rules established during Space Station definition studies. The first approach is the 'centralized' approach, which uses a large central fan and heat exchanger which maintains a supply of cooled air to module racks, via a network of interconnected ducting and flow isolation valves. The second approach is the 'distributed'approach, which uses individual fan/heat exchanger packages for each rack. Detailed tests and analyses are presented for both concepts. Both are indicated to have unique attributes and limitations while imposing different burdens on the vehicle systems. It is concluded that both approaches can be designed to satisfy Space Station avionics heat removal requirements. R.E.P.

A90-27429
A PRELIMINARY HEAT FLOW ANALYSIS OF THE U.S. LABORATORY AND HABITATION MODULES
W. D. BEVERLY, R. E. DANDRIDGE, and R. D. PRODEN (Boeing Aerospace and Electronics, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p.
(SAE PAPER 891460) Copyright

The results of a preliminary evaluation of the heat loads for

the Space Station Freedom U.S. Laboratory and Habitation modules are presented. The data for this analysis was based on a rack-by-rack assessment of preliminary module configurations. Data gathered included cooling requirements, temperature range, duty cycle and cooling split between liquid and air coolants for representative subsystem and experiment heat loads. A Monte Carlo analysis of the heat load data was performed. The analysis results allowed initial sizing of the module cabin air, avionics air, and liquid cooling systems. The analysis allowed assessment of the effects of additional experiment automation as well as the effects of decreased avionics air cooling capacity. Although the heat load data and module configuration are preliminary in nature and will undergo significant revision as the Space Station Freedom design progresses, the results of this analysis provide a first look at the module energy flow. Author

A90-27430
CONCEPTUAL DESIGN OF THE SPACE STATION POLAR PLATFORM THERMAL CONTROL SUBSYSTEM
H. E. BOND, D. J. BENKO, D. R. CHALMERS, and S. D. PERGAMENT (General Electric Co., Astro-Space Div., Princeton, NJ) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p. refs
(SAE PAPER 891461) Copyright

NASA's Space Station Freedom Program encompasses unmanned polar-orbiting platforms (POPs) in low-earth orbit (LEO) designed to support a variety of scientific and earth-observation missions. The platforms are modular in design, permitting in-orbit maintenance and replacement of limited-life subsystem and payload components. Such in-orbit servicing can extend the platform's useful life to 15 years or more, far exceeding that of a typical LEO spacecraft. The long life and modular design has forced a new approach to thermal control subsystem (TCS) design. The platforms's TCS must be readily adaptable to, and compatible with, the physical reconfiguration and resultant heat load changes. NASA has, in fact, identified thermal management as a critical factor in the overall platform design. A dual approach was used for the current polar platform TCS design. Platform thermal control is maintained using a distributed network of heat pipe panels, while payload thermal control is maintained via a centralized system of two-phase capillary pumped loops. This paper describes this baseline platform thermal design and the analytical tools used to validate the design concepts. Author

A90-27432* LTV Missiles and Electronics Group, Dallas, TX.
CONTACT CONDUCTANCE EVALUATION FOR A FULL SCALE SPACE ERECTABLE RADIATOR PRESSURIZED INTERFACE
R. JOHN DUSCHATKO (LTV Corp., Missiles and Electronics Group, Grand Prairie, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p.
(Contract NAS9-17495)
(SAE PAPER 891463) Copyright

The baseline thermal control configuration for the Space Station Freedom includes a contact heat exchanger to provide efficient heat transfer between the two-phase thermal bus heat collection/delivery system and the radiator panel heat rejection system. The contact heat exchanger provides a dry interface for a modular radiator system with easy on-orbit panel replacement. July 1988 testing of the Space Erectable Radiator System (SERS) at NASA-JSC provided thermal/vacuum data for three full-scale prototype units of a pressurized dry contact heat exchanger design. Derived contact conductance values agreed with predictions and previous element tests and demonstrated high conductance for relatively low pressure levels. A limited amount of data was also obtained below the operating pressure, resulting in contact conductance trends with respect to interface pressure. Author

A90-27433
TWO-PHASE LOOP HEAT TRANSPORT SYSTEMS
H. KREEB, R. SIEPMANN (Dornier GmbH, Friedrichshafen, Federal Republic of Germany), and W. SUPPER (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p.
(SAE PAPER 891465) Copyright

The objectives, development status, and test results of an ESA-sponsored study of two-phase loop heat transport systems are reviewed. The ESA two-phase loop system is driven by an electrically powered liquid pump and is provided with a capillary cold plate and an evaporative heat exchanger mounted in parallel. The system is designed for a heat load of 10-20 kw, a length of 20 m, a working temperature of 20 C, and liquid R114 as the working fluid. Two other studies of two-phase heat transport conducted in West Germany are also discussed. V.L.

A90-27434
TWO-PHASE CAPILLARY-PUMPED LOOP - A POTENTIAL HEAT TRANSPORT SYSTEM
R. S. BHATTI, S. VAN OOST (Societe Anonyme Belge de Constructions Aeronautiques, Brussels, Belgium), W. SUPPER (ESTEC, Noordwijk, Netherlands), and H. WILZ (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p.
(SAE PAPER 891466) Copyright

This paper presents the general objectives, the design concept and the potential performances of the two-phase capillary pumping loop (CPL) as a heat transportation system. In particular the actual design of the ESA funded development program 'CPL', designed and developed by SABCA and DORNIER will be shown as well as of its development status. Results obtained with the first breadboard CPL model are reported together with comparison of predicted against tested performances. Author

A90-27437
FIFTEEN YEARS OF SATELLITE HEAT PIPE LIFE TESTING
M. GROLL (Institut fuer Kernenergetik und Energiesysteme, Federal Republic of Germany), S. ROESLER (Stuttgart, Universitaet, Federal Republic of Germany), and B. AALDERS (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p.
(SAE PAPER 891469) Copyright

Life and performance test results are reported for five stainless steel/ammonia artery heat pipes and six axially grooved aluminum/ammonia heat pipes. In the case of artery heat pipes, practically no degradation of maximum performance and isothermality was observed over the 15-year testing period. The aluminum axially grooved pipes show temperature differences that increase slightly with life time. Details of the test procedures are discussed. V.L.

A90-27465
INTELLIGENT FAULT TOLERANT SYSTEMS FOR THERMAL CONTROL IN SPACE APPLICATIONS
P. OSELLA (Microtecnica S.p.A., Turin, Italy) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 15 p.
(SAE PAPER 891498) Copyright

Two smart fault tolerant systems being developed as part of European space programs, the Eureca Thermal Control Unit (TCU) and the Pump Package Electronic Control Unit (ECU), are characterized with emphasis on their fault tolerance capabilities. The Eureca TCU is capable of recovering from multiple failures in different functions with a reliability of about 99 percent over a six-moth mission period. The Pump Package ECU exists in the form of a conceptual study. The main areas being investigated are improvements in volume and weight. These can be obtained through the use of state-of-the-art electronic components and innovative techniques, such as surface mounting and gate arrays. V.L.

A90-27483
ACTIVE THERMAL CONTROL DESIGN OF COLUMBUS PRESSURIZED MODULES
SILVIO DOLCE, MICHELE TRICHILO, and CHARLES DODD

(Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p.
(SAE PAPER 891518) Copyright

The active thermal control architecture of the Columbus Pressurized Modules APM (Attached Pressurized Module) and PM-MTFF (Pressurized Modules coupled to the Resource Module to form the Man Tended Free Flyer) is examined. In particular, attention is given to the trade-offs and design activities performed to provide an optimized thermal control design for the Pressurized Modules. It is noted that further refinements to the design of the PM-MTFF are needed to take into account requirements and mission scenario changes. V.L.

A90-27484
THERMAL CONTROL SYSTEM FOR JAPANESE EXPERIMENT MODULE
KOUKI SAIGA and TADAHITO KOMIYAMA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p. Research supported by NASDA.
(SAE PAPER 891519) Copyright

The results of a preliminary design study which defined the baseline configuration of the Thermal Control System (TCS) of the Space Station Japanese Experiment Module (JEM) are summarized. The discussion covers an overview of the JEM TCS design, some trade-offs studied, and analyses performed during the preliminary design phase. A schematic diagram of the JEM Active Thermal Control System is presented. V.L.

A90-27486
THERMAL BALANCE TEST OF EURECA THERMAL MODEL
A. MOSCATELLI, V. PEROTTO, and S. TAVERA (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p. Research sponsored by ESA.
(SAE PAPER 891521) Copyright

The results are presented of a thermal balance test performed at subsystem level on the thermal model of Eureca (EUropean REtrievable CArrier) in the ESTEC LSS Vacuum Chamber. The test article, thermally representative of the most relevant items of the flight unit, was equipped both with 'passive' thermal control hardware (MLI blankets, heaters) and 'active' thermal control hardware (fluid loop, cold plates, radiators). This test consisted of several phases with different functioning conditions. Solar lamps and heated plates were used to reproduce solar, albedo and IR fluxes. The analysis of the test results confirmed the adequacy of the thermal control design, in particular, of the key items of the fluid loop and MLI, while an extensive correlation campaign validated the thermal mathematical model. Author

A90-27519
MANIP - A MODELLING AND SIMULATION TOOL FOR THERMAL ENGINEERS
R. J. M. KOOL (BSA/Eindhoven AT, Netherlands) and A. LEBRU (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p. Research supported by ESTEC.
(SAE PAPER 891557) Copyright

MANIP, an integrated interactive software tool developed at ESTEC for the design of spacecraft thermal-control systems, is described. MANIP is menu-driven, with a user-configurable menu tree, and is written in C to run under UNIX on a 32-bit processor. Particular attention is given to the procedures for geometric and mathematical model construction, the syntax of the MANIP model-description language, the MANIP simulation executive, MANIP tools for analysis of simulation results, and the improvements made in MANIP-1 (1984-1986) to produce the current version, MANIP-2. A diagram of the software architecture and a sample graphic showing a spacecraft temperature distribution are provided. T.K.

A90-27520
ESATAN, A REVIEW AFTER FOUR YEARS IN USE
J. J. REBIS (GEC Engineering Research Centre, Leicester, England) and C. J. M. STROOM (ESA, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p. refs
(SAE PAPER 891558) Copyright

The ESA Thermal Analysis Network (ESATAN) software has since 1985 been replacing SINDA as the primary tool for thermal analysis applications, due to a powerful hierarchical submodel structure which allows the independent development of submodels which can be integrated at a subsequent stage. Such integrations can occur without restriction concerning code or conductor numbering, or even any other model-specific entity. After presenting a development history of ESATAN, its current configuration and prospective improvements are discussed. O.C.

A90-27523
COMPUTER-BASED MULTIOBJECTIVE HIERARCHICAL DESIGN OF SPACECRAFT THERMAL CONTROL SYSTEMS
CHRISTIAN L. STRUBLE, EDUARDO BASCARAN, RICHARD B. BANNEROT, and FARROKH MISTREE (Houston, University, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 11 p. Research supported by the BF Goodrich Co. refs
(SAE PAPER 891561) Copyright

A computer program to aid in the design of spacecraft active thermal control systems (ATCSs) is described and demonstrated. The problem addressed is the selection of a working fluid and thermal-cycle type to meet ATCS performance requirements; the user simulates and compares ATCSs designed with different factors (system mass, pumping power, fluid toxicity, etc.) as the primary constraint. The resulting coupled selection-compromise decision-support problem (as defined by Muster and Mistree, 1988) is solved using the program DSIDES (Mistree and Kamal, 1988). Consideration is given to the hierarchical decision process, thermal analysis and ATCS modeling, weight and sizing analyses, and the implementation of the program on a VAX mainframe computer. Results are presented in graphs for a case study of the International Space Station ATCS (using either water, NH3, R-11, or R-114 as the working fluid and either a vapor-compression or a pumped two-phase thermal cycle). T.K.

A90-27524
AN INTEGRATED MODEL OF THE LMSC TWO-PHASE THERMAL BUS, DESIGNED FOR ACTIVE THERMAL CONTROL SYSTEM OF SPACE STATION FREEDOM
KAMBIX KHEYR ANDISH and ROBERT S. HARRIS (Lockheed Engineering and Sciences Co., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 15 p. refs
(SAE PAPER 891562) Copyright

An integrated model of the central Active Thermal Control System (ATCS) of the Space Station has been developed, based on the thermal bus described by Holmes et al. (1987). Both 75 and 35 degree F thermal buses are analyzed at various thermal loads. The model incorporates results from simulating the performance of various ATCS subsystems and predicts the flow rate, temperature, and pressure maps of the buses for steady-state and transient cases under cyclic environmental heat loads and variable module heat rejection requirements. Also, predictions of the overall bus performance are given, including sizing the orifices and setting valve stem positions and pump speed. R.B.

A90-27525* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPARATIVE THERMAL ANALYSIS OF THE SPACE STATION FREEDOM PHOTOVOLTAIC DEPLOYABLE BOOM STRUCTURE USING TRASYS, NEVADA, AND SINDA PROGRAMS
JOSEPH F. BAUMEISTER (NASA, Lewis Research Center; Analex Corp., Cleveland, OH), DUANE E. BEACH, and SASAN C. ARMAND (NASA, Lewis Research Center, Cleveland, OH) SAE, Intersociety

Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p. Previously announced in STAR as N89-26177.
(SAE PAPER 891563) Copyright

The proposed Space Station Photovoltaic Deployable Boom was analyzed for operating temperatures. The boom glass/epoxy structure design needs protective shielding from environmental degradation. The protective shielding optical properties (solar absorptivity and emissivity) dictate the operating temperatures of the boom components. The Space Station Boom protective shielding must also withstand the effects of the extendible/retractable coiling acting within the mast canister. A thermal analysis method was developed for the Space Station Deployable Boom to predict transient temperatures for a variety of surface properties. The modeling procedures used to evaluate temperatures within the boom structure incorporated the TRASYS, NEVADA, and SINDA thermal analysis programs. Use of these programs led to a comparison between TRASYS and NEVADA analysis methods. Comparing TRASYS and NEVADA results exposed differences in the environmental solar flux predictions. Author

A90-27527* Grumman Aerospace Corp., Bethpage, NY.
CONCEPTUAL DESIGN OF A LIQUID DROPLET RADIATOR SPACE FLIGHT EXPERIMENT
S. PFEIFFER (Grumman Corp., Grumman Space Systems Div., Bethpage, NY) and A. WHITE (NASA, Lewis Research Center, Cleveland, OH) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(SAE PAPER 891565) Copyright

This paper discusses the conceptual design of a shuttle-attached Liquid Droplet Radiator (LDR) experiment. The Liquid Droplet Radiator is an advanced lightweight heat rejection concept that can be used to reject heat from future high-powered space platforms. In the LDR concept, submillimeter-sized droplets are generated, radiate heat as they pass through space and are then collected and recirculated back to the heat source. The LDR experiment is designed to be attached to the shuttle longeron and integrated into the shuttle bay using standard shuttle/experiment interfaces. Overall power, weight, and data requirements of the experiment are detailed. Conceptual design and shuttle integration issues are discussed. Author

A90-27528* OAO Corp., Greenbelt, MD.
AN IMPROVED HIGH POWER HYBRID CAPILLARY PUMPED LOOP
JENTUNG KU, EDWARD J. KROLICZEK (OAO Corp., Greenbelt, MD), and MICHAEL E. MCCABE, JR. (NASA, Goddard Space Flight Center, Greenbelt, MD) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 11 p. refs
(SAE PAPER 891566) Copyright

In order to improve performance testing, NASA's High-Power Spacecraft Thermal Management system has been modified through (1) an augmentation of heat-dissipation capacity of the condenser sink for steady-state high power operation, (2) the addition of more pressure transducers for pressure-drop monitoring in various system components, (3) the installation of pressure-contact thermocouples on the evaporators to measure heating surface temperature, (4) the provision of a coolant loop to one of the evaporator plates, (5) the placing of a transient fluid flow-monitoring load cell in the reservoir, and (6) the reorientation of the reservoir to reduce compressed vapor effects. The system is now capable of 10 hours of continuous capillary mode operation at an input power level of 20 kW. O.C.

A90-27529
DEVELOPMENT OF A TWO-PHASE ACCUMULATOR FOR A SPACE-BASED AMMONIA THERMAL BUS SYSTEM
CHARLES E. KALB and RICHARD F. BROWN (Grumman Corp., Grumman Space Systems Div., Bethpage, NY) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 17 p. refs
(SAE PAPER 891567) Copyright

A two-phase accumulator for use in two-phase active thermal control systems has been developed and successfully tested as part of the Grumman Prototype Two-Phase Thermal Bus system. The two-phase accumulator works on the principle of direct energy transfer out of and into the vapor space of the accumulator via subcooled liquid spray and warm vapor addition. Analysis and design of this unique accumulator are discussed, as well as the test results obtained during ambient testing in the NASA-JSC Thermal Test Bed. Test results indicated the ability of the accumulator to control bus setpoint within 2 deg F over a wide variety of load and environmental conditions. Author

A90-27711
DEVELOPMENT OF A DEPLOYABLE FILM TYPE RADIATOR
MASAHITO OGUMA, SHINTARO ENYA (Ishikawajima-Harima Heavy Industries Co., Ltd., Yokohama, Japan), YUICHIRO ASANO, HIROSHI MURAMOTO (Showa Aluminum Corp., Tokyo, Japan), and NOBUHIRO TANATSUGU (Institute of Space and Astronautical Science, Sagamihara, Japan) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0883-6272), vol. 8, no. 4, 1989, p. 469-475.
(IAF PAPER ICOSP89-4-8) Copyright

A space radiator of novel design using a liquid heat transfer fluid has been constructed. Its form is a long ribbon (1.45 m x 0.15 m) which, in the inactive state, is coiled up. Upon deployment, it unrolls to full extension under coolant pressure. Since coolant channels remain deflated until deployment, such a radiator takes up less space than the standard ones. Investigating radiator performance, it was estimated to be about 1/20th the weight and with 1/25th the packaging volume of an ordinary radiator of equivalent heat rejection capability. Experimental measurements confirm numerical simulation results. Author

N90-13460*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
LARGE DEPLOYABLE REFLECTOR (LDR) THERMAL CHARACTERISTICS
R. N. MIYAKE and Y. C. WU *In its* Report of the Asilomar 3 LDR Workshop p 70-71 15 Aug. 1988
Avail: NTIS HC A08/MF A01 CSCL 22/2

The thermal support group, which is part of the lightweight composite reflector panel program, developed thermal test and analysis evaluation tools necessary to support the integrated interdisciplinary analysis (IIDA) capability. A detailed thermal mathematical model and a simplified spacecraft thermal math model were written. These models determine the orbital temperature level and variation, and the thermally induced gradients through and across a panel, for inclusion in the IIDA. Author

N90-13510# European Space Agency, Paris (France).
THE PAYLOAD STRUCTURE
T. VANDERLAAN and E. JAEKEL *In its* The Hipparcos Mission. Prelaunch Status. Volume 1: The Hipparcos Satellite p 113-116 Jun. 1989
Copyright Avail: NTIS HC A16/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The design analysis and the manufacturing solutions for the Hipparcos payload structure are examined. Special attention is paid to the thermal and temporal stability of the relative positions of the optical components. The requirements concerning the mechanical interfaces with the satellite, the focal assembly units and harness, the variation and the effect of the gravity release are considered. The following telescope structure subassemblies are analyzed: the main structure, the mirror mounts, the focal plane assembly platform, and the Cherenkov shielding. ESA

N90-13511# European Space Agency, Paris (France).
PAYLOAD THERMAL CONTROL
E. JAEKEL *In its* The Hipparcos Mission. Prelaunch Status. Volume 1: The Hipparcos Satellite p 117-119 Jun. 1989
Copyright Avail: NTIS HC A16/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The Hipparcos payload thermal control is presented. It ensures

the active and passive thermal control with a temperature stability better than 0.05C over short periods, and about 2C over the entire mission duration. The payload structure, manufactured from carbon fiber reinforced plastic, is described. The principles of the active thermal control system are indicated, and its characteristics are listed. ESA

N90-16147# Department of the Air Force, Washington, DC.
EXPANDABLE RADIATOR Patent
DONALD L. REINMULLER, inventor (to Air Force) 27 Jun. 1989 5 p Filed 11 Oct. 1988 Supersedes US-Patent-Appl-SN-255803 (AD-D014258; US-PATENT-4,842,045; US-PATENT-APPL-SN-255803) Avail: US Patent and Trademark Office CSCL 22/5

An expandable heat rejection system for radiating heat from a source of heat on a spacecraft or like vehicle is described and comprises a fluid heat exchange medium in operative circulating heat exchange relationship with the source for absorbing heat by evaporation of a liquid phase or the medium, an elongate inflatable sleeve defining an expandable and collapsible volume closed at a first end and including an inlet and outlet at a second end and further defining a condensation surface on the inner surface of the sleeve and a heat radiating surface on the outer surface of the sleeve, a reel attachable to the vehicle and operatively attached to the first end of the sleeve for selectively winding and unwinding the sleeve in response to pressure generated within the system. GRA

N90-18455# European Space Agency, Paris (France).
SPACECRAFT THERMAL CONTROL DESIGN DATA, VOLUME 1
Nov. 1989 613 p Prepared in cooperation with ESA/ESTEC, Noordwijk, Netherlands and Univ. Politecnica de Madrid, Spain (ESA-PSS-03-108-ISSUE-1-VOL-1; ISSN-0379-4059; ETN-90-96211) Copyright Avail: NTIS HC A99/MF A04

A handbook in several volumes was prepared with the aim of assisting the thermal control design engineer by presenting a single document containing all the information relevant to spacecraft thermal control design. It is intended to issue revisions and additions as they become available so that the handbook will remain up to date with state of the art information and development in the field. View factors, holes, grooves and cavities, spacecraft surface temperature, conductive heat transfer and structural materials are detailed. ESA

N90-18456# European Space Agency, Paris (France).
SPACECRAFT THERMAL CONTROL DESIGN DATA, VOLUME 2
Nov. 1989 630 p Prepared in cooperation with ESA/ESTEC, Noordwijk, Netherlands and Univ. Politecnica de Madrid, Spain (ESA-PSS-03-108-ISSUE-1-VOL-2; ISSN-0379-4059; ETN-90-96212) Copyright Avail: NTIS HC A99/MF A04

A handbook in several volumes was prepared with the aim of assisting the thermal control design engineer by presenting a single document containing all the information relevant to spacecraft thermal control design. It is intended to issue revision and additions as they become available so that the handbook will remain up to date with state of the art information and developments in the field. Thermal control surfaces and insulations are detailed. ESA

N90-18457# European Space Agency, Paris (France).
SPACECRAFT THERMAL CONTROL DESIGN DATA, VOLUME 3
Nov. 1989 539 p Prepared in cooperation with ESA/ESTEC, Noordwijk, Netherlands and Univ. Politecnica de Madrid, Spain (ESA-PSS-03-108-ISSUE-1-VOL-3; ISSN-0379-4059; ETN-90-96213) Copyright Avail: NTIS HC A23/MF A03

A handbook in several volumes was prepared with the aim of assisting the thermal control design engineer by presenting a single document containing all the information relevant to spacecraft thermal control design. It is intended to issue revision and additions as they become available so that the handbook will remain up to date with state of the art information and developments in the field. Heat pipes, radiators, phase-change capacitors, electrical heating and louvers are detailed. ESA

N90-18458# European Space Agency, Paris (France).
SPACECRAFT THERMAL CONTROL DESIGN DATA, VOLUME 4
Nov. 1989 559 p Prepared in cooperation with ESA/ESTEC, Noordwijk, Netherlands and Univ. Politecnica de Madrid, Spain (ESA-PSS-03-108-ISSUE-1-VOL-4; ISSN-0379-4059; ETN-90-96214) Copyright Avail: NTIS HC A24/MF A03

A handbook in several volumes was prepared with the aim of assisting the thermal control design engineer by presenting a single document containing all the information relevant to spacecraft thermal control design. It is intended to issue revisions and additions as they become available so that the handbook will remain up to date with state of the art information and developments in the field. Fluid loops are detailed. ESA

N90-19267*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
REFLECTOR SURFACE DISTORTION ANALYSIS TECHNIQUES (THERMAL DISTORTION ANALYSIS OF ANTENNAS IN SPACE)
R. SHARP, M. LIAO, J. GIRIUNAS, J. HEIGHWAY, A. LAGIN, and R. STEINBACH *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 273293 Jul. 1989 Avail: NTIS HC A17/MF A03 CSCL 20/14

A group of large computer programs are used to predict the farfield antenna pattern of reflector antennas in the thermal environment of space. Thermal Radiation Analysis Systems (TRASYS) is a thermal radiation analyzer that interfaces with Systems Improved Numerical Differencing Analyzer (SINDA), a finite difference thermal analysis program. The programs linked together for this analysis can now be used to predict antenna performance in the constantly changing space environment. They can be used for very complex spacecraft and antenna geometries. Performance degradation caused by methods of antenna reflector construction and materials selection are also taken into consideration. However, the principal advantage of using this program linkage is to account for distortions caused by the thermal environment of space and the hygroscopic effects of the dry-out of graphite/epoxy materials after the antenna is placed into orbit. The results of this type of analysis could ultimately be used to predict antenna reflector shape versus orbital position. A phased array antenna distortion compensation system could then use this data to make RF phase front corrections. That is, the phase front could be adjusted to account for the distortions in the antenna feed and reflector geometry for a particular orbital position. Author

12

POWER SYSTEMS

Analyses, systems and trade studies of electric power generation, storage, conditioning and distribution.

A90-10075
THE ORGANIC RANKINE PROCESS FOR SOLAR-DYNAMIC ENERGY PRODUCTION IN SPACE [DER ORGANISCHE RANKINE-PROZESS ZUR SOLARDYNAMISCHEN ENERGIEERZEUGUNG IM WELTRAUM]
W. ZOERNER and J. BLUMENBERG (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 13, July-Aug. 1989, p. 260-270. In German. refs
Copyright

A version of the organic Rankine cycle of solar-dynamic power generation for use in near-future space stations is developed, and

its merits are compared with those of other power conversion cycle candidates. The optimization of the process and the nature of the process medium are discussed, and the components of the device and its two-phase thermal management system are described. The Rankine cycle's low maximum temperature yields decisive advantages such as high lifetime, high system reliability, and immediate technological readiness. C.D.

A90-10296#
POWERING ESA'S SPACECRAFT
D. O'SULLIVAN (ESA, Power and Energy Conversion Div., Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 59, Aug. 1989, p. 56-61.
Copyright

The problem of optimizing the configuration of a power system to meet the requirements of a specific mission is addressed. Consideration is given to energy source and storage characteristics such as solar arrays, batteries, subsystem and payload converters, and power-system topologies. Recommended power systems for LEO and GEO applications are given. It is suggested that an unregulated power bus or a hybrid power bus are best for LEO missions, while a sunlight-regulated bus or a regulated bus are best for GEO missions. R.B.

A90-10355
AUTONOMOUS CONTROL OF SPACECRAFT NUCLEAR REACTORS
JOHN A. BERNARD, KWAN S. KWOK, and TAKASHI WASHIO (MIT, Cambridge, MA) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 28-45. Research supported by Sandia National Laboratories. refs
(Contract DE-AC02-86NE-37962-A000)
Copyright

Recent theoretical and experimental progress toward the achievement of an autonomous control system for spacecraft nuclear reactors is reported. A controller having a multitiered structure with the capability for both supervisory and predictive control as well as automated reasoning is proposed. Such a system would establish bounds for permitted operation (supervisory control), facilitate the inference of system response (predictive control), and provide a means for assessing its own performance (automated reasoning). Recent developments concerning specific features of this controller are reported including the use of energy constraints for supervisory control, the performance of automated reactor startups using the MIT-SNL Period-Generated Minimum Time Laws, and considerations relevant to the use of pattern recognition, expert systems, and causal analysis for the on-line assessment of controller performance. Also, an overview is given of the MIT program on reactor control. Author

A90-10373* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE STATION POWER SYSTEM AUTONOMY DEMONSTRATION
JAMES A. KISH, JAMES L. DOLCE (NASA, Lewis Research Center, Cleveland, OH), and DAVID J. WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 218-225. refs
Copyright

The Systems Autonomy Demonstration Program (SADP) represents NASA's major effort to demonstrate, through a series of complex ground experiments, the application and benefits of applying advanced automation technologies to the Space Station project. Lewis Research Center (LeRC) and Marshall Space Flight Center (MSFC) will first jointly develop an autonomous power system using existing Space Station testbed facilities at each center. The subsequent 1990 power-thermal demonstration will then involve the cooperative operation of the LeRC/MSFC power system with the Johnson Space Center (JSC's) thermal control and DMS/OMS testbed facilities. The testbeds and expert systems at each of the NASA centers will be interconnected via communication links. The appropriate knowledge-based technology will be developed for each testbed and applied to problems requiring intersystem cooperation. Primary emphasis will be focused on failure detection and classification, system reconfiguration, planning and scheduling of electrical power resources, and integration of knowledge-based and conventional control system software into the design and operation of Space Station testbeds. C.E.

A90-11096#
SATELLITE POWER SYSTEM TOPOLOGIES
D. O'SULLIVAN (ESA, Power and Energy Conversion Div., Noordwijk, Netherlands) ESA Journal (ISSN 0379-2285), vol. 13, no. 2, 1989, p. 77-88.
Copyright

Consideration is given to the problem of optimizing power-system design to meet specific mission requirements. The basic elements of system design are described, including subsystem and payload converters, and energy sources. The various types of power system topologies are examined, including unregulated power buses, regulated power buses, sunlight-regulated power buses, and hybrid power buses. The optimal power systems for various types of missions are determined, showing that the hybrid power bus is optimal for LEO missions and the regulated bus is optimal for all other missions. R.B.

A90-11989
SOLAR ENGINEERING - 1989; PROCEEDINGS OF THE ELEVENTH ANNUAL ASME SOLAR ENERGY CONFERENCE, SAN DIEGO, CA, APR. 2-5, 1989
A. H. FANNEY, ED. (NIST, Gaithersburg, MD) and K. O. LUND, ED. (San Diego State University, CA) Conference sponsored by ASME. New York, American Society of Mechanical Engineers, 1989, 545 p. For individual items see A90-11990 to A90-11998.
Copyright

Papers on engineering and solar energy are presented, covering topics such as solar space power systems, simulation and optimization, solar thermal systems, passive building and conservations, and components of solar thermal systems. Other subjects include solar energy fundamentals, ocean energy, dessicant and dessicant-assisted cooling and drying, solar ponds, and testing and measurements. Specific papers include the optical performance of stretched-membrane mirror modules, the nonlinear steady-state performance curve for medium temperature solar energy collectors, solar flux distribution on the side wall of cylindrical cavity solar receivers, a solar receiver for the hybrid space station Braytron engine, thermal energy storage flight experiments, thermal simulation of a NASA Get Away Special payload, inflatable concentrators for solar propulsion and dynamic space power, and the potential of advanced-design solar central receiver power systems. R.B.

A90-11991
SOLAR RECEIVER EXPERIMENT FOR THE HYBRID SPACE STATION BRAYTON ENGINE
H. J. STRUMPF and M. G. COOMBS (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., Torrance, CA) IN: Solar engineering - 1989; Proceedings of the Eleventh Annual ASME Solar Energy Conference, San Diego, CA, Apr. 2-5, 1989. New York, American Society of Mechanical Engineers, 1989, p. 11-17.
Copyright

An experimental investigation has been conducted to develop fabrication procedures and acquire test data for a heat receiver assembly (HRA) in support of the design and development effort for the Brayton engine solar receiver for the NASA hybrid Space Station. The HRA configuration is a cylindrical receiver lined with tubes; each tube is surrounded by phase change material (PCM). The Brayton cycle working fluid flows inside the tubes. The PCM surrounding the tubes, a eutectic mixture of LiF and CaF2, is contained in a series of sealed metallic containment canisters.

During periods of sunlight, heat is transferred through the PCM to the Brayton cycle working fluid; during periods of eclipse, the PCM gives up its heat to the working fluid. A section of a full-size receiver tube was fabricated, assembled, and tested. Performance of the receiver tube qualitatively validates the expected receiver performance. Over 3000 cycles (of approximately 90-min duration) had been completed as of November 30, 1988. Author

A90-11992* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THERMAL ENERGY STORAGE FLIGHT EXPERIMENTS
D. NAMKOONG (NASA, Lewis Research Center, Cleveland, OH) IN: Solar engineering - 1989; Proceedings of the Eleventh Annual ASME Solar Energy Conference, San Diego, CA, Apr. 2-5, 1989. New York, American Society of Mechanical Engineers, 1989, p. 19-24.
Copyright

Consideration is given to the development of an experimental program to study heat transfer, energy storage, fluid movement, and void location under microgravity. Plans for experimental flight packages containing Thermal Energy Storage (TES) material applicable for advanced solar heat receivers are discussed. Candidate materials for TES include fluoride salts, salt eutectics, silicides, and metals. The development of a three-dimensional computer program to describe TES material behavior undergoing melting and freezing under microgravity is also discussed. The TES experiment concept and plans for ground and flight tests are outlined. R.B.

A90-11993* Rockwell International Corp., Canoga Park, CA.
SPACE STATION SOLAR DYNAMIC MODULE MODELLING AND SIMULATION
A. TYLIM (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: Solar engineering - 1989; Proceedings of the Eleventh Annual ASME Solar Energy Conference, San Diego, CA, Apr. 2-5, 1989. New York, American Society of Mechanical Engineers, 1989, p. 25-30.
(Contract NAS3-25082)
Copyright

Efforts to model and simulate the Solar Dynamic Power Module (SDPM) for the Space Station are discussed. The SDPM configuration is given and the SDPM subsytems are described, including the concentrator assembly, the fine pointing and tracking system, the power generation system, the heat rejection assembly, the electrical equipment, the interface structure and integration hardware, and the beta gimbal assembly. Performance requirements and design considerations are given. The development of models to simulate the SDPM is examined, noting research on models such as the Electric Power System Transient Analysis Model, the Electric Power System on Orbit Performance model, and a spatial flux distribution function. R.B.

A90-13295*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE STATION FREEDOM POWER MANAGEMENT AND DISTRIBUTION SYSTEM DESIGN
FRED TEREN (NASA, Lewis Research Center, Cleveland, OH) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. Previously announced in STAR as N89-26045.
(IAF PAPER 89-078) Copyright

The design is described of the Space Station Freedom Power Management and Distribution (PMAD) System. In addition, the significant trade studies which were conducted are described, which led to the current PMAD system configuration. Author

A90-13407#
RECEIVER WITH INTEGRAL THERMAL ENERGY STORAGE FOR SOLAR DYNAMIC SPACE POWER SYSTEMS
S. WEINGARTNER and J. BLUMENBERG (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-252)

The present development status evaluation for a solar concentrator system receiver design which incorporates an integral thermal energy storage system for eclipse periods gives attention to the distinctive technical problems associated with each candidate receiver design. The relevance of microgravity to the heat of fusion storage capacity is discussed. The mass and performance design goals of Brayton and Stirling cycle receivers derived from a preliminary simulation model indicate that a reduction of the containment mass and an increase of the cavity's peak flux are the essential starting-points for receiver optimization. O.C.

A90-13408#
THE PROVISION OF EFFICIENCY OF THE LIQUID METALS EVAPORATORS IN THE SPACE SOLAR ENERGY CONVERTORS
V. F. PRISNIAKOV, IU. D. MOROZOV, A. N. PRIVALOV, IU. K. GONTAREV, and S. A. BELOGUROV (Dnepropetrovskii Gosudarstvennyi Universitet, Dnepropetrovsk, USSR) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p. refs
(IAF PAPER 89-253) Copyright

The present investigation of the subtleties entailed by development and operation of alkali metal parallel evaporators employed by a Rankine cycle heat engine gives attention to the diminution of microgravity's influence on the evaporation process and to the provision of full-evaporation conditions for all of the liquid without heat transfer problems. The contact between liquid metal and container wall has been broken by means of metallic fiber wall coatings in single-channel evaporator models. The working fluid used in the study was potassium. O.C.

A90-13409*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PHOTOVOLTAIC POWER FOR A LUNAR BASE
GEOFFREY A. LANDIS, SHEILA G. BAILEY, HENRY B. CURTIS, DAVID J. BRINKER, and DENNIS J. FLOOD (NASA, Lewis Research Center, Cleveland, OH) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 16 p. refs
(IAF PAPER 89-254) Copyright

A lunar base is an attractive option for space exploration plans early in the next century. The primary options for a lunar base power system are solar and nuclear. This paper details the requirements for a photovoltaic powered lunar base. Topics covered are (1) requirements for power during the lunar day and during the night, (2) solar cells, present and future availability, efficiency, specific power, and temperature sensitivity, (3) storage options for the lunar night, (4) arrays and system integration, and (5) the potential for production of photovoltaic arrays and storage capability from locally available materials. Author

A90-13413#
REMOTE ELECTRICAL POWER PLANTS FOR SPACECRAFT
LUCIEN DESCHAMPS (Electricite de France, Clamart) and MARCEL TOUSSAINT (Eurospace, Paris, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-258) Copyright

This paper reviews the present technologies for producing electricity in space, particularly on low orbit, and their constraints. It also reviews the possibilities that exist for the use of remotely situated space power plants, capable of producing electricity, and transferring it at a distance for use by in-orbit infrastructure elements or space platforms not equipped with power plants of their own. The conclusion is that these technologies are now mature enough to give an economic interest to the development of small powersats capable of replacing classical power systems for platforms situated on the orbit of the international Space Station. A development plan based on this idea is proposed. Author

A90-13414#
SPACE NUCLEAR POWER SYSTEM STUDIES IN FRANCE AND ENVISAGED MISSIONS
F. CARRE, J. DELAPLACE, E. PROUST, and Z. TILLIETTE (CEA,

Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. Research sponsored by CNES and CEA.
(IAF PAPER 89-266) Copyright

Since 1982, the development of 20 to 200 kWe French space nuclear power systems adapted to the Ariane and V launcher has been considered for two reference missions: space based radar and electric propulsion. The first development phase (1983-1986) included conceptual studies, operating transient analyses, and cost assessment of a 200 kWe nuclear power system meeting the power needs of an orbit transfer vehicle with electric propulsion. The second phase (1986-1989) involves the assessment of technical and economic bases for the development of a 20 kWe nuclear power system, likely to meet the energy needs of European space missions from year 2005 onwards. With this aim in view, a comprehensive study program of 20 kWe nuclear power systems has been conducted to provide the basis for selecting the design options and the development strategy of a first European space nuclear system. C.E.

A90-13415#
THE PROBLEM OF FINDING SPACE MISSIONS FOR NUCLEAR GENERATORS
CLAUDE POHER (CNES, Paris, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-269) Copyright

Different French and European candidate space missions studies are being conducted on future nuclear power systems foreseen to be in orbit after 2005. The aim of this work is to establish the feasibility and cost of such systems, along with the best development procedures and some application choices. The candidate space missions included the LEO-GEO electric OTV, space-based radars, manned space stations, unmanned but visited space stations, planetary explorations, and 'classical' space applications missions. The results of the candidate space missions studies are discussed. C.E.

A90-14851
IEEE PHOTOVOLTAIC SPECIALISTS CONFERENCE, 20TH, LAS VEGAS, NV, SEPT. 26-30, 1988, CONFERENCE RECORD. VOLUMES 1 & 2
Conference sponsored by IEEE. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. Vol. 1, 853 p.; vol. 2, 884 p. For individual items see A90-14852 to A90-14970.
Copyright

Various papers on photovoltaics are presented. The general topics considered include: amorphous materials and cells; amorphous silicon-based solar cells and modules; amorphous silicon-based materials and processes; amorphous materials characterization; amorphous silicon; high-efficiency single crystal solar cells; multijunction and heterojunction cells; high-efficiency III-V cells; modeling and characterization of high-efficiency cells; LIPS flight experience; space mission requirements and technology; advanced space solar cell technology; space environmental effects and modeling; space solar cell and array technology; terrestrial systems and array technology; terrestrial utility and stand-alone applications and testing; terrestrial concentrator and storage technology; terrestrial stand-alone systems applications; terrestrial systems test and evaluation; terrestrial flatplate and concentrator technology; use of polycrystalline materials; polycrystalline II-VI compound solar cells; analysis of and fabrication procedures for compound solar cells. C.D.

A90-14852* Aerospace Corp., El Segundo, CA.
ISSUES AND OPPORTUNITIES IN SPACE PHOTOVOLTAICS
ROBERT W. FRANCIS, W. A. SOMERVILLE (Aerospace Corp., El Segundo, CA), and DENNIS J. FLOOD (NASA, Lewis Research Center, Cleveland, OH) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 8-20. Previously announced in STAR as N89-15171. refs
Copyright

Space power sources are becoming a central focus for determining man's potential and schedule for exploring and utilizing the benefits of space. The ability to search, probe, survey, and communicate throughout the universe will depend on providing adequate power to the instruments to do these jobs. Power requirements for space platforms are increasing and will continue to increase into the 21st century. Photovoltaics have been a dependable power source for space for the last 30 years and have served as the primary source of power on virtually all DOD and NASA satellites. The performance of silicon (Si) solar cells has increased from 10 percent air mass zero (AM0) solar energy conversion efficiency in the early 60's to almost 15 percent on today's spacecraft. Some technologists even think that the potential for solar photovoltaics has reached a plateau. However, present and near-future Air Force and NASA requirements show needs that, if the problems are looked upon as opportunities, can elevate the photovoltaic power source scientist and array structure engineer into the next technological photovoltaic growth curve. Author

A90-14880
IMPROVED PREDICTION AND ANALYSIS OF CELL PERFORMANCE AT ELEVATED TEMPERATURES
G. F. J. GARLICK and B. S. SMITH (Spectrolab, Inc., Sylmar, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 587-590. refs
Copyright

Improved modeling and analysis have been applied to data on cells made for the Magellan satellite (Venus orbits) at temperatures from -50 to 100 deg C. Derived saturation currents for the cells have been used to calculate base minority carrier lifetimes. These rise with temperature, showing some saturation near 100 deg C. Data are quantitatively explained by an energy band model with divacancy levels at 0.25 eV and impurity levels at 0.6 eV above the valence band. Close fits to experimental results are found for concentrations of 6 x 10 to the 12th/cu cm and 1.5-2 x 10 to the 11th/cu cm for the 0.25 and 0.6 eV levels, respectively. At 100 deg C the saturation is controlled by the latter, while divacancies affect the lifetimes at lower temperatures. It is concluded that this analysis of quite usual test data for cells, coupled with temperature variation, provides a powerful insight into basic parameters which determine the cell operational performance. I.E.

A90-14900* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THIN, LIGHT-TRAPPING SILICON SOLAR CELLS FOR SPACE
GEOFFREY A. LANDIS (NASA, Lewis Research Center, Cleveland, OH) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 708-712. Research supported by DOE. refs
Copyright

Ultrathin silicon solar cells with high efficiency and radiation tolerance can be made by incorporating light-trapping and heterojunction surface passivation. Calculations show that a 2-micron-thick light-trapping cell remains over 18 percent efficient after the equivalent of 20 years in geosynchronous orbit. Including a 50-micron coverglass, the thin cells had, after irradiation, a specific power over ten times higher than that of the baseline design. I.E.

A90-14918
LIPS III - A SOLAR CELL TEST BED IN SPACE
J. G. SEVERNS, R. M. HOBBS, N. P. ELLIOTT, R. H. TOWSLEY, R. W. CONWAY (U.S. Navy, Naval Research Laboratory, Washington, DC) et al. IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 801-807.
Copyright

The operation of the Lips (Living Plume Shield) III spacecraft and the experiments placed aboard it are described. The purpose of the satellite is to provide a platform for long-term testing of innovative solar cells and concentrator systems. In all, 140 distinct I-V curves are measured from cells mounted on 30 panels provided by 18 different laboratories. Included are cells of GaAs, AlGaAs, InGaAs, silicon (crystalline and amorphous), InP, and CuInSe2. With the exception of one, all of the experiments aboard Lips III are photovoltaic in nature. Two indium phosphide and three thin-film cell experiments are aboard Lips III. Three concentrator concepts included among the Lips III experiments are also briefly reviewed. The problems encountered are summarized. I.E.

A90-14919#
THE SPACE PERFORMANCE OF SILICON VERTICAL JUNCTION SOLAR CELLS ON THE LIPS-III SATELLITE
RICHARD L. STATLER and DELORES H. WALKER (U.S. Navy, Naval Research Laboratory, Washington, DC) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 808-812. Research supported by the U.S. Navy. refs

The preliminary analysis and results are presented of a space experiment to evaluate the performance of a new generation of silicon vertical junction solar cells and three adhesives for attaching coverglass to the solar cells. Two of the adhesives are used for the first time in coverglass applications in the space environment. The Solarex vertical junction solar cells, which are of 10-ohm-cm silicon with back surface fields and back surface reflectors, are compared to Solarex planar junction cells of the same silicon. The results for up to 386 days in space indicate that the two types of solar cell show about the same degradation rate in power output. There are no significant differences in the performance of the three adhesives. I.E.

A90-14920
LIPS III SOLAR ARRAY EXPERIMENT USING HIGH EMISSIVITY COATED COVERSLIDES
B. S. SMITH and D. E. JOSLIN (Spectrolab, Inc., Sylmar, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 813-818.

The design, construction, and experimental results of coupons flown on the US Naval Research Laboratory's Lips III mission are summarized. The main experiment is a comparison of performance in orbit of solar cells covered by standard coverslide material and those covered by coverslides coated with high-emissivity fused silica or CMS coatings. Preliminary optical measurements of the coatings suggest that the emissivity can be increased by as much as 10 percent, thus reducing the equilibrium temperature of the panel in sunlight and increasing the cell operating efficiency. High-emissivity CMS on thin silicon reduces temperature by over 9 C, whereas high-emissivity fused silica on GaAs produces a reduction of only 2 C. It is not known why the reduction in temperature for the latter is lower than predicted, although the accuracy of measurements of all data is at this time in doubt and may partially explain the inconsistency. I.E.

A90-14921* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INP HOMOJUNCTION SOLAR CELL PERFORMANCE ON THE LIPS III FLIGHT EXPERIMENT
DAVID J. BRINKER, RUSSELL E. HART, JR., IRVING WEINBERG (NASA, Lewis Research Center, Cleveland, OH), and BRIAN S. SMITH (Spectrolab, Inc., Sylmar, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 819-823. Previously announced in STAR as N89-12123. refs

Performance data for the NASA Lewis Research Center indium phosphide n+p homojunction solar cell module on the LIPS 3 flight experiment is presented. The objective of the experiment is to measure the performance of InP cells in the natural radiation environment of the 1100 km altitude, 60+ deg inclination orbit. Analysis of flight data indicates that the performance of the four cells throughout the first year is near expected values. No degradation in short-circuit current was seen, as was expected from radiation tolerance studies of similar cells. Details of the cell structure and flight module design are discussed. The results of the temperature dependency and radiation tolerance studies necessary for normalization and analysis of the data are included. Author

A90-14922
ASEC/AIR FORCE LIPS-3 TEST PANEL RESULTS
P. A. ILES, K. I. CHANG, K. S. LING, C. CHU (Applied Solar Energy Corp., City of Industry, CA), J. WISE (USAF, Wright-Patterson AFB, OH) et al. IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 826-830.

Preorbit and in-orbit test panel results are presented. The test panel contained three types of cell: GaAs/Ge, GaAs, and silicon. The test results showed anomalies in tracking the cell performance in ground tests and into orbit. There was also in-orbit degradation greater than that expected from the radiation models used for the Lips-3 orbit. With these reservations, the GaAs/Ge cell performance confirmed recent advances in explaining the electrical performance of these cells. Both the GaAs/Ge and GaAs cells have deeper p-n junction depths than current cells, and this probably caused some of the in-orbit degradation. For the silicon cells, the in-orbit degradation was greater than expected for their design and may have been affected by mechanical factors in panel assembly or mounting on the satellite. I.E.

A90-14923
RADIATION RESISTANT SPACE EXPERIMENT - LIPS III
W. E. HORNE, S. CANNADAY, M. A. THOMPSON, P. BROTHERS, and M. MORGAN (Boeing Electronics, Bellevue, WA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 831-836. refs

A description of three Lips III flight experiments is presented. The experiments provide data on three concepts for radiation-resistant, survivable space power systems. The concepts are an in-orbit annealable silicon solar array, a concentrating GaAs solar array based on total internal reflection, and a lightweight radiation-resistant CuInSe2 polycrystalline-film solar array. The experiments are in a 600-nm circular orbit, and on-orbit data are being collected. Preliminary results from the on-orbit data are presented. I.E.

A90-14924
INTERIM RESULTS OF THE SLATS CONCENTRATOR EXPERIMENT ON LIPS-III
THEODORE G. STERN (General Dynamics Corp., Space Systems Div., San Diego, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 837-840.

An analysis of four months of data from SLATS concentrator experiments on Lips-III is presented. The array panel includes three mirrors, each focusing on two different linear solar cell strings. Small changes in current, voltage, and temperature have been observed in all six experiments. The use of unglassed solar cells on four of the six strings does not seem to affect these performance trends, confirming that the surrounding mirror and cell assembly components can be used as cell shielding. Analysis of current output during off-pointed periods allows a determination of

concentrator pointing tolerances. Results show the ability of the design to withstand launch and deployment forces and maintain the accuracy needed for optical efficiency. I.E.

A90-14925
SPACE SOLAR CELL PERFORMANCE FOR ADVANCED GAAS AND SI SOLAR CELLS
JOHN TRACY (Applied Solar Energy Corp., City of Industry, CA) and JOSEPH WISE (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 841-847. refs
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The relative performances of the panel components of space power systems that incorporate advanced GaAs and Si cells in both rigid and flexible (including advanced photovoltaic array) configurations are analyzed. Realistic assumptions about the panel components are made. Various performance parameters are calculated. The required beginning-of-life power is computed. Some figures of merit are defined to estimate the performances of overall systems that include specific panel configurations. I.E.

A90-14926
MISSION DURATION AND POWER DEGRADATION IN PHOTOVOLTAIC POWER SUBSYSTEMS FOR MILITARY SPACECRAFT
J. H. ARNOLD, D. W. HARRIS (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), G. R. BROOKS, and D. ZEMMRICH (Spectrolab, Inc., Sylmar, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 848-853.
Copyright

Several of the more widely discussed orbits for military missions and how their environments affect the sizing of advanced planar arrays are examined. Also provided are sizing guidelines as they are affected by years in orbit or mission duration, so that planners can trade off variables on a preliminary basis as an integral portion of their decision process. The model system masses are formulated on 1990-1995 array technology for maximizing survivability in natural hostile environments. The findings of the analyses and computer coding show that geosynchronous orbit is the most benign from the standpoints of encountering high radiation damage levels, space debris, meteoroids, plasma interaction, and eclipse times. I.E.

A90-14927
50 KW SOLAR SPACE POWER SYSTEM
E. L. RALPH (Hughes Aircraft Co., El Segundo, CA) and MICHAEL A. CHUNG (USAF, Wright-Patterson AFB, OH) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 854-859.
(Contract F33615-86-C-2715)
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A photovoltaic space power system that provides improved overall operating efficiency is analyzed. The system incorporates high-efficiency, multijunction, multibandgap solar cells in conjunction with a concentrating solar array so that the cells operate at a concentration ratio of greater than 50:1 and exhibit an operating efficiency of 31 percent (beginning of life) at 91 C. This results in an overall 50-kW system-specific power of 13 W/lb (about 28 W/kg). The strawman design consists of two clam-shell-shaped wings, each 10.5 m by 10.8 m in size. Each wing has a series of small, flat mirrors mounted on a parabolic radiator structure, and the focal point is a linear solar cell cavity located along the two outer edges of the array. Solar cells of three different bandgap materials (AlGaAs, GaAs, and InGaAs) are utilized to convert sunlight to electric power efficiently, and the excess heat is collected in a heat pipe system to be redistributed to the radiator structure. I.E.

A90-14929*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ASSESSMENT OF THE EFFECTS OF SPACE DEBRIS AND METEOROIDS ENVIRONMENT ON THE SPACE STATION SOLAR ARRAY ASSEMBLY
HENRY K. NAHRA (NASA, Lewis Research Center, Cleveland, OH) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 868-873. Previously announced in STAR as N88-28959. refs

The methodology used to assess the probability of no impact of space debris and meteoroids on a spacecraft structure is applied to the Space Station solar array assembly. Starting with space debris and meteoroid flux models, the projected surface area of the solar cell string circuit of the solar array panel and the mast longeron, and the design lifetime, the possibility of no impact on the solar mast and solar cell string circuits was determined as a function of particle size. The probability of no impact on the cell string circuits was used to derive the probability of no open circuit panel. The probability of meeting a certain power requirement at the end of the design lifetime was then calculated as a function of impacting particle size. Coupled with a penetration and damage models/correlations which relate the particle size to penetration depth and damage, the results of this analysis can be used to determine the probability of meeting the lower power requirement given a degree of redundancy, and the probability of no impact on the solar array mast. Author

A90-14936
ELECTRON AND PROTON RADIATION EFFECTS ON GAAS AND CUINSE2 THIN FILM SOLAR CELLS
R. M. BURGESS, W. S. CHEN, W. E. DEVANEY, D. H. DOYLE, N. P. KIM (Boeing High Technology Center, Seattle, WA) et al. IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 909-912. refs
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The effects of proton and electron radiation on the performances of GaAs and CuInSe2/CdZnS (CIS) thin-film solar cells are evaluated. Bare cells (i.e., with no coverglass) were exposed to several energies of electron and proton radiation, and their performances were monitored by illuminated I-V curves, dark I-V curves, and spectral response measurements at different fluence levels. These experiments reconfirm that no measurable damage occurs to CIS solar cells when exposed to 1 and 2 MeV electrons to a total fluence of 5.0 x 10 to the 15th/sq cm. For proton irradiations, the results indicate that CIS cells are more radiation resistant than GaAs cells, by a factor of ten, when compared at the same energy levels. Comparison of the electron and proton irradiation results to those reported in the literature shows that the thin-film GaAs solar cells are as radiation resistant as other GaAs bulk cells at 1.0 MeV protons and are more radiation resistant at both the 1.0-MeV electron and 200-keV proton energies. I.E.

A90-14937
ANOMALOUS SOLAR ARRAY PERFORMANCE ON GPS
DEAN C. MARVIN, WARREN C. HWANG, and EDWARD J. SIMBURGER (Aerospace Corp., Los Angeles, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 913-917. refs
(Contract F04701-85-C-0086)
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The general issue of degradation of optical surfaces on spacecraft is reviewed in order to understand the observed behavior of the Navstar solar arrays. The solar arrays on GPS Navstars 1-6 have shown anomalous degradation during the 5-year mission life and beyond. The departure from predicted performance consists of an extra 2.5 percent per year degradation in excess of the

radiation model estimates. Examination of optical solar reflector (OSR) data from a variety of spacecraft reveals variations in OSR degradation rates which correlate with the vehicle design. These data support the idea that contaminants outgassing from the vehicle are photodeposited on the optical surfaces, leading to degradation of their reflectivity. Contamination data taken from an OSR flown on Navstar 5 are used to predict the solar array degradation. The predicted effect of contamination on the array output is consistent with the observed behavior of the five Block I vehicles. I.E.

A90-14938
GAAS ON GE CELL AND PANEL TECHNOLOGY FOR ADVANCED SPACE FLIGHT APPLICATION
B. T. CAVICCHI, D. R. LILLINGTON, G. F. J. GARLICK, G. S. GLENN (Spectrolab, Inc., Sylmar, CA), and S. P. TOBIN (Spire Corp., Bedford, MA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 918-923. refs
Copyright

Tandem junction GaAs/Ge solar cells measuring 2-cm x 2-cm were fabricated with efficiencies up to 18.2 percent (AM0, 28 C) using in-house grown material. Previously, efficiency of 21.7 percent (AM0, 25 C) was demonstrated. Welded tab pull strengths greater than 3.3 N (340 gms) were achieved with no electrical degradation or mechanical damage for both the front and back contacts. A panel incorporating CIC'd GaAs/Ge cells was built to demonstrate this assembly technology. Modeling shows that with proper design, the thin dual-junction GaAs/Ge cell can be made with efficiencies of 24 percent (AM0, 28 C) by improving optical coatings and reducing the effect of interface and back surface recombination. I.E.

A90-14939
ELECTRON RADIATION AND ANNEALING OF MOCVD GAAS AND GAAS/GE SOLAR CELLS
M. A. CHUNG (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH), D. L. MEIER, J. R. SZEDON, and J. BARTKO (Westinghouse Research and Development Center, Pittsburgh, PA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 924-929. refs
Copyright

A comparison of the radiation tolerances of MOCVD-grown GaAs/GaAs cells and GaAs/Ge cells was undertaken using 1 MeV electrons. The electron radiation was delivered in doses of 1 x 1016 cm-2 up to a total dose of 1 x 10 to the 17th/sq cm for GaAs/GaAs and a total dose of 7 x 10 to the 16th/sq cm for GaAs/Ge. Following each dose, the cells were annealed at either 250 C or 300 C for 1 h in nitrogen. It was found that the radiation tolerance of the GaAs/Ge cells was superior to that of the GaAs/GaAs cells. DLTS and EBIC measurements are presented. I.E.

A90-14940
GALLIUM ARSENIDE CONCENTRATOR SOLAR CELLS WITH HIGHLY STABLE METALLIZATION
M. B. SPITZER, J. E. DINGLE, R. P. GALE, P. ZAVRACKY, M. BODEN (Kopin Corp., Taunton, MA) et al. IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 930-933.
Copyright

The development of GaAs/AlGaAs double-heterostructure concentrator cells for space operation that are capable of surviving 5-min thermal excursions to temperatures well beyond 500 C without significant degradation is presented. The cells are formed epitaxially using the organometallic chemical vapor deposition growth process. The design utilizes a contact system that yields high stability at elevated temperature, and AM0 efficiency of up to 20 percent has been obtained with this approach. The efficiency is observed to change by less than 10 percent after a 5-min excursion to temperatures as high as 700 C. Stability at higher temperatures and for longer times is discussed, and a comparison is made to the stability of conventional concentrator cells characterized by AM0 efficiencies of up to 23 percent. I.E.

A90-14941* Spectrolab, Inc., Sylmar, CA.
OPTIMIZATION OF SILICON 8 CM X 8 CM WRAPTHROUGH SPACE STATION CELLS FOR 'ON ORBIT' OPERATION
D. R. LILLINGTON, J. R. KUKULKA, A. V. MASON (Spectrolab, Inc., Sylmar, CA), B. L. SATER (NASA, Lewis Research Center, Cleveland, OH), and J. SANCHEZ (Optical Coating Laboratory, Inc., Santa Rosa, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 934-939.
(Contract NAS3-24672)
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The optimization of Space Station cells for on-orbit performance is described. Design trades were performed in which back DAR coating thickness was traded against thermal absorptance and performance under front and back (albedo) illumination. Typical examples of modeled cell performance under different scenarios are given. Experimental illuminated output data under back illumination for specific DAR coating thicknesses are also given. Computer modeling of the solar array using TRASYS and SINDA programs also provide on-orbit thermal data and performance predictions. The overall backside response from albedo illumination was found to make a considerable contribution to the total array performance, particularly during the early stages of space station assembly when the arrays are feathered. I.E.

A90-14945
RECENT SILICON SPACE PRODUCT ADVANCES
S. M. BUNYAN, D. E. JOSLIN, J. R. KUKULKA (Spectrolab, Inc., Sylmar, CA), and R. E. DANIEL (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 954-959.
Copyright

Silicon solar cell products have been developed to meet near-term spacecraft mission performance objectives of greater power per area and power per weight ratios. Aspects of advanced design include large area (8 x 8 cm), a thin (2.5 mil) silicon substrate, IR transparency (gridded back contacts), and wrap-through contacts. Cell types with these advances are described, and their performance is characterized. Various environmental tests were performed, and results are presented. Solar cells that incorporate this advanced technology are available or are currently in production. I.E.

A90-14946
PERFORMANCE OF LARGE AREA, THIN SILICON CELLS
S. KHEMTHONG, P. ILES, M. ROBERTS, C. KARNOPP, and N. SENK (Applied Solar Energy Corp., City of Industry, CA) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 960-963.
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It is shown that cell manufacturers have established processing methods that produce cells that meet the requirements for electrical output, solar absorptivity, radiation resistance, contact performance, and environmental stability. In addition, some current cell designs are described that involve more complicated features such as the placement of all contacting areas on the back surface and a back surface contact that either has very high reflectance or high transparency for the wavelengths in the solar spectrum that are beyond the cutoff wavelength for silicon (greater than 1.1 micron). Many of the cell designs feature rugged, weldable contacts. I.E.

A90-14947
EXTENDED LIFE INTERCONNECT FOR LARGE SOLAR CELL SPACE ARRAYS
EDWARD M. GADDY (Solarex Corp., Aerospace Div., Rockville, MD) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 964-967. refs
Copyright

Calculations are presented that show that the stress in this interconnect is reduced by a factor of 60 as compared to interconnects that make use of only the intercell spacing for their stress relief loop. The reason is that traditional interconnects use only an intercell spacing of about 0.5 mm to absorb stress. The extended life interconnect positions the stress interconnect member parallel to the gap between the cells. Therefore, the interconnect's stressed member can be much longer and the stress consequently less. Also presented are the results of mechanically cycling the interconnect. I.E.

A90-14952* Wayne State Univ., Detroit, MI.
RADIATION RESISTANCE STUDIES OF AMORPHOUS SILICON FILMS
J. SCOTT PAYSON and JAMES R. WOODYARD (Wayne State University, Detroit, MI) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 990-995. Research supported by Wayne State University. refs
(Contract NAG3-833)
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A study of hydrogenated amorphous silicon thin films irradiated with 2.00 MeV helium ions using fluences ranging from 1E11 to 1E15/sq cm is presented. The films were characterized using photothermal deflection spectroscopy, transmission and reflection spectroscopy, and photoconductivity and annealing measurements. Large changes were observed in the subband-gap optical absorption for energies between 0.9 and 1.7 eV. The steady-state photoconductivity showed decreases of almost five orders of magnitude for a fluence of 1E15/sq cm, but the slope of the intensity dependence of the photoconductivity remained almost constant for all fluences. Substantial annealing occurs even at room temperature, and for temperatures greater than 448 K the damage is completely annealed. The data are analyzed to describe the defects and the density of states function. I.E.

A90-14953
THE ASGA EXPERIMENT ON EURECA PLATFORM - TESTING OF ADVANCED GAAS SOLAR CELLS IN LEO
L. BERTOTTI, C. FLORES, F. PALETTA (CISE S.p.A., Milan, Italy), J. GARNER (Pilkington PE, Ltd., Space Technology, Bodelwyddan, Wales), and J. WHARF (Royal Aerospace Establishment, Farnborough, England) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1002-1006. Research supported by CNR and Ministry of Defence Procurement Executive.
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Consideration is given to the problems faced in designing, manufacturing, and testing flight hardware and, in particular, in fabricating and testing concentrator and 100-micron-thick GaAs solar cells. The Advanced Solar GaAs Array (ASGA) experiment is designed to evaluate gallium arsenide solar cells and concentrator optics in space. It will be flown on the European Retrievable Carrier (Eureca) for 6 months. The experiment configuration is defined on the basis of the Eureca mission analysis (orbit condition, natural environment) and includes solar cells of different types, with different junction depths and different thicknesses. The experiment also includes a concentrator solar array which is designed to be representative of a section of a full-size spacecraft array. I.E.

A90-14954* ENTECH Corp., Dallas-Fort Worth Airport, TX.
AN ADVANCED SPACE PHOTOVOLTAIC CONCENTRATOR ARRAY USING FRESNEL LENSES, GALLIUM ARSENIDE CELLS, AND PRISMATIC CELL COVERS
MARK J. O'NEILL (Entech, Inc., Fort Worth, TX) and MICHAEL F. PISZCZOR (NASA, Lewis Research Center, Cleveland, OH) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1007-1012. refs
Copyright

The current status of a space concentrator array which uses refractive optics, gallium arsenide cells, and prismatic cell covers to achieve excellent performance at a very low array mass is documented. The prismatically covered cells have established records for space cell performance (24.2 percent efficient at 100 AM0 suns and 25 C) and terrestrial single-junction cell performance (29.3 percent efficient at 200 AM1.5 suns and 25 C). I.E.

A90-14956*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PERFORMANCE OF GAAS CONCENTRATOR CELLS UNDER ELECTRON IRRADIATIONS FROM 0.4 TO 2.3 MEV
HENRY B. CURTIS and RUSSELL E. HART, JR. (NASA, Lewis Research Center, Cleveland, OH) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1020-1023.

Gallium arsenide concentrator cells were irradiated with electrons with energies varying from 0.4 to 2.3 MeV, and their electrical performance was measured. The cells are 5 x 5 mm square with a 4-mm diameter illuminated area. At each of four different electron energy levels (0.4, 0.7, 1.0, and 2.3 MeV), three n/p and two p/n cells were irradiated. I-V performance measurements were made prior to irradiation and at several intermediate fluence levels. The final fluence level was 3 X 10 to the 15th e/sq cm. It is concluded that the power degradation is independent of the temperature at which it is measured. I.E.

A90-14957#
STATUS OF LIPS-II GAAS AFTER FIVE YEARS IN ORBIT
J. D. SCOFIELD (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: IEEE Photovoltaic Specialists Conference, 20th, Las Vegas, NV, Sept. 26-30, 1988, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1024-1026. refs

Updated and reduced data through day 1995 as well as conclusions about the performance and behavior of the GaAs panel are presented. The performance of the GaAs panel, after initial severe degradation, is encouraging. The results support other data indicating that GaAs solar cells are a viable space power system component. Taking into account recent advances such as Ge substrate use, multibandgap efforts, and significant performance gains, the author concludes that GaAs cells are ready to become the next generation of photovoltaic cells supplying space power for military and commercial missions. I.E.

A90-16374*# TRW, Inc., Redondo Beach, CA.
SOLAR DYNAMIC POWER FOR THE SPACE STATION
J. S. ARCHER and E. S. DIAMANT (TRW, Inc., Redondo Beach, CA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Nov.-Dec. 1989, p. 744-749. Previously cited in issue 18, p. 2623, Accession no. A86-39906.
(Contract NAS3-24655)
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A90-18828*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
HIGH PERFORMANCE ARRAYS FOR LIGHTWEIGHT SPACECRAFT
PAUL M. STELLA (JPL, Pasadena, CA) IN: AIAA/DARPA Meeting on Lightweight Satellite Systems, Monterey, CA, Aug. 4-6, 1987,

Collection of Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 21-24. refs
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JPL is developing the solar arrays for NASA's ultralightweight spacecraft, the Lunar Get-Away Special (L-GAS), which requires 1 kWe after its slow passage through the Van Allen Belts. The solar array design developed for the mission extended recent NASA-developed photovoltain array technology to power levels well below those conventionally considered practical for deployable lightweight array technology. It has become feasible by these means to consider the design of lightweight spacecraft which require up to 3 kWe at the begining of their service life. O.C.

A90-20150#
INVESTIGATION REPORT ON ENERGY SYSTEMS AND RESOURCES IN SPACE
TATSUO TANI, KAZUYOSHI NAGAI, YUTAKA HAYASHI, MASANORI FUJIWARA, KOICHI SAKUTA et al. Electrotechnical Laboratory, Circulars (ISSN 0366-9084), no. 218, Dec. 1987, 176 p. In Japanese, with abstract in English. refs

The current development status of technology for space electrical-energy generation and material-resource management is surveyed, with an emphasis on systems applicable to a large free-flying laboratory or a space factory. Consideration is given to the introduction of plants and microorganisms for food production; solar cells, solar-thermal generation, solar-excited lasers, pyroelectric generation, electrical insulation, thermal processing, energy and material processing cycles, and overall energy requirements for manned and unmanned spacecraft. Diagrams, drawings, graphs, and tables of numerical data are provided. T.K.

A90-20828
HIGHLY VECTORIZED ALGORITHM FOR TRANSIENT SIMULATION OF SPACE REACTOR SYSTEMS
B. NASSERSHARIF, J. S. PEERY, and M. D. DEHART (Texas A & M University, College Station) IN: Supercomputing '88; Proceedings of the First Meeting, Orlando, FL, Nov. 14-18, 1988. New York, IEEE Computer Society Press, 1988, p. 393-399. Research supported by the Texas A & M University. refs
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A project to develop a code specifically designed to model and analyze space reactor systems is discussed. The code, named CENTAR (Code for Extended Nonlinear Transient Analysis of Extraterrestrial Reactors), is highly vectorizable and machine-independnent. Timing tests of the code have been run on VAX, Cray, NEC, Convex and SUN systems. It has been found that CENTAR executes approximately seven times faster in vector mode than scalar mode on a Cray X-MP. A one-loop model of a thermoelectric-based space reactor system (SP-100-like) was developed to demonstrate the code's capabilities. The model consisted of 24 components containing a total of 67 computational cells. Using a constant time step, this model ran two times faster than real time on a Cray X-MP. A code assessment plan is currently under development. I.E.

A90-21226#
ELECTRICAL POWER SYSTEM FOR LOW-EARTH-ORBIT SPACECRAFT APPLICATIONS
P. R. K. CHETTY (Fairchild Space Co., Germantown, MD) (IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1, p. 281-287) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, Jan.-Feb. 1990, p. 63-68. Research supported by the U.S. Navy. Previously cited in issue 02, p. 140, Accession no. A88-11817. refs
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A90-21447#
TESTING OF SPACE FUEL CELLS AT ESTEC
M. SCHAUTZ and G. DUDLEY (ESTEC, Electrical Systems Dept., Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 60, Nov. 1989, p. 39-44.
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The role of fuel cells in ESA plans for manned space programs is examined. The characteristics and applications of fuel cells are reviewed and plans to use fuel cells on the Hermes craft are noted. The ESA Fuel-Cell Test Facility is described in detail, including the test benches and equipment for testing fuel cells, the types of cells to be tested, and fuel-cell test control. Plans to use the test facility in the Hermes program are discussed. R.B.

A90-23197
THE SOLAR POWER SATELLITE (SPS)
PETER E. GLASER Journal of Practical Applications in Space (ISSN 1046-8757), vol. 1, Fall 1989, p. 7-28. refs
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The Solar Power Satellite (SPS), which is proposed for the conversion of solar energy in space for use on earth is examined. The major developments in key SPS-related technologies are outlined. Consideration is given to the significance of these developments to the use of SPS in alternative energy for use on earth and as a potential stimulus for space infrastructure developments. The solar energy conversion process and power transmission from space to earth are described. Also, economic, environmental, and policy issues related to the development of SPS are discussed. R.B.

A90-24788# General Electric Co., San Jose, CA.
SP-100, A FLEXIBLE TECHNOLOGY FOR SPACE POWER FROM 10S TO 100S OF KWE
PHILIP R. PLUTA, MICHAEL A. SMITH (General Electric Co., Astro-Space Div., San Jose, CA), and DONALD N. MATTEO (General Electric Co., Astro-Space Div., Philadelphia, PA) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 122-129. Research sponsored by NASA and SDIO.
(Contract DE-AC03-86SF-16006)
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The SP-100 program to develop space reactor power system technology is discussed, focusing on the development of an SP-100 power system to provide 10s to 100s of KW of electricity. The generic flight system design power plant and its nuclear and space subsystems are described. Consideration is given to the safety features of the flight system and the use of the system for space manufacturing and to deliver power to a space habitat. The status of the technology development process for the SP-100 program is evaluated and plans for testing the nuclear assembly and the integrated assembly are outlined. R.B.

A90-24789#
BEAMED POWER TRANSMISSION AND TRANSPORTATION SYSTEMS IN THE EQUATORIAL PLANE
WILLIAM C. BROWN (Microwave Power Transmission Systems, Weston, MA) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 130-137. refs
Copyright

Beamed power transmission and transportation systems in the equatorial plane are discussed in the context of the Solar Power Satellite System. A scenario in which a mass of 60,000,000 kilograms is transferred annually from low earth orbit to geosynchronous orbit for the construction of solar power satellites is examined. The costs are estimated for such a transportation system. Key technologies are discussed. Author

A90-25606#
INTELSAT VII SOLAR ARRAY ELECTRICAL AND MECHANICAL DESIGN
J. CELLI, N. LOMAS, H. POLLARD, and N. TOTAH (Ford Aerospace Corp., Space Systems Div., Palo Alto, CA) IN: AIAA International

Communication Satellite Systems Conference and Exhibit, 13th, Los Angeles, CA, Mar. 11-15, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 34-41. refs
(AIAA PAPER 90-0780) Copyright

Electrical power for the Intelsat VII communications satellite will be provided by a deployable array of silicon solar cells mounted on flat panel substrates. Composed of two identical solar wings, the solar array is designed for future growth of the payload. The baseline design will generate, at minimum, 3.9 kW of electrical power after 10.9 years in geosynchronous orbit. The power output can be easily extended to 5 kW by installing two additional solar panels. This paper outlines the performance requirements and describes the electrical and mechanical design of the Intelsat VII solar array. Author

A90-25608#
FAULT AVOIDANCE IN SPACE POWER DISTRIBUTION SYSTEM TOPOLOGIES
PHILIP A. TONEY (COMSAT General Corp., El Segundo, CA) IN: *AIAA International Communication Satellite Systems Conference* and Exhibit, 13th, Los Angeles, CA, Mar. 11-15, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 52-58.
(AIAA PAPER 90-0782) Copyright

Power distribution system architectures employed in space applications have exhibited a troubling inconsistency from program to program in terms of their tolerance to catastrophic single point failures (SPFs). In certain instances, 'soft' designs have resulted in a loss or serious disruption of the mission - the European Telecom 1B and U.S. INSAT C failures are recent examples. This paper contends that ALL such failures are avoidable by rigorous application of simple fault isolation techniques applied during the spacecraft's concept and design phases of work. The design methodology described, although certainly not the only approach available, is shown to be one means of achieving that objective. Author

A90-26837* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE FUEL CELL IN SPACE - YESTERDAY, TODAY AND TOMORROW
MARVIN WARSHAY and PAUL R. PROKOPIUS (NASA, Lewis Research Center, Cleveland, OH) (IBC Technical Services, Ltd., British Gas, PLC, British Petroleum Co., PLC, et al., Grove Anniversary Fuel Cell Symposium, London, England, Sept. 18-21, 1989) Journal of Power Sources (ISSN 0378-7753), vol. 29, Jan. 1990, p. 193-200. Previously announced in STAR as N90-11804.
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The past, present, and future of space fuel cell power systems is reviewed, starting with the first practical fuel cell by F. T. Bacon which led to the 1.5 kW Apollo alkaline fuel cell. However, the first fuel cell to be used for space power was the Gemini 1.0 kW Acid IEM fuel cell. The successor to the Apollo fuel cell is today's 12 kW Orbiter alkaline fuel cell whose technology is considerably different and considerably better than that of its ancestor, the Bacon cell. And in terms of specific weight there has been a steady improvement from the past to the present, from the close to 200 lb/kW of Apollo to the 20 lb/kW of the orbiter. For NASA future Lunar and Martian surface power requirements the regenerative fuel cell (RFC) energy storage system is enabling technology, with the alkaline and the PEM the leading RFC candidate systems. The U.S. Air Force continues to support fuel cell high power density technology development for its future short duration applications. Author

A90-26838
EUROPEAN SPACE AGENCY FUEL CELL ACTIVITIES
F. BARON (ESA, Noordwijk, Netherlands) (IBC Technical Services, Ltd., British Gas, PLC, British Petroleum Co., PLC, et al., Grove Anniversary Fuel Cell Symposium, London, England, Sept. 18-21, 1989) Journal of Power Sources (ISSN 0378-7753), vol. 29, Jan. 1990, p. 207-221.
Copyright

A development history and status evaluation is presented for ESA's Hermes reusable manned spacecraft fuel cell program. The two fuel cell powerplants used by Hermes will consume an average of about 4.6 kW, and an energy of about 1220 kW-h, for a 12-day mission. A regenerative fuel cell system operating cyclically could be combined with Hermes' environmental control and life support system, to create a regenerative life-support system. A static KOH regenerative fuel cell is currently favored over three other candidates. O.C.

A90-26975*# Maxwell Labs., Inc., La Jolla, CA.
EPSAT - A WORKBENCH FOR DESIGNING HIGH-POWER SYSTEMS FOR THE SPACE ENVIRONMENT
R. A. KUHARSKI, G. A. JONGEWARD, K. G. WILCOX, E. M. KENNEDY (Maxwell Laboratories, Inc., La Jolla, CA), N. J. STEVENS, R. M. PUTNAM (TRW, Inc., Space and Technology Group, Redondo Beach, CA), and J. C. ROCHE (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 5 p.
(AIAA PAPER 90-0637) Copyright

The Environment Power System Analysis Tool (EPSAT) is being developed to provide space power system design engineers with an analysis tool for determining the performance of power systems in both naturally occurring and self-induced environments. This paper presents the results of the project after two years of a three-year development program. The relevance of the project result for SDI are pointed out, and models of the interaction of the environment and power systems are discussed. C.D.

A90-27542* Ergenics, Inc., Wyckoff, NJ.
A FUEL CELL ENERGY STORAGE SYSTEM CONCEPT FOR THE SPACE STATION FREEDOM EXTRAVEHICULAR MOBILITY UNIT
OTTO J. ADLHART, MATTHEW J. ROSSO, JR. (Ergenics Power Systems, Inc., Wyckoff, NJ), and JOSE MARMOLEJO (NASA, Johnson Space Center, Houston, TX) SAE, International Congress and Exposition, Detroit, MI, Feb. 27-Mar. 3, 1989. 8 p.
(Contract NAS9-17775)
(SAE PAPER 891582) Copyright

An update is given on work to design and build a Fuel Cell Energy Storage System (FCESS) bench-tested unit for the Space Station Freedom Extravehicular Mobility Unit (EMU). Fueled by oxygen and hydride-stored hydrogen, the FCESS is being considered as an alternative to the EMU zinc-silver oxide battery. Superior cycle life and quick recharge are the main attributes of FCESS. The design and performance of a nonventing, 28 V, 34 Ahr system with 7 amp rating are discussed. C.D.

A90-27706
OPTIMAL DESIGN OF THERMAL ENERGY STORAGE FOR SPACE POWER
HAMID TORAB (Gannon University, Erie, PA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0883-6272), vol. 8, no. 4, 1989, p. 415-423. refs
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This paper considers the problem of optimization of high-temperature thermal energy storage (TES) in space, using encapsulated phase-change material (PCM). The PCM considered is lithium hydride, with Li assumed to be the heat transport fluid. A total orbit time of 6000 sec is assumed with a sprint period of 600 sec. The goal of the optimization is to minimize the volume of the TES for a given operating condition. A one-dimensional model, based on the constant-temperature approach, is used to calculate the temperature distribution of the fluid and the PCM. This temperautre distribution (and, therefore, the total energy in the TES) is influenced by the particle size and relative dimensions of the TES. Optimal design variables can be chosen, depending on the design constraints, to maximize the energy density in the TES. I.S.

A90-27707
ADVANCED CONCEPTS FOR LATENT THERMAL ENERGY STORAGE FOR SOLAR DYNAMIC RECEIVERS
KOTARO TANAKA, YOSHIYUKI ABE, KATSUHIKO KANARI, OSAMI NOMURA, and MASAYUKI KAMIMOTO (Electrotechnical Laboratory, Tsukuba, Japan) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0883-6272), *vol. 8, no. 4, 1989, p. 425-434. refs*
(IAF PAPER ICOSP89-3-4) Copyright

The present paper discusses latent thermal energy storage (LTES) systems designed for a closed Brayton cycle dynamic power generator. Two new LTES concepts are proposed. The first is the addition of volumetrically variable fins which remain unwetted by the phase change materials (PCM). The use of such fins can reduce mechanical stress on the containment walls. The second is encapsulation of the PCM within a submicron-sized porous ceramic structure. Considerable weight reduction can be achieved by introducing such ceramic-PCM composite systems. A thermal and stress analysis on melting and solidification has been performed. In addition, results are covered from an experiment on void formation and from preliminary cyclic performance tests on receiver LTES components. Author

A90-27708
ADVANCED NICKEL-HYDROGEN BATTERIES
DAVID F. PICKETT (Hughes Aircraft Co., El Segundo, CA) (IAF, International Conference on Space Power, Cleveland, OH, June 5-7, 1989) Space Power (ISSN 0883-6272), vol. 8, no. 4, 1989, p. 435-441. refs
(IAF PAPER ICOSP89-3-6) Copyright

The nickel-hydrogen battery is the secondary power source of choice for almost all satellite systems within the USA. This paper discusses the state-of-the-art and recent advances in the nickel-hydrogen cell technology. Comparisons are presented between nickel-hydrogen cell technology and other technologies in competition with nickel-hydrogen batteries for spacecraft energy storage, such as regenerative-fuel cell systems, sodium-sulfur batteries, and nickel-cadmium batteries. Nickel-hydrogen batteries are scheduled for a LEO launch on the Hubble Space Telescope and on Space Station in the 1990s. There are a number of improvements in the nickel-hydrogen cell which indicate that its current LEO cycle life performance can be exended by five times and its specific energy in GEO can be doubled or tripled. I.S.

N90-10140*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SECOND BEAMED SPACE-POWER WORKSHOP
RUSSELL J. DEYOUNG, ed. Washington Jul. 1989 439 p Workshop held in Hampton, VA, 28 Feb. - 2 Mar. 1989
(NASA-CP-3037; L-16590; NAS 1.55:3037) Avail: NTIS HC A19/MF A03 CSCL 10/2

Potential missions for microwave and laser power beaming in space are discussed. Power beaming options, millimeter wave technology, laser technology, lunar bases, spacecraft propulsion, and near-Earth applications are covered.

N90-10154*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OVERVIEW OF LASER CONCEPTS
EDMUND J. CONWAY *In its* Second Beamed Space-Power Workshop p 261-286 Jul. 1989
Avail: NTIS HC A19/MF A03 CSCL 20/5

The concepts of laser power-beaming applicable to advanced NASA missions are reviewed. The types of lasers, (the iodine lasers and the diode lasers) which are central to the laser miniworkshop presentations are discussed. Author

N90-10155*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
OVERVIEW OF MICROWAVE CONCEPTS
KARL A. FAYMON *In* NASA. Langley Research Center, Second Beamed Space-Power Workshop p 287-290 Jul. 1989
Avail: NTIS HC A19/MF A03 CSCL 20/14

An overview of microwave beamed power concepts is given in outline form. Concepts such as power transmission to operational satellites, spacecraft propulsion, lunar/planetary outpost power and planetary rover propulsion are listed in chart form and characterized in columns titled power level, benefits, and comments. Author

N90-10165*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MICROWAVE BEAM POWER
KARL A. FAYMON *In* NASA. Langley Research Center, Second Beamed Space-Power Workshop p 397-403 Jul. 1989
Avail: NTIS HC A19/MF A03 CSCL 10/2

Information on microwave beam power is given in viewgraph form. Information is given on orbit transfer proulsion applications, costs of delivering 100 kWe of usable power, and costs of delivering a 1 kg payload into orbit. Author

N90-10166*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CENTRAL ELECTRICAL UTILITY POWER FOR A SATELLITE RING CITY IN LOW EARTH ORBIT SPACE
IRA T. MYERS, KARL A. FAYMON, and A. D. PATTON (Texas A&M Univ., College Station.) *In* NASA. Langley Research Center, Second Beamed Space-Power Workshop p 409-418 Jul. 1989
Avail: NTIS HC A19/MF A03 CSCL 10/3

Information is given in viewgraph form on central electrical power for a satellite ring city, defined as a group of large free flyers of 10 to 20 units with perhaps 100 people in each unit, and organized in a circle so that power can be fed from a central location. The free flyers would be located at 300 to 700 miles in altitude, and spaced about a kilometer apart. Potential activities of a ring city are listed as well as the electrical power needs. Information is given on costs and individual and centralized solar arrays and nuclear reactor systems. Author

N90-10167*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
BEAMED LASER POWER IN SUPPORT OF NEAR-EARTH MISSIONS
EDMUND J. CONWAY, GREGORY L. SCHUSTER, WILLARD WEAVER, and DONALD H. HUMES *In its* Second Beamed Space-Power Workshop p 419-429 Jul. 1989
Avail: NTIS HC A19/MF A03 CSCL 20/5

It was found that solar-pumped laser-beamed power is lighter than photovoltaic for power requirements of 150 KWe and above, and is competitive with combined photovoltaic/solar-dynamic over the entire power range investigated. A space station supported by laser-beamed power can be a lower-g facility (reduced drag) than with PV or PV + SD power; has greater freedom of orientation (small receiver moves rather than large arrays or concentrators); and requires less structure (arrays, alpha joints, booms) permitting easier control and fewer vibrational modes. Laser power beaming offers a revolutionary concept for planning designing, and powering large orbiting spacecraft. Author

N90-10173# Sandia National Labs., Albuquerque, NM.
CIRCUIT LEVEL MODELING OF INDUCTIVE ELEMENTS
G. P. MUYSHONDT and W. M. PORTNOY (Texas Technological Univ., Lubbock.) 1989 5 p Presented at the 24th Intersociety Energy Conversion Engineering Conference, Washington, DC, 6-11 Aug. 1989
(Contract DE-AC04-76DP-00789)
(DE89-015122; SAND-89-1625C; CONF-890815-18) Avail: NTIS HC A01/MF A01

Design and analysis of spacecraft power systems have been difficult to perform because of the lack of circuit level models for nonlinear inductive elements. This paper reviews some of the models which have been proposed, their limitations, and applications. An improved saturation dependent model will be described. The model has been implemented in SPICE and with a commercial circuit program and demonstrated to be satisfactory in both implementations. DOE

N90-10174*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A FEASIBILITY ASSESSMENT OF INSTALLATION, OPERATION AND DISPOSAL OPTIONS FOR NUCLEAR REACTOR POWER SYSTEM CONCEPTS FOR A NASA GROWTH SPACE STATION
HARVEY S. BLOOMFIELD and JACK A. HELLER Jun. 1987 37 p
(NASA-TM-89923; E-3622; NAS 1.15:89923) Avail: NTIS HC A03/MF A01 CSCL 21/8

A preliminary feasibility assessment of the integration of reactor power system concepts with a projected growth space station architecture was conducted to address a variety of installation, operational disposition, and safety issues. A previous NASA sponsored study, which showed the advantages of space station - attached concepts, served as the basis for this study. A study methodology was defined and implemented to assess compatible combinations of reactor power installation concepts, disposal destinations, and propulsion methods. Three installation concepts that met a set of integration criteria were characterized from a configuration and operational viewpoint, with end-of-life disposal mass identified. Disposal destinations that met current aerospace nuclear safety criteria were identified and characterized from an operational and energy requirements viewpoint, with delta-V energy requirement as a key parameter. Chemical propulsion methods that met current and near-term application criteria were identified and payload mass and delta-V capabilities were characterized. These capabilities were matched against concept disposal mass and destination delta-V requirements to provide the feasibility of each combination. Author

N90-11804*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE FUEL CELL IN SPACE: YESTERDAY, TODAY AND TOMORROW
MARVIN WARSHAY and PAUL R. PROKOPIUS Sep. 1989 11 p Presented at the Grove Anniversary (1839-1989) Fuel Cell Symposium, London, England, 18-21 Sep. 1989; sponsored in part by the Royal Institution
(NASA-TM-102366; E-5084; NAS 1.15:102366) Avail: NTIS HC A03/MF A01 CSCL 10/2

The past, present, and future of space fuel cell power systems is reviewed, starting with the first practical fuel cell by F.T. Bacon which led to the 1.5 kW Apollo alkaline fuel cell. However, the first fuel cell to be used for space power was the Gemini 1.0 kW Acid IEM fuel cell. The successor to the Apollo fuel cell is today's 12 kW Orbiter alkaline fuel cell whose technology is considerably different and considerably better than that of its ancestor, the Bacon cell. And in terms of specific weight there has been a steady improvement from the past to the present, from the close to 200 lb/kW of Apollo to the 20 lb/kW of the orbiter. For NASA future Lunar and Martian surface power requirements the regenerative fuel cell (RFC) energy storage system is enabling technology, with the alkaline and the PEM the leading RFC candidate systems. The U.S. Air Force continues to support fuel cell high power density technology development for its future short duration applications. Author

N90-12653 Virginia Polytechnic Inst. and State Univ., Blacksburg.
ANALYSIS AND SIMULATION OF DYNAMICS OF SPACECRAFT POWER SYSTEMS Ph.D. Thesis
JAE RYONG LEE 1988 219 p
Avail: Univ. Microfilms Order No. DA8907514

Comprehensive analyses, including dc, small-signal, and large-signal analyses, of the dynamics of various spacecraft power systems were performed. Systems dynamics are analyzed for various operating modes, such as the shunt, battery-charge and battery discharge modes, as well as the transition mode. Computer models using the EASY5 program were developed for the Direct Energy Transfer (DET) system, solar array switching system, and partial shunt system to facilitate design, analysis, and performance verification. Large-signal analyses were performed to identify stability conditions and to predict large-signal dynamic behavior for each mode of operation. Small-signal analyses of the DET system were performed for the three modes of operation. Various spacecraft power systems, such as solar array switching systems, a partial shunt system, a peak power tracking system, and the Cosmic Background Explorer (COBE) power system were analyzed and simulated. Design guidelines of the power conditioning equipment for each system were provided. Dissert. Abstr.

N90-12654*# Tennessee Univ. Space Inst., Tullahoma.
THE FAULT MONITORING AND DIAGNOSIS KNOWLEDGE-BASED SYSTEM FOR SPACE POWER SYSTEMS: AMPERES, PHASE 1 Final Report
S. C. LEE Nov. 1989 44 p
(Contract NAG8-721)
(NASA-CR-185486; NAS 1.26:185486) Avail: NTIS HC A03/MF A01 CSCL 10/2

The objective is to develop a real time fault monitoring and diagnosis knowledge-based system (KBS) for space power systems which can save costly operational manpower and can achieve more reliable space power system operation. The proposed KBS was developed using the Autonomously Managed Power System (AMPS) test facility currently installed at NASA Marshall Space Flight Center (MSFC), but the basic approach taken for this project could be applicable for other space power systems. The proposed KBS is entitled Autonomously Managed Power-System Extendible Real-time Expert System (AMPERES). In Phase 1 the emphasis was put on the design of the overall KBS, the identification of the basic research required, the initial performance of the research, and the development of a prototype KBS. In Phase 2, emphasis is put on the completion of the research initiated in Phase 1, and the enhancement of the prototype KBS developed in Phase 1. This enhancement is intended to achieve a working real time KBS incorporated with the NASA space power system test facilities. Three major research areas were identified and progress was made in each area. These areas are real time data acquisition and its supporting data structure; sensor value validations; development of inference scheme for effective fault monitoring and diagnosis, and its supporting knowledge representation scheme. Author

N90-12850# Mission Research Corp., Albuquerque, NM.
AIRBORNE/SPACEBORNE PULSED POWER SOURCE Final Report, 15 Aug. 1988 - 14 Apr. 1989
GEORGE Z. HUTCHESON Aug. 1989 85 p
(Contract F33615-88-C-2855)
(AD-A211762; WRDC-TR-89-2120) Avail: NTIS HC A05/MF A01 CSCL 09/1

Mission Research Corporation (MRC) has completed a design study for a compact lightweight pulsed power source for airborne and spaceborne applications. Two designs were developed during the contract. Both design were constrained to -500 kV output pluses, 10 Hz repetition rates, and 2 ft. diameters. The designs utilized high voltage pulse-forming networks and (PFN) composed of liquid capacitors and air-core inductors. Dual resonance spiral strip transformers were incorporated into the designs for charging the PFNs from lower voltage capacitor banks. A mixture of water and ethylene glycol was used in the capacitor designs in order that the operating temperatures (-45 C to +110 C) of the designs could be extended beyond that of pure water. A pulser built from the final design would be capable of nominally producing -500 kV, 100 ns, 10 ohms pulses (i.e., 3 kJ). Such a pulser would be 10.9 ft. long (without prime power, power conditioning, and load) and would weigh 1300 lbs (with power conditioning but without prime power and load). The design has the unique advantage of being mechanically tunable to any desired pulse length (100 ns to 500 ns) or impedance (10 ohms to 50 ohms) as long as the output energy of the pulser is not changed from 3 kJ. GRA

N90-13515# European Space Agency, Paris (France).
POWER GENERATION AND DISTRIBUTION
H. K. FIEBRICH *In its* The Hipparcos Mission. Prelaunch Status. Volume 1: The Hipparcos Satellite p 147-164 Jun. 1989

Copyright Avail: NTIS HC A16/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The three subsystems involved in the generation and distribution of electrical power of the Hipparcos mission, are presented. The mechanical and electrical properties of the solar generator subsystem are summarized. The operational concept of the electrical power subsystem, which provides 50V main direct current bus to all satellite power users, is detailed. The spacecraft harness subsystem, which provides all the electrical connections for all electrical units of the payload, is described. Moreover, the following topics are included: the shint regulator unit, the batteries, the batteries unit control and discharge regulator, the electrical integration unit, the auxiliary power supply, and the pyrotechnic relay unit. ESA

N90-13581*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

THE SPACE STATION PHOTOVOLTAIC PANELS PLASMA INTERACTION TEST PROGRAM: TEST PLAN AND RESULTS

HENRY K. NAHRA, MARIAN C. FELDER, BERNARD L. SATER, and JOHN V. STASKUS 1989 11 p Presented at the 28th Aerospace Sciences Meeting, Reno, NV, 8-11 Jan. 1990; sponsored by AIAA

(NASA-TM-102474; E-5261; NAS 1.15:102474; AIAA-90-0722) Avail: NTIS HC A03/MF A01 CSCL 22/2

The Plasma Interaction Test performed on two space station solar array panels is addressed. This includes a discussion of the test requirements, test plan, experimental set-up, and test results. It was found that parasitic current collection was insignificant (0.3 percent of the solar array delivered power). The measured arcing threshold ranged from -210 to -457 V with respect to the plasma potential. Furthermore, the dynamic response of the panels showed the panel time constant to range between 1 and 5 microsec, and the panel capacitance to be between .01 and .02 microF. Author

N90-13596*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

THE US SPACE STATION AND ITS ELECTRIC POWER SYSTEM

RONALD L. THOMAS 1988 26 p Presented at the 10th South Pacific Electrical International Convention, Brisbane, Australia, 2-5 May 1988; sponsored by the Electrical Development Association of Queensland, Inc.

(NASA-TM-101974; E-4674; NAS 1.15:101974) Avail: NTIS HC A03/MF A01 CSCL 10/2

The United States has embarked on a major development program to have a space station operating in low earth orbit by the mid-1990s. This endeavor draws on the talents of NASA and most of the aerospace firms in the U.S. Plans are being pursued to include the participation of Canada, Japan, and the European Space Agency in the space station. From the start of the program these was a focus on the utilization of the space station for science, technology, and commercial endeavors. These requirements were utilized in the design of the station and manifest themselves in: pressurized volume; crew time; power availability and level of power; external payload accommodations; microgravity levels; servicing facilities; and the ability to grow and evolve the space station to meet future needs. President Reagan directed NASA to develop a permanently manned space station in his 1984 State of the Union message. Since then the definition phase was completed and the development phase initiated. A major subsystem of the space station is its 75 kW electric power system. The electric power system has characteristics similar to those of terrestrial power systems. Routine maintenance and replacement of failed equipment must be accomplished safely and easily and in a minimum time while providing reliable power to users. Because of the very high value placed on crew time it is essential that the power system operate in an autonomous mode to minimize crew time required. The power system design must also easily accommodate growth as the power demands by users are expected to grow. An overview of the U.S. space station is provided with special emphasis on its electrical power system. Author

N90-14060*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

MODELING OF POWER ELECTRONIC SYSTEMS WITH EMTP

KWA-SUR TAM (Virginia Polytechnic Inst. and State Univ., Blacksburg.) and NARAYAN V. DRAVID Dec. 1989 10 p

(NASA-TM-102375; E-5109; NAS 1.15:102375) Avail: NTIS HC A02/MF A01 CSCL 12/2

In view of the potential impact of power electronics on power systems, there is need for a computer modeling/analysis tool to perform simulation studies on power systems with power electronic components as well as to educate engineering students about such systems. The modeling of the major power electronic components of the NASA Space Station Freedom Electric Power System is described along with ElectroMagnetic Transients Program (EMTP) and it is demonstrated that EMTP can serve as a very useful tool for teaching, design, analysis, and research in the area of power systems with power electronic components. EMTP modeling of power electronic circuits is described and simulation results are presented. Author

N90-14279*# Toledo Univ., OH. Dept. of Electrical Engineering.

ELECTRICAL PERFORMANCE CHARACTERISTICS OF HIGH POWER CONVERTERS FOR SPACE POWER APPLICATIONS Final Report, 1 Jan. 1988 - 30 Sep. 1989

THOMAS A. STUART and ROGER J. KING Sep. 1989 149 p (Contract NAG3-708)

(NASA-CR-185947; NAS 1.26:185947) Avail: NTIS HC A07/MF A01 CSCL 10/2

The first goal of this project was to investigate various converters that would be suitable for processing electric power derived from a nuclear reactor. The implementation is indicated of a 20 kHz system that includes a source converter, a ballast converter, and a fixed frequency converter for generating the 20 kHz output. This system can be converted to dc simply by removing the fixed frequency converter. This present study emphasized the design and testing of the source and ballast converters. A push-pull current-fed (PPCF) design was selected for the source converter, and a 2.7 kW version of this was implemented using three 900 watt modules in parallel. The characteristic equation for two converters in parallel was derived, but this analysis did not yield any experimental methods for measuring relative stability. The three source modules were first tested individually and then in parallel as a 2.7 kW system. All tests proved to be satisfactory; the system was stable; efficiency and regulation were acceptable; and the system was fault tolerant. The design of a ballast-load converter, which was operated as a shunt regulator, was investigated. The proposed power circuit is suitable for use with BJTs because proportional base drive is easily implemented. A control circuit which minimizes switching frequency ripple and automatically bypasses a faulty shunt section was developed. A nonlinear state-space-averaged model of the shunt regulator was developed and shown to produce an accurate incremental (small-signal) dynamic model, even though the usual state-space-averaging assumptions were not met. The nonlinear model was also shown to be useful for large-signal dynamic simulation using PSpice. Author

N90-14281*# ENTECH Corp., Dallas-Fort Worth Airport, TX.

CONCEPTUAL DESIGN STUDY OF A 5 KILOWATT SOLAR DYNAMIC BRAYTON POWER SYSTEM USING A DOME FRESNEL LENS SOLAR CONCENTRATOR Final Report

MARK J. ONEILL, A. J. MCDANAL, and DON H. SPEARS Dec. 1989 48 p

(Contract NAS3-24877)

(NASA-CR-185134; NAS 1.26:185134) Avail: NTIS HC A03/MF A01 CSCL 10/2

The primary project objective was to generate a conceptual design for a nominal 5 kW solar dynamic space power system, which uses a unique, patented, transmittance-optimized, dome-shaped, point-focus Fresnel lens as the optical concentrator. Compared to reflective concentrators, the dome lens allows 200 times larger slope errors for the same image displacement.

Additionally, the dome lens allows the energy receiver, the power conversion unit (PCU), and the heat rejection radiator to be independently optimized in configuration and orientation, since none of these elements causes any aperture blockage. Based on optical and thermal trade studies, a 6.6 m diameter lens with a focal length of 7.2 m was selected. This lens should provide 87 percent net optical efficienty at 800X geometric concentration ratio. The large lens is comprised of 24 gores, which compactly stow together during launch, and automatically deploy on orbit. The total mass of the microglass lens panels, the graphite/epoxy support structure, and miscellaneous hardware is about 1.2 kg per square meter of aperture. The key problem for the dome lens approach relates to the selection of a space-durable lens material. For the first time, all-glass Fresnel lens samples were successfully made by a sol-gel casting process. Author

N90-14283*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A HEAT RECEIVER DESIGN FOR SOLAR DYNAMIC SPACE POWER SYSTEMS
KARL W. BAKER, MILES O. DUSTIN, and ROGER CRANE (University of South Florida, Tampa.) 1990 7 p Prepared for presentation at the 1990 International Solar Energy Conference, Miami, FL, 1-4 Apr. 1990; sponsored by ASME
(NASA-TM-102473; E-5253; NAS 1.15:102473) Avail: NTIS HC A02/MF A01 CSCL 10/2

An advanced heat pipe receiver designed for a solar dynamic space power system is described. The power system consists of a solar concentrator, solar heat receiver, Stirling heat engine, linear alternator and waste heat radiator. The solar concentrator focuses the sun's energy into a heat receiver. The engine and alternator convert a portion of this energy to electric power and the remaining heat is rejected by a waste heat radiator. Primary liquid metal heat pipes transport heat energy to the Stirling engine. Thermal energy storage allows this power system to operate during the shade portion of an orbit. Lithium fluoride/calcium fluoride eutectic is the thermal energy storage material. Thermal energy storage canisters are attached to the midsection of each heat pipe. The primary heat pipes pass through a secondary vapor cavity heat pipe near the engine and receiver interface. The secondary vapor cavity heat pipe serves three important functions. First, it smooths out hot spots in the solar cavity and provides even distribution of heat to the engine. Second, the event of a heat pipe failure, the secondary heat pipe cavity can efficiently transfer heat from other operating primary heat pipes to the engine heat exchanger of the defunct heat pipe. Third, the secondary heat pipe vapor cavity reduces temperature drops caused by heat flow into the engine. This unique design provides a high level of reliability and performance. Author

N90-14285*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ON PROTECTION OF FREEDOM'S SOLAR DYNAMIC RADIATOR FROM THE ORBITAL DEBRIS ENVIRONMENT. PART 1: PRELIMINARY ANALYSES AND TESTING
JENNIFER L. RHATIGAN, ERIC L. CHRISTIANSEN, and MICHAEL L. FLEMING (LTV Missiles and Electronics Group, Dallas, TX.) 1990 10 p Prepared for presentation at the International Solar Energy Conference, Miami, FL, 1-4 Apr. 1990; sponsored by ASME
(NASA-TM-102458; E-5245; NAS 1.15:102458) Avail: NTIS HC A02/MF A01 CSCL 10/2

A great deal of experimentation and analysis was performed to quantify penetration thresholds of components which will experience orbital debris impacts. Penetration was found to depend upon mission specific parameters such as orbital altitude, inclination, and orientation of the component; and upon component specific parameters such as material, density and the geometry particular to its shielding. Experimental results are highly dependent upon shield configuration and cannot be extrapolated with confidence to alternate shield configurations. Also, current experimental capabilities are limited to velocities which only approach the lower limit of predicted orbital debris velocities. Therefore, prediction of the penetrating particle size for a particular component having a complex geometry remains highly uncertain. An approach is described which was developed to assess on-orbit survivability of the solar dynamic radiator due to micrometeoroid and space debris impacts. Preliminary analyses are presented to quantify the solar dynamic radiator survivability, and include the type of particle and particle population expected to defeat the radiator bumpering (i.e., penetrate a fluid flow tube). Results of preliminary hypervelocity impact testing performed on radiator panel samples (in the 6 to 7 km/sec velocity range) are also presented. Plans for further analyses and testing are discussed. These efforts are expected to lead to a radiator design which will perform to requirements over the expected lifetime. Author

N90-14678*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TECHNOLOGY DEVELOPMENT PROGRAM FOR AN ADVANCED MICROSHEET GLASS CONCENTRATOR
SCOTT W. RICHTER (Sverdrup Technology, Inc., Cleveland, OH.) and DOVIE E. LACY 1990 8 p Prepared for presentation at the 1990 International Solar Energy Conference, Miami, FL, 1-4 Apr. 1990; sponsored in part by ASME
(NASA-TM-102406; E-5158; NAS 1.15:102406) Avail: NTIS HC A02/MF A01 CSCL 10/1

Solar Dynamic Space Power Systems are candidate electrical power generating systems for future NASA missions. One of the key components in a solar dynamic power system is the concentrator which collects the sun's energy and focuses it into a receiver. In 1985, the NASA Lewis Research Center initiated the Advanced Solar Dynamic Concentrator Program with funding from NASA's Office of Aeronautics and Space Technology (OAST). The objectives of the Advanced Concentrator Program is to develop the technology that will lead to lightweight, highly reflective, accurate, scaleable, and long lived (7 to 10 years) space solar dynamic concentrators. The Advanced Concentrator Program encompasses new and innovative concepts, fabrication techniques, materials selection, and simulated space environmental testing. The Advanced Microsheet Glass Concentrator Program, a reflector concept, that is currently being investigated both in-house and under contract is discussed. Author

N90-14897# Westinghouse Hanford Co., Richland, WA.
INTRODUCTORY TESTIMONY: HEARING ON NUCLEAR POWER IN SPACE
JOHN NOLAN Sep. 1989 61 p
(Contract DE-AC06-87RL-10930)
(DE90-001137; WHC-SA-0727) Avail: NTIS HC A04/MF A01

The uses of nuclear power in space are examined. Various systems are discussed and an outline of a slide presentation is given. The testing and safety of these programs is also briefly mentioned. DOE

N90-15126# Case Western Reserve Univ., Cleveland, OH. Dept. of Systems Engineering.
RELIABILITY ANALYSIS OF THE SPACE STATION FREEDOM ELECTRICAL POWER SYSTEM M.S. Thesis
MICHAEL C. TALBOTT Aug. 1989 158 p
(AD-A214105) Avail: NTIS HC A08/MF A01 CSCL 10/2

The on-board electrical power system of a space station has to provide the power needed for scientific missions (discretionary loads) and everyday station housekeeping chores (non-discretionary loads). Due to size constraints of the spacecraft, the electrical power system's output, efficiency and reliability will be constrained producing a system that is imperfect. This thesis applies traditional reliability techniques and modified methods to evaluate the reliability of the proposed NASA Space Station electrical power system. The modified methods take into account components and assemblies that have different levels of failure affecting the power output. These components and assemblies with failure levels other than all or nothing power outputs define each power output level between complete failure and expected nominal power. By applying this analysis approach to the proposed space station electrical power system in conjunction with some

reasonable assumptions, different levels of the electrical power output are identified along with the exceedance probability that each interval will occur at a specified time. GRA

N90-15840*# Little (Arthur D.), Inc., Cambridge, MA.
THE SOLAR POWER SATELLITE (SPS): PROGRESS SO FAR
PETER E. GLASER *In* NASA, Langley Research Center, Report of NASA Lunar Energy Enterprise Case Study Task Force p 68-83 Jul. 1989
Avail: NTIS HC A09/MF A02 CSCL 22/2

Major developments in key Solar Power Satellite (SPS)-related technologies are outlined and the significance of these developments are evaluated considering the SPS, both as an alternate energy option for use on Earth and as a potential stimulus for space infrastructure developments and expansion of the use of extraterrestrial resources. B.G.

N90-15995# Argonne National Lab., IL.
DYNAMICS ANALYSES OF SPACE POWER SYSTEMS USING THE SALT CODE
HOWARD K. GEYER, SAMIT K. BHATTACHARYYA, NELSON A. HANAN, and JULIE M. LIVINGSTON (Westinghouse Electric Corp., Pittsburgh, PA.) 1989 10 p Presented at the 7th Symposium on Space Nuclear Power Systems, Albuquerque, NM, 7-11 Jan. 1990
(Contract W-31-109-ENG-38)
(DE90-002274; CONF-900109-12) Avail: NTIS HC A02/MF A01

The dynamic behavior of large space power systems has been identified as a significant technical issue. To date several analyses of reactor kinetics have been reported in the literature, but there have been few (if any) studies of the dynamic response of the entire space power system. The problem is complex and required analytical methods are not generally available. Furthermore, given the conceptual state of current MMW space power systems designs, dynamic models of components are not generally available. The SALT code was used to perform preliminary analyses of the startup and shutdown transients of several proposed MMW system designs. A description is provided of the code methodology along with the results of the analyses performed for the NERVA derivative reactor (NDR) system. DOE

N90-16036# Argonne National Lab., IL. Materials and Components Technology Div.
THE ONSET OF BOILING OF THE LIQUID ALKALI METALS
ROBERT E. HOLTZ and PAUL A. LOTTES 1989 7 p Presented at the 7th Symposium on Space Nuclear Power Systems, Albuquerque, NM, 7-11 Jan. 1990
(Contract W-31-109-ENG-38)
(DE90-002276; CONF-900109-13) Avail: NTIS HC A02/MF A01

Studies pertinent to the liquid superheat required to initiate boiling and the subsequent behavior of the two phase fluid have been conducted for many years. Knowledge of the incipient boiling superheats is important because of the proposed use of liquid metals as reactor coolants, Rankine cycle working fluids, and heat rejection fluids in space energy conversion systems. Some of the parameters that have been postulated to influence the incipient boiling superheats and the subsequent two phase flow behavior of the alkali metals include the system pressure, the pressure-temperature-time history, heat flux, liquid purity, dissolved gas content, surface condition, nuclear radiation, heating method, length of time of operation (for example, aging), liquid velocity, and the approach to boiling. The prediction of incipient boiling superheats is complex, and the influence of some of these parameters needs additional clarification. DOE

N90-16496*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SCALING STUDY FOR SP-100 REACTOR TECHNOLOGY
A. C. MARSHALL (Sandia National Labs., Albuquerque, NM.) and B. MCKISSOCK 1989 8 p Presented at the 7th Symposium on Space Nuclear Power Systems, Albuquerque, NM, 7-11 Jan. 1990
(Contract DE-AC04-76DP-00789)
(NASA-TM-897140; NAS 1.15:897140; DE89-014967; SAND-89-1635C; CONF-900109-4) Avail: NTIS HC A02/MF A01 CSCL 18/9

Several ways were explored of extending SP-100 reactor technology to higher power levels. One approach was to use the reference SP-100 pin design and increase the fuel pin length and the number of fuel pins as needed to provide higher capability. The impact on scaling of a modified and advanced SP-100 reactor technology was also explored. Finally, the effect of using alternative power conversion subsystems, with SP-100 reactor technology was investigated. One of the principal concerns for any space based system is mass; consequently, this study focused on estimating reactor, shield, and total system mass. The RSMASS code (Marshall 1986) was used to estimate reactor and shield mass. Simple algorithms developed at NASA-Lewis were used to estimate the balance of system mass. Power ranges from 100 kWe to 10 MWe were explored assuming both one year and seven years of operation. Thermoelectric, Stirling, Rankine, and Brayton power conversion systems were investigated. The impact on safety, reliability, and other system attributes, caused by extending the technology to higher power levels, was also investigated. DOE

N90-17677*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PRELIMINARY EVALUATION OF SPACE STATION TRANSMISSION LINE IN A RING CONFIGURATION
MARY ELLEN ROTH Jan. 1990 7 p
(NASA-TM-102461; E-5248; NAS 1.15:102461) Avail: NTIS HC A02/MF A01 CSCL 10/2

The results of a preliminary evaluation of a space station type transmission line and commercial transmission lines in a ring configuration, are reported. In a ring configuration, each node has two paths for the return current of each wire. The additional path can create an unbalanced condition, where the magnetic fields created by the forward and return currents do not cancel. This evaluation was to quantify the effects of the unbalanced case upon the external fields. The transmission lines evaluated were standard commercial coaxial cables, RG59 and RG213, and a space station designed flat Litz transmission line. Each was evaluated in a balanced and unbalanced mode of operation. Currents and their harmonic content were recorded and compared. As expected, the harmonic content of the different current (I delta) was substantial for the unbalanced case as compared to the balanced case. For the balanced case, very little difference was noted among the various transmission lines evaluated. The evaluation is discussed, and the test circuit, the measurements, and the resulting data are described. Author

N90-17678# European Space Agency, Paris (France).
EUROPEAN SPACE POWER, VOLUME 1
JOCELYNE LANDEAU, ed. Aug. 1989 447 p Conference held in Madrid, Spain, 2-6 Oct. 1989; sponsored by ESA, Univ. Politecnica de Madrid, and Inst. Nacional de Tecnica Aeroespacial
(ESA-SP-294-VOL-1; ISSN-0379-6566; ETN-90-96194) Copyright Avail: NTIS HC A19/MF A03

Power systems for manned missions, power system equipment development modeling, and testing for a variety of space applications are discussed. Batteries and fuel cells, battery management, technology and testing techniques are described. Power electronics, modeling and analysis, and resonant and high voltage converters are discussed. The research and planning carried out by members of ESA in all of these areas is described. ESA

N90-17679# Allgemeine Elektrizitaets-Gesellschaft, Wedel (Germany, F.R.).
THE 120 VDC TEST BED FOR COLUMBUS POWER SYSTEM
MICHAEL KOSS and VOLKER LEISTEN *In* ESA, European Space Power, Volume 1 p 5-12 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

The results, objectives, and tasks of the test bed part of the Multiple Power Bus Management (MPBM) (bus voltage 120 voltage

direct current, VDC) program are described. Hardware configurations, equipment modularity, growth potential, performance characteristics, and test results are discussed. An improved method of impedance measurement is presented. A short comparison between the MPBM results and the actual needs of the Columbus program is presented. ESA

N90-17680# National Space Development Agency, Tokyo (Japan).
JAPANESE EXPERIMENT MODULE ELECTRICAL POWER SYSTEM
YASUKI KAWAMURA *In* ESA, European Space Power, Volume 1 p 13-17 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

The Japanese Experiment Module (JEM), an element of the Space Station, is described. The electrical power system is outlined. A 120 voltage direct current (VDC) power bus line is used. It will also be used on future Japanese Spacecraft. Power system management and control systems are described. The functions of JEM are verified by several different models including the power functional model, system architecture study, power confirming model and hardware models. Further study is proposed. ESA

N90-17681*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TOWARD AN ELECTRICAL POWER UTILITY FOR SPACE EXPLORATION
ROBERT W. BERCAW *In* ESA, European Space Power, Volume 1 p 19-22 Aug. 1989 Previously announced as N89-27704
Copyright Avail: NTIS HC A19/MF A03 CSCL 10/2

Future electrical power requirements for space exploration are discussed. Megawatts of power with enough reliability for multi-year missions and with enough flexibility to adapt to needs unanticipated at design time are some of the criteria which space power systems must be able to meet. The reasons for considering the power management and distribution in the various systems, from a total mission perspective rather than simply extrapolating current spacecraft design practice, are discussed. A utility approach to electric power integrating requirements from a broad selection of current development programs, with studies in which both space and terrestrial technologies are conceptually applied to exploration mission scenarios, is described. ESA

N90-17683# Societe Crouzet, Valence (France).
THE 120V 10A SSPC FOR THE COLUMBUS PROGRAMME
F. FACHINETTI and D. LEVINS (European Space Agency, Paris, France) *In* ESA, European Space Power, Volume 1 p 33-38 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

The Solid State Power Controller (SSPC) planned for incorporation into the power distribution network of Columbus is described. The SSPC switches the power line on and off, limits the output current in case of overload, and provides interfaces for easy use. The electrical design of the system is described. The design involves the use of thick film hybrid technology for the power sections and discrete parts for the rest of the electronics. A space qualified SSPC of less than 200 g mass is predicted. ESA

N90-17685# British Aerospace Public Ltd. Co., Bristol (England). Space Systems Div.
THE DESIGN AND PERFORMANCE OF A GENERAL PURPOSE 57 KILOWATT SOLAR ARRAY SIMULATOR FOR CURRENT AND FUTURE LARGE SPACECRAFT
K. M. REDFORD and A. B. WILLIAMS *In* ESA, European Space Power, Volume 1 p 45-51 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

The general purpose solar array power simulator is described. It provides a modular 57 kilowatt power source for ground testing of complete spacecraft or spacecraft power subsystems prior to launch. The equipment can provide power to shunt or series Array Switching Regulators (ASR), linear power subsystem regulators or battery charging regulators. Power is provided in array section modules of up to 1.5 kilowatts at 20 to 150 volts and 0 to 10 amps. The design, and performance characteristics of the completed simulator is described. ESA

N90-17686# Alcatel Espace, Toulouse (France).
THE COLUMBUS POWER SYSTEM SIMULATION PROGRAMME
J. VANDUIVENBODE and A. CAPEL *In* ESA, European Space Power, Volume 1 p 53-60 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

A simulation program used in integrating all the parameters involved in designing a space vehicle power system is described. The COLumbus MODel (COLMOD) program can evaluate a power system quickly by calculating the evolution of the battery charge, taking into account the influence of solar array characteristics, harness, power conditioning, and payload. The program calculates energy and mass balances. A menu interface designed to make the COLMOD program user friendly ensures direct feedback of simulation results to the user. ESA

N90-17687# Allgemeine Elektrizitaets-Gesellschaft, Wedel (Germany, F.R.).
NEW POWER SYSTEM MODELLING APPROACHES ON THE BASIS OF EQUIVALENT STATE VARIABLES
GERT EGGERS *In* ESA, European Space Power, Volume 1 p 61-70 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

A method is presented which models switched-mode dc-to-dc power stages by using equivalent state variables. Compact analytical expressions in terms of bilinear forms are derived for the principal transfer functions. Conclusions concentrate on non-minimum phase properties of the considered power stages which seriously affect their stability behavior. Procedures regarding topology extension are developed in order to circumvent non-minimum phase properties. ESA

N90-17695*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CHALLENGES FOR FUTURE SPACE POWER SYSTEMS
HENRY W. BRANDHORST, JR. *In* ESA, European Space Power, Volume 1 p 133-136 Aug. 1989 Previously announced as N89-25506
Copyright Avail: NTIS HC A19/MF A03 CSCL 10/2

Forecasts of space power needs are presented. The needs fall into three broad categories: survival, self-sufficiency, and industrialization. The cost of delivering payloads to orbital locations and from Low Earth Orbit (LEO) to Mars are determined. Future launch cost reductions are predicted. From these projections the performances necessary for future solar and nuclear space power options are identified. The availability of plentiful cost effective electric power and of low cost access to space are identified as crucial factors in the future extension of human presence in space. ESA

N90-17696# Aerospatiale, Cannes (France).
THE 25 KWE SPACEBORNE SOLAR DYNAMIC GENERATOR
F. ANDRIEUX and L. PELENC *In* ESA, European Space Power, Volume 1 p 137-142 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

Research is presented comparing photovoltaic, solar dynamic and nuclear electric power generating techniques. It is concluded that a solar dynamic system associated with thermal storage is competitive in terms of performance (20 percent global efficiency, 10 W/kg power to weight ratio) The system constituents, concentrator, receiver, storage, thermodynamic cycle, alternator and radiator are discussed. Design, performance and critical items are defined. The most critical aspects, which are the receiver and the thermal storage concept, are discussed in detail. ESA

N90-17697# Commissariat a l'Energie Atomique, Gif-sur-Yvette (France). Centre d'Etudes Nucleaires.
CNES-CEA COMPARATIVE EVALUATION STUDY OF VARIOUS CANDIDATE 20 KWE SPACE POWER SYSTEMS

F. CARRE, E. PROUST, and P. KEIRLE *In* ESA, European Space Power, Volume 1 p 143-149 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

A preliminary comparison study between radioisotopic, solar, and nuclear space power systems likely to supply 20 kWe in high earth orbit is presented. The criteria considered for this comparison include, launch safety, mass performance, operational reliability, integration with the launch vehicle, and estimated development and recurrent costs. The most promising candidates emerging from the study are the solar photovoltaic generator with AsGa cells and nickel/hydrogen batteries, and the nuclear power system. The major assets of the solar photovoltaic generator relate mainly to the absence of specific risk in case of launch abort and reentry into the atmosphere. The major advantages of the nuclear power system include autonomous operation, large scaling potential, and a recurrent cost estimated at 20 percent of that of an equivalent 20 kWe solar photovoltaic generator. ESA

N90-17701# *Ford Aerospace and Communications Corp., Palo* Alto, CA. Space Systems Div.
SPACE STATION FREEDOM ENERGY STORAGE SYSTEM DESIGN AND DEVELOPMENT
R. J. HAAS and C. W. KOEHLER *In* ESA, European Space Power, Volume 1 p 169-172 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

The NASA Space Station Freedom 75 kW energy storage system using nickel hydrogen (Ni-H2) batteries to provide electrical power during eclipse and peak load operation is described. The 81-Ah battery cells are designed for a five year life in low earth orbit (LEO) with a 35 depth-of-discharge. The batteries consist of 30 individual pressure vessel (IPV) cells enclosed in an orbital replaceable unit (ORU). The basic cell, battery and ORU design, development and production are described. The key system design issues include the mechanical and thermal interfaces for both the battery and the ORU assembly. Verification plans for the mission critical components such as the nickel electrode and Inconel 718 pressure vessel are discussed. ESA

N90-17707*# Los Alamos National Lab., NM. Advanced Engineering Technology Group.
ADVANCED SPACE POWER PEM FUEL CELL SYSTEMS
N. E. VANDERBORGH, J. HEDSTROM, and J. R. HUFF *In* ESA, European Space Power, Volume 1 p 211-216 Aug. 1989 Sponsored by NASA, Lewis Research Center and DOE, Morgantown, WV
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A model showing mass and heat transfer in proton exchange membrane (PEM) single cells is presented. For space applications, stack operation requiring combined water and thermal management is needed. Advanced hardware designs able to combine these two techniques are available. Test results are shown for membrane materials which can operate with sufficiently fast diffusive water transport to sustain current densities of 300 ma per square centimeter. Higher power density levels are predicted to require active water removal. ESA

N90-17709# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
EUROPEAN REGENERATIVE FUEL CELL TECHNOLOGY FOR SPACE USE
FRANCIS BARON, RALF PHILIPPI, and WERNER TILLMETZ (Dornier System G.m.b.H., Friedrichshafen, Germany, F.R.) *In its* European Space Power, Volume 1 p 221-226 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

The results of two studies within the framework of the European regenerative fuel cell system research program are presented. Four different technologies are considered: the immobile alkaline electrolyte system, the proton exchange membrane system, mixed systems with these solutions, and the mobile alkaline electrolyte system. A comparison of the different systems concerning their application in space is given. Emphasis is laid on the comparison of performance, efficiency and mass of the systems. The immobile alkaline electrolyte system is shown to present several advantages within those parameters. ESA

N90-17713# Commissariat a l'Energie Atomique, Grenoble (France). Centre d'Etudes Nucleaires.
SOLID POLYMER ELECTROLYTE WATER ELECTROLYSIS AS A MEAN OF ENERGY STORAGE FOR SPACE APPLICATIONS
P. MILLET, T. ALLEAU, P. MATHONNET, M. PINERI, and R. DURAND (Centre de Recherche en Electrochimie Minerale et en Genie des Procedes, Saint Martin-d'Heres, France) *In* ESA, European Space Power, Volume 1 p 245-249 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

Research in the development of a solid polymer electrolyte water electrolysis regenerative fuel cell system is presented. Results concerning the preparation of membrane-electrode assemblies are presented. Life tests performed on lab-scale samples show that the electrochemical performance can be maintained over 15,000 hours of continuous electrolysis without any problem. A filter-press type electrolyzer is designed and constructed. Electrochemical test results of the electrolyzer are presented. ESA

N90-17719# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
OPTIMIZED SENSIBLE HEAT STORAGE SYSTEMS FOR APPLICATION TO SOLAR DYNAMIC POWER GENERATION
W. J. DENNER, A. A. FRITZSCHE, and P. JANY *In* ESA, European Space Power, Volume 1 p 281-286 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

The transient behavior of a sensible heat storage system is investigated numerically. With a counterflow scheme and a matrix of BeO-spheres, a thermal efficiency of 98.5 percent and almost constant fluid outlet temperature during 85 percent of discharge time are obtained, proving the potential of this storage alternative for application to solar dynamic power generation in space. Some preliminary results of the overall system simulation, comprising the storage, induced transient behavior of turbine, radiator etc. indicate that the electrical power output can be kept constant within a few percent. ESA

N90-17720# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Stuttgart (Germany, F.R.). Inst. fuer Technische Thermodynamik.
DEVELOPMENT OF A HIGH TEMPERATURE STORAGE UNIT FOR INTEGRATION WITH SOLAR DYNAMIC SYSTEMS
H. J. STAEHLE and F. LINDNER *In* ESA, European Space Power, Volume 1 p 287-291 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

Lithium fluoride in its capacity as a suitable energy storage material is investigated. Energy is stored as latent heat by melting the LiF. The energy is later released during recrystallization of the salt. Drawbacks to this system are described. The high corrosivity in molten state may lead to container failure in long term use. In order to avoid destruction of canisters, a graphite container is developed as graphite is not wetted by liquid LiF and thus does not suffer any corrosion. In order to match the mechanical forces caused by the volume increase during melting, a channel-like internal structure is tested. The melt formed first can expand into these channels and no pressure is built up. The results of these tests are presented. ESA

N90-17734# *Pisa Univ. (Italy).* Inst. of Electricity.
VARIABLE STRUCTURE CONTROL SYSTEM APPLIED TO MULTILEVEL POWER CONDITIONING CONVERTERS
D. CASINI, M. MARCHESONI, and L. PUGLISI (Genoa Univ., Italy) *In* ESA, European Space Power, Volume 1 p 381-388 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

A control technique devised to obtain high dynamic responses from a multilevel power conditioning converter is presented. A variable structure system with sliding mode is followed, taking into account problems that may be encountered in space environments.

The analytical data provides general tools for ac power conditioning systems design. The control scheme, its mathematical analysis and digital simulation results relevant to a 115 V/400 Hz ac power system are presented and discussed. ESA

N90-17744# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
POWER CONDITIONING FOR ACTIVE ARRAY SAR ANTENNAS
W. SCHAEPER *In* ESA, European Space Power, Volume 1 p 457-461 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

A trade off between different overall concepts rather than circuit details, in designing active array SAR (synthetic aperture radar) antenna power conditioning and distribution subsystems, is presented. A hierarchically structured system employing ac distribution is shown to be favorable. Active antennas are shown to be failure tolerant to a certain extent. Special attention is paid to particular reliability aspects. Breadboard hardware is presented. A discussion of further improvement of pulse energy storage is included. ESA

N90-17748# European Space Agency, Paris (France).
EUROPEAN SPACE POWER, VOLUME 2
JOCELYNE LANDEAU, ed. Aug. 1989 352 p Conference held in Madrid, Spain, 2-6 Oct. 1989; sponsored by ESA, Univ. Politecnica de Madrid, and Inst. Nacional de Tecnica Aeroespacial
(ESA-SP-294-VOL-2; ISSN-0379-6566; ETN-90-96195) Copyright Avail: NTIS HC A16/MF A03

Solar cells are discussed both from a performance and a manufacturing stand point. Solar array simulations, design procedures and deployment are discussed. Solar array assembly technology, solar generators, manufacturing considerations, testing procedures and welding techniques are described. Performance optimization for all sorts of solar cell and solar array types are discussed.

ESA

N90-17759# Allgemeine Elektrizitaets-Gesellschaft, Wedel (Germany, F.R.).
APPLICATION OF GALLIUM ARSENIDE SOLAR CELL ARRAYS FOR LONG DURATION LOW EARTH ORBIT MISSIONS LIKE COLUMBUS
F. REISSMANN and M. BAUMGART (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne, Germany, F.R.) *In* ESA, European Space Power, Volume 2 p 545-548 Aug. 1989 Sponsored by Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt and BMFT
Copyright Avail: NTIS HC A16/MF A03

A comparison of low earth orbit area to power and power to mass figures for GaAs, Si and Si-bifacial solar generators is presented. It is shown that the use of GaAs solar cells leads to a significant increase in power to area ratio. This is due to the low temperature sensitivity of the GaAs cells and lower particle degradation characteristics. First module experience with ultrasonic welding of GaAs solar cells shows good results. The development of the module technology, in the context of the German national GaAs module technology development contract, is discussed.

ESA

N90-17764# Fokker B.V., Amsterdam (Netherlands). Solar Array Mechanism Group.
SOLAR ARRAY DESIGNS FOR COLUMBUS ELEMENTS
HENK J. CRUIJSSEN *In* ESA, European Space Power, Volume 2 p 573-584 Aug. 1989
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Four possible solar array subsystem concepts for the Columbus elements are presented. The solar array sub-system requirements are different between the polar platform and the free flying laboratory. A maximum design commonality is achieved with the flat-pack solar array. This design can be used with small modifications for the Columbus polar platform option A or B and the Columbus free flying laboratory. Details of the solar arrays used in each of these instances are provided. ESA

N90-17767# Aerospatiale, Cannes (France).
THE ISO SOLAR GENERATOR: SOLAR CELLS AND OSR MIXED
J. C. CHIARINI *In* ESA, European Space Power, Volume 2 p 597-600 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03 CSCL 04/64

The solar generator system of the Infrared Space Observatory (ISO) is described. The solar protection system, which increases the whole system reliability, does away with a deployable structure and offers cost and mass-saving advantages, is described. The design of the solar array, made up of aluminum skins and honeycomb core panels linked to the spacecraft via a glass fiber truss, is described. The silicon solar cells mixed with MgF2-coated Optical Solar Reflectors (OSRs) are described. ESA

N90-17768# Allgemeine Elektrizitaets-Gesellschaft, Wedel (Germany, F.R.).
DESIGN DEVELOPMENT AND QUALIFICATION OF A SOLAR ARRAY WITH OSRS (SSM) BONDED TO THE ISO SPACECRAFT RIGID SUNSHIELD
J. SCHMIDT-ZURBORG and B. WODKE *In* ESA, European Space Power, Volume 2 p 601-606 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

The solar array system of the Infrared Space Observatory (ISO) is described. Solar cells and Optical Solar Reflectors (OSRs) cover the sunshield which protects the cryogenic system of the telescope from direct illumination. The sunshield, separated into two parts creating a 150 degrees dihedral, is described. A 30C seasonal variation in solar array temperature results in a wide variation in power output. Ways in which this fluctuation power output are compensated for are described. Power profile optimization techniques are outlined. ESA

N90-17771# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
DEVELOPMENT OF AN ALUMINIUM SOLAR CELL INTERCONNECTOR TECHNOLOGY
J. C. LARUE and UWE HOFFMANN (Allgemeine Elektrizitaets-Gesellschaft, Wedel, Germany, F.R.) *In its* European Space Power, Volume 2 p 617-621 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

A space solar cell interconnection technique based on the ultrasonic welding of aluminum alloy foil interconnectors is described. The technique provides protection against atomic oxygen erosion and significant weight reduction. In the present state of development, it could be considered for assembly of 2 cm by 4 cm cells on solar arrays used on five year low earth orbit missions. Metallurgical improvement work in progress to increase the fatigue lifetime and to adapt it to the assembly of larger solar cells is described. ESA

N90-17788# Sharp Corp., Nara (Japan).
CIC TYPE THIN DIODE FOR SOLAR ARRAY
K. KAMIMURA, Y. TONOMURA, H. YOSHIOKA, Y. UCHIDA, Y. KIYOTA, T. MATSUTANI, A. SUZUKI, S. IKEGAMI, H. ARAI, K. MURATA (Nippon Electric Co. Ltd., Kanagawa, Japan) et al. *In* ESA, European Space Power, Volume 2 p 721-726 Aug. 1989 Sponsored by the New Energy and Industrial Technology Development Organization
Copyright Avail: NTIS HC A16/MF A03

A thin diode, which has a similar shape to Connector Integrated solar Cells (CIC) is described. The diode consists of a 100 micron thick n type silicon diode chip, a gold plated silver interconnector, and a 1000 micron thick optical solar reflector. The diode has good electrical characteristics. It has low forward voltage, low reverse current, and high breakdown voltage. Results of evaluation tests of its reliability for space applications are presented. ESA

N90-17796# Allgemeine Elektrizitaets-Gesellschaft, Wedel (Germany, F.R.).
DESIGN DEVELOPMENT, QUALIFICATION, AND FLIGHT PRODUCTION OF AN ATOX RESISTANT FLEXIBLE SOLAR ARRAY FOR LOW EARTH ORBIT MISSION
D. POECK *In* ESA, European Space Power, Volume 2 p 771-774 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

The space telescope solar array is described. It features a double rollout array made up of two wings. Each of the wings contains two blankets. The ability of the array components to withstand the Atomic Oxygen (ATOX) environment and survive 30,000 thermal cycle fluctuations between -100 C to 100 C is discussed. The qualification procedures for the components are described. ESA

N90-17797*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE ADVANCED PHOTOVOLTAIC SOLAR ARRAY PROGRAM
R. M. KURLAND (TRW Space Technology Labs., Redondo Beach, CA.) and PAUL M. STELLA *In* ESA, European Space Power, Volume 2 p 775-781 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03 CSCL 10/2

The background and development status of an ultralightweight flexible-blanket flatpack, fold-out solar array is presented. It is scheduled for prototype demonstration in late 1989. The Advanced Photovoltaic Solar Array (APSA) design represents a critical intermediate milestone of the goal of 300 W/kg at beginning-of-life (BOL) with specific performance characteristics of 130 W/kg (BOL) and 100 W/kg at end-of-life (EOL) for a 10-year geosynchronous geostationary earth orbit 10-kW (BOL) space power system. The APSA wing design is scalable over a power range of 2 to 15 kW and is suitable for a full range of missions including Low Earth Orbit (LEO), orbital transfer from LEO to geostationary earth orbit and interplanetary flight. ESA

N90-17798# Tokyo Univ. (Japan).
THE SOLAR ARRAY OF JAPANESE SOLAR OBSERVATORY SATELLITE SOLAR-A
A. USHIROKAWA, J. ONODA, M. KOHBATA, Y. SHIBAYAMA, H. IRIKADO, and J. TAKAHASHI (Nippon Electric Co. Aerospace Systems Corp., Japan) *In* ESA, European Space Power, Volume 2 p 783-788 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

The solar array of the Solar-A solar observatory, to be launched in the Summer of 1991, is described. The solar array consists of two rigid deployable three-axis solar panels. The structure, mechanical design and analysis tests, that were involved in the development of these solar arrays, are described. Results of deployment tests, release tests, static load tests, and vibration tests are presented. ESA

N90-17799# Centre National d'Etudes Spatiales, Toulouse (France).
THE SOLAR ARRAY DESIGN OF THE VESTA SMALL BODIES SPACECRAFT
D. J. P. MOURA and E. RAPP *In* ESA, European Space Power, Volume 2 p 789-794 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

The solar array which is to equip the Vesta mission is described. Tests carried out to ensure that the solar array will be able to withstand the severe conditions to which it will be exposed during its deep space mission are described. Ninety-six solar cells from the array are submitted to the proton radiation, solar flux, and low temperatures of deep space conditions. Mechanical analysis of the honeycomb reinforcements of the carbon fiber skins is described. Thermal analysis of an aerodynamic deflector located on the upper edge of the panels to decrease the temperature of the solar arrays, is outlined. ESA

N90-17801# Tokyo Univ. (Japan). Inst. of Space and Astronautical Science.
OUTLINE OF HIGH VOLTAGE SOLAR ARRAY EXPERIMENT USING SFU PLATFORM
H. KUNINAKA, K. TAKAHASHI, M. NATORI, A. USHIROKAWA, K. KURIKI, K. MURATA, K. MATUI, H. ARAI, and S. IKEGAMI (Nippon Electric Co. Ltd., Yokohama, Japan) *In* ESA, European Space Power, Volume 2 p 803-808 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

Series connection between solar cells on a Space Flyer Unit (SFU) is used to generate high voltage power by a series parallel connection technique. Interference due to space plasma is shown to be severe for such a high voltage solar array. Ionospheric plasma interactions are studied numerically and experimentally based on a similarity law so as to find the plasma-induced force and the level of material degradation. A second two dimensional high voltage solar array experiment designed to determine the upper limit of the operational voltage in low earth orbit, is outlined. ESA

N90-17802# Physikalisch-Technische Studien G.m.b.H., Freiburg (Germany, F.R.).
SOLAR ARRAYS IN THE LEO-PLASMA ENVIRONMENT: A MODEL FOR LEAKAGE CURRENT PHENOMENA DEDUCED FROM EXPERIMENTAL AND THEORETICAL STUDIES
H. THIEMANN, ROBERT W. SCHUNK, and L. GERLACH (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, European Space Power, Volume 2 p 809-813 Aug. 1989
Copyright Avail: NTIS HC A16/MF A03

The interactions between high voltage solar arrays and Low Earth Orbit (LEO) plasma are described. It is shown that one of the main effects of plasma/solar array interactions is leakage current which can significantly reduce the power capacity of the solar arrays. Leakage current can lead to discharges and arcing, leading to material degradation and electrical power deficiencies. The leakage current effect is studied. A preliminary interaction model is developed. The model shows a large current surge during the voltage turn-on. ESA

N90-17803# Centre d'Etudes et de Recherches, Toulouse (France). Dept. d'Etudes et de Recherches Technologie Spatiale.
REVIEW OF SYNERGISTIC ENVIRONMENTAL INTERACTIONS: GUIDELINES FOR NEW TESTING APPROACHES ON FUTURE SOLAR ARRAYS
J. BERRY, L. LEVY, A. PAILLOUS, K. BOGUS, L. GERLACH, L. PELENC, and N. PCHALEK (Allgemeine Elektrizitaets-Gesellschaft, Wedel, Germany, F.R.) *In* ESA, European Space Power, Volume 2 p 815-821 Aug. 1989
(Contract ESTEC-7438/87)
Copyright Avail: NTIS HC A16/MF A03

The difficulties involved in accurately reproducing space environment conditions in simulation tests are discussed. Most existing test facilities test the effect of a single space environment component. The need for multifactor environment simulation facilities in order to effectively understand solar array failures that have occurred in orbit is stressed. Since no such multifactor test facilities are available, a review is presented of already available one component effect information. An extrapolation of this data towards a synergistic effects analysis is outlined. ESA

N90-18097*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CHANGES IN IMPEDANCE OF NI ELECTRODES UPON STANDING AND CYCLING
MARGARET A. REID 1989 16 p Presented at the 1989 Fall Meeting of the Electrochemical Society, Hollywood, FL, 15-20 Oct. 1989
(NASA-TM-102438; E-5207; NAS 1.15:102438) Avail: NTIS HC A03/MF A01 CSCL 10/1

Impedances of Ni electrodes vary with many factors including voltage, cycling, and manufacturer. However, results from Ni/H2 cells being tested for Space Station Freedom show that consistent

results are obtained within a group of cells from the same manufacturer if the cells are cycled and stored in the same manner. Impedance changes with storage and cycling are being investigated. Impedances are low in the fully charged state but rise abruptly by several orders of magnitude at a voltage corresponding to a very low state-of-charge. After standing for several months, this increase occurred at a higher voltage, consistent with an increase in structural order during storage which hinders diffusion of protons and reduces high rate capacity. Early measurements on the effects of cycling on Ni/H2 cells being tested for Space Station Freedom show differences between cells from different manufacturers. Author

N90-19373*# National Aeronautics and Space Administration. *Lewis Research Center, Cleveland, OH.*
HOT FILAMENT TECHNIQUE FOR MEASURING THE THERMAL CONDUCTIVITY OF MOLTEN LITHIUM FLUORIDE
DONALD A. JAWORSKE and WILLIAM D. PERRY (Auburn Univ., AL.) 1990 13 p Proposed for presentation at the AIChE Summer National Meeting Session on Space Power Systems Technology, San Diego, CA, 19-22 Aug. 1990; sponsored by *American Institute of Chemical Engineers*
(NASA-TM-102506; E-5308; NAS 1.15:102506) Avail: NTIS HC A03/MF A01 CSCL 11/3

Molten salts, such as lithium fluoride, are attractive candidates for thermal energy storage in solar dynamic space power systems because of their high latent heat of fusion. However, these same salts have poor thermal conductivities which inhibit the transfer of heat into the solid phase and out of the liquid phase. One concept for improving the thermal conductivity of the thermal energy storage system is to add a conductive filler material to the molten salt. High thermal conductivity pitch-based graphite fibers are being considered for this application. Although there is some information available on the thermal conductivity of lithium fluoride solid, there is very little information on lithium fluoride liquid, and no information on molten salt graphite fiber composites. This paper describes a hot filament technique for determining the thermal conductivity of molten salts. The hot filament technique was used to find the thermal conductivity of molten lithium fluoride at 930 C, and the thermal conductivity values ranged from 1.2 to 1.6 W/mK. These values are comparable to the slightly larger value of 5.0 W/mK for lithium fluoride solid. In addition, two molten salt graphite fiber composites were characterized with the hot filament technique and these results are also presented. Author

N90-19835# Argonne National Lab., IL.
ANALYSIS AND EVALUATION OF ZPPR (ZERO POWER PHYSICS REACTOR) CRITICAL EXPERIMENTS FOR A 100 KILOWATT-ELECTRIC SPACE REACTOR
HAROLD F. MCFARLANE, PETER J. COLLINS, STUART G. CARPENTER, DAVID N. OLSEN, DALE M. SMITH, ROBERT W. SCHAEFER, RICHARD A. DONCALS, SANDRA ANDRE, CHARLES A. PORTER, CHARLES L. COWAN (General Electric Co., San Jose, CA.) et al. 1990 14 p Presented at the International Conference on the Physics of Reactors: Operation, Design and Computation, Marseilles (France), 23-27 Apr. 1990
(Contract W-31-109-ENG-38; DE-AC03-868S-16006)
(DE90-005634; CONF-900418-4) Avail: NTIS HC A03/MF A01

ZPPR critical experiments were used for physics testing the reactor design of the SP-100, a 100-kW thermoelectric LMR that is being developed to provide electrical power for space applications. These tests validated all key physics characteristics of the design, including the ultimate safety in the event of a launch or re-entry accident. Both the experiments and the analysis required the use of techniques not previously applied to fast reactor designs. A few significant discrepancies between the experimental and calculated results leave opportunities for further optimization. An initial investigation was made into application of the ZPPR-20 results, along with those of other relevant integral data, to the SP-100 design. DOE

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ELECTRONIC SYSTEMS & EQUIPMENT

Design and operation of electrical equipment such as motors, switch gear, connectors and other fixtures.

A90-11672
FIBER OPTIC SWITCHES FOR MISSILE AND SPACE ENVIRONMENTS
J. R. SISK (SCI Technology, Inc., Huntsville, AL) and J. B. HADAWAY (Alabama, University, Huntsville) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 173-177. refs Copyright

As fiber optic systems are integrated into missile and space platforms, a growing need emerges for fiber optic switches capable of withstanding and operating in severe environments. Present commercial devices do not meet the stringent requirements for missile or space environments, nor are they always available in the required configuration. This paper explores some of the design considerations for a single-mode fiber optic crossbar switch for harsh environments. Some possible implementations of switching elements are described, and the design features of the chosen switch implementation are also described. Loss mechanisms for the switch are discussed, and test results are given for the selected design. Author

A90-25607#
ANALYSIS OF THE PUBLIC RECORD OF SPACECRAFT ANOMALIES
RAY SPERBER (Societe Europeenne des Satellites, Betzdorf, Luxemburg) IN: AIAA International Communication Satellite Systems Conference and Exhibit, 13th, Los Angeles, CA, Mar. 11-15, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 42-51. refs
(AIAA PAPER 90-0781) Copyright

The concept of using publicly available data and merging them into a single 'Public Record Spacecaft Anomaly Data Base' is explored. Anomaly classifications by subsystem and severity are discussed along with rankings, and anomalies are discussed as a function of mission time. The results suggest what 'classic' anomalies may be and also may indicate key areas for technical development to make future spacecraft more reliable. C.D.

A90-31355* National Aeronautics and Space Administration. *Goddard Space Flight Center, Greenbelt, MD.*
USABILITY TESTING AND REQUIREMENTS DERIVATION FOR EMU-COMPATIBLE ELECTRICAL CONNECTORS
RAY A. REAUX, THOMAS J. GRIFFIN (CTA, Inc., Rockville, MD), and RUTHAN LEWIS (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Human Factors Society, Annual Meeting, 33rd, Denver, CO, Oct. 16-20, 1989, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1989, p. 144-148. refs Copyright

On-orbit servicing of payloads is simplified when a spacecraft has been designed for serviceability. A key design criterion for a serviceable spaceraft is standardization of electrical connectors. This paper investigates the effects of extravehicular mobility unit (EMU) glove size, connector size, and connector type on usability of electrical connectors. An experiment was conducted exploring participants' ability to mate and demate connectors in an evacuated glovebox. Independent variables were two EMU glove-sizes, five connector size groups, and seven connector types. Significant differences in performance times and heart rate changes during mate and demate operations were found. Subjective assessments of connectors were collected from participants with a usability questionnaire. The data were used to derive design recommendations for a NASA-recommended EMU-compatible electrical connector. Author

N90-10175*# General Dynamics Corp., San Diego, CA. Space Systems Div.
BIDIRECTIONAL POWER CONVERTER CONTROL ELECTRONICS Final Report
J. W. MILDICE Nov. 1987 103 p
(Contract NAS3-23878)
(NASA-CR-175070; NAS 1.26:175070) Avail: NTIS HC A06/MF A01 CSCL 21/8

The object of this program was to design, build, test, and deliver a set of control electronics suitable for control of bidirectional resonant power processing equipment of the direct output type. The program is described, including the technical background, and results discussed. Even though the initial program tested only the logic outputs, the hardware was subsequently tested with high-power breadboard equipment, and in the testbed of NASA contract NAS3-24399. The completed equipment is now operating as part of the Space Station Power System Test Facility at NASA Lewis Research Center. Author

N90-11033# Rome Univ. (Italy). Dept. of Aerospace.
STUDY OF A GALLIUM ARSENIDE SOLAR CELL INTERCONNECTOR
R. S. CAPITANIO, M. MARCHETTI, and S. TIZZI *In* ESA, Spacecraft Structures and Mechanical Testing p 351-357 Jan. 1989 Sponsored by Fabrica Italiana Apparecchiature Radioelettriche S.p.A., Milan
Copyright Avail: NTIS HC A99/MF E06

Out-of-plane stress relief loop interconnectors and in-plane solutions are tested for a gallium arsenide solar cell. Stress distributions in interconnector loops are calculated using mathematical models and finite element methods. The importance of substrate choice is emphasized. Stresses induced in the interconnector loops by a carbon fiber composite sandwich are found to be substantially inferior (35 to 40 percent less) to those induced by an aluminum sandwich. A theoretical analysis of fatigue life is presented for the interconnector, which is subjected to up to 60,000 thermal cycles in a ten year lifetime in low earth orbit. ESA

N90-14865# California Univ., Berkeley. Lawrence Berkeley Lab. Energy Div.
SUPERCONDUCTING MAGNETS IN SPACE
MICHAEL A. GREEN Aug. 1989 8 p Presented at the Winter Annual Meeting of the American Society of Mechanical Engineers, San Francisco, CA, 10-15 Dec. 1989
(Contract DE-AC03-76SF-00098)
(DE90-002671; LBL-27745; CONF-891208-23) Avail: NTIS HC A02/MF A01

Applications for superconducting magnets in space include particle astrophysics detectors, semiconductor crystal growth, magnetic refrigerators to reach temperatures of a few millikelvin and magnetic energy storage. Superconducting magnets are well suited for use in space because they consume very little power, and superconductors can operate at current densities which are much higher than conventional conductors. The general requirements are presented for superconducting magnets in space. The selection of a cryogenic working fluid and the selection of superconductor for space magnets are discussed. A 260 mm warm bore 3 T solenoid and the ASTROMAG particle astrophysics experiment solenoid for the space station are presented as examples of superconducting magnetic technology for use in space. DOE

N90-15819# Sandia National Labs., Albuquerque, NM. Power System Electronics Div.
POWER SEMICONDUCTOR DEVICES FOR SPACE NUCLEAR POWER SYSTEMS
D. H. LOESCHER and WILLIAM R. DAWES, JR. 1989 6 p Presented at the 7th Symposium on Space Nuclear Power Systems, Albuquerque, NM, 7-11 Jan. 1990 Sponsored in part by Wright Research and Development Center, Wright-Patterson AFB, OH
(Contract DE-AC04-76DP-00789)
(DE90-001178; SAND-89-2374C; CONF-900109-9) Avail: NTIS HC A02/MF A01

Silicon power diodes, transistors, thyristors and other devices can be damaged by elevated temperatures, temperature cycling, and radiation. The vulnerability is discussed of devices that integrate bipolar and MOSFET (metal oxide semiconductor field effect transistor) devices onto a single chip. Such devices offer the advantages of good current carrying capability that is characteristic of bipolar structures and high impedance control nodes that are characteristic of MOSFET devices. Devices located near a space based fission power source will be subjected to high temperatures, temperature cycling, naturally occurring radiation, radiation from the reactor; and these devices may be subjected to radiation from or caused by weapons used to attack the power source. Damaging radiation includes electrons and protons trapped in naturally occurring radiation belts, electrons pumped into these belts as a result of nuclear explosions, cosmic rays, neutrons from the reactor, and high energy photons (gamma rays and x rays). DOE

N90-17724# Fabrica Italiana Apparecchiature Radioelettriche S.p.A., Milan.
THE 120V 20A PWM SWITCH FOR APPLICATIONS IN HIGH POWER DISTRIBUTION
V. BORELLI and W. NIMAL (Etudes Techniques et Constructions Aerospatiales, Charleroi, Belgium) *In* ESA, European Space Power, Volume 1 p 317-321 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

A 20A/120VDC (voltage direct current) PWM (Pulse Width Modulation) Solid State Power Controller (SSPC) developed under ESA contract to be used in the power distribution system of Columbus is described. The general characteristics are discussed and the project specification defined. The benefits of a PWM solution over a more conventional approach, for the specific application considered are presented. An introduction to the SSPC characteristics and a functional description are presented. ESA

N90-17725# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
MAGNETIC COUPLED CURRENT SENSING TECHNIQUES FOR SPACECRAFT POWER SYSTEMS
L. GHISLANZONI *In its* European Space Power, Volume 1 p 323-327 Aug. 1989
Copyright Avail: NTIS HC A19/MF A03

A simple technique suitable for current sensing in spacecraft power systems is described. A review of existing magnetic coupled current sensors is presented. An alternative approach which needs very simple electronics and yet equals the performances of more sophisticated devices is described. Problems overcome by the technique are described including the high impedance value, which for applications such as zero ripple dc/dc converters, must be as low as possible, and core losses that dramatically restrict the choice of available magnetic materials. ESA

N90-19234*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INDUCTION MOTOR CONTROL
IRVING G. HANSEN 1990 5 p Prepared for presentation at the National Aerospace and Electronics Conference, Dayton, Ohio, 21-25 May 1990; sponsored in part by the IEEE
(NASA-TM-102533; E-5342; NAS 1.15:102533) Avail: NTIS HC A01/MF A01 CSCL 21/5

Electromechanical actuators developed to date have commonly utilized permanent magnet (PM) synchronous motors. More recently switched reluctance (SR) motors have been advocated due to their robust characteristics. Implications of work which utilizes induction motors and advanced control techniques are discussed. When induction motors are operated from an energy source capable of controlling voltages and frequencies independently, drive characteristics are obtained which are superior to either PM or SR motors. By synthesizing the machine frequency from a high frequency carrier (nominally 20 kHz), high efficiencies, low distortion, and rapid torque response are available. At this time

multiple horsepower machine drives were demonstrated, and work is on-going to develop a 20 hp average, 40 hp peak class of aerospace actuators. This effort is based upon high frequency power distribution and management techniques developed by NASA for Space Station Freedom. Author

N90-19786# West Virginia Univ., Morgantown. Dept. of Mathematics.
PANCONNECTIVITY OF LOCALLY CONNECTED K(1,3)-FREE GRAPHS Final Technical Report, Nov. 1988 - Oct. 1989
CUN-QUAN ZHANG 15 Oct. 1989 29 p
(Contract AF-AFOSR-0068-89; AF PROJ. 2304)
(AD-A216548; AFOSR-89-1866TR) Avail: NTIS HC A03/MF A01
CSCL 12/2

A locally connected, K(1,3)-free graph is panconnected if and only if the graph is 3-connected. GRA

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DATA & COMMUNICATION SYSTEMS

Communication and data storage or retrieval systems. Includes control systems and also computer networks and software.

A90-10360
SOFTWARE SAFETY ISSUES FOR THE SPACE STATION FLIGHT TELEROBOTIC SERVICER
KAI-HSIUNG CHANG, JAMES H. CROSS, II, and R. STEVE DANNELLY (Auburn University, AL) IN: Space Station automation IV; Proceedings of the Meeting, Cambridge, MA, Nov. 7-9, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 80-85. refs
Copyright

The purpose of the Space Station Flight Telerobotic Servicer (FTS) is to assist the astronauts in assembly, maintenance, servicing, and inspection tasks on the Space Station and the Space Shuttle. The FTS safety requirement is not dependent only on the visible hardware components such as manipulators and hydraulic systems, but also on the underlying software which controls every action of the hardware components. An acceptable level of safety can only be reached by analyzing and implementing safety issues through the conceptualization, design, construction, and operation phases of the FTS. Three issues have been found critical in achieving software safety: software design philosophy, software operating modes and warning levels, and a safety subsystem software (Watchdog). C.E.

A90-10476
AIAA COMPUTERS IN AEROSPACE CONFERENCE, 7TH, MONTEREY, CA, OCT. 3-5, 1989, TECHNICAL PAPERS. PARTS 1 & 2
Conference sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. Pt. 1, 593 p.; pt. 2, 562 p. For individual items see A90-10477 to A90-10617.
Copyright

Various papers on computers in aerospace studies are presented. The general topics addressed include: real-time hardware/software issues, GaAs and RISC processor architectures, system software development, knowledge-based systems in aerospace applications, verification and validation of expert systems, spaceborne processor architecture, autonomous systems, configuration management, diagnostics and fault monitoring, signal processors, principles of software reuse, AI initiatives in the Air Force, architecture for telescience, intelligent tutoring systems, satellite architecture, Ada, software reuse tools, and intelligent maintenance aids. Also considered are: modeling and simulation environments, project and software management, advanced fault-tolerant computer architecture, spacecraft command and control, fault tolerance for software-intensive systems, system acquisition management, neural nets, crew-systems integration, model-based approaches to diagnostics, parallel processing applications, software requirements engineering, planning and scheduling, software safety, computer security, and real-time embedded AI systems. C.D.

A90-10499#
A METHODOLOGY FOR DESIGNING SPACECRAFT ONBOARD COMPUTING SYSTEMS
MOHAMMAD N. AHMAD (Pan Data Systems, Rockville, MD) and JOHN D. CARPINELLI (New Jersey Institute of Technology, Newark) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 189-199. refs
(AIAA PAPER 89-2986) Copyright

A generalized methodology for designing spacecraft onboard computer systems is described. The system design is understood to be a sequence of the following hierarchical layers: the dedicated processing layer, the application and support processing layer, and the communications processing layer. It is shown that each layer can be implemented independently by a distinct set of resources. Because of the present methodology, subcontractors have the freedom to implement and test hardware and software at their own facilities. K.K.

A90-10532*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
IMPROVING THE ON-BOARD COMPUTING CAPABILITY OF THE NASA MULTIMISSION MODULAR SPACECRAFT
BARBARA SCOTT (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 444-453.
(AIAA PAPER 89-3032) Copyright

This paper presents the development of onboard computing improvements for NASA's Multimission Modular Spacecraft. The first MMS spacecraft being enhanced by an additional flight computer is the Explorer Platform. The selection process for both the flight hardware (MIL-STD-1750A Co-Processor) and flight software (Ada high level language) are discussed, followed by the lessons learned during the last three years. Author

A90-10554*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON THE FEASIBILITY OF A SPACEBORNE FAULT-TOLERANT HYPERCUBE
DAVID A. RENNELS, FRANK P. MATHUR, SAVIO N. CHAU, and JOHN A. ROHR (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 634-644. refs
(AIAA PAPER 89-3065) Copyright

The feasibility of implementing a fault-tolerant hypercube architecture for space applications is discussed. Node-level architectures and designs are considered and a first-order reliability model is presented. It is shown how error recovery can be implemented using program rollback or roll-forward techniques. Shared memory augmentations to the message-passing structure can be used to get around the inefficiencies of multicomputers to provide efficient use of hardware to achieve the needed reliabilities while maintaining performance. K.K.

A90-10584*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SELECTIVE SIMULATION AND SELECTIVE SENSOR INTERPRETATION IN MONITORING
RICHARD J. DOYLE, DANIEL BERLEANT, LORETTA P. FALCONE, and USAMA M. FAYYAD (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5,

1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 859-870. refs
(AIAA PAPER 89-3101) Copyright

An approach to selective processing in monitoring is described. The approach is designed to provide informative feedback on whether a system is performing nominally in the current operating context without exceeding available resources for prediction and interpretation. At the center of the approach to selective sensor interpretation and simulation is a causal model of the system being monitored. The architecture of the monitoring system, called PREMON, is described as well as how causal models of physical systems are represented and simulated. K.K.

A90-10626*# Lockheed Missiles and Space Co., Houston, TX.
ADA COMPILER EVALUATION ON THE SPACE STATION FREEDOM SOFTWARE SUPPORT ENVIRONMENT PROJECT
D. L. BADAL (Lockheed Missiles and Space Co., Inc., Houston, TX) AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989. 10 p. refs
(Contract NAS9-17830)
(AIAA PAPER 89-3062) Copyright

This paper describes the work in progress to select the Ada compilers for the Space Station Freedom Program (SSFP) Software Support Environment (SSE) project. The purpose of the SSE Ada compiler evaluation team is to establish the criteria, test suites, and benchmarks to be used for evaluating Ada compilers for the mainframes, workstations, and the realtime target for flight- and ground-based computers. The combined efforts and cooperation of the customer, subcontractors, vendors, academia and SIGAda groups made it possible to acquire the necessary background information, benchmarks, test suites, and criteria used. Author

A90-10630#
AN APPROACH TO DATA SECURITY AND PRIVACY FOR THE SPACE STATION FREEDOM PROGRAM
ERIN Y. OMORI (McDonnell Douglas Space Systems Co., Space Station Div., Huntington Beach, CA) AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989. 8 p.
(AIAA PAPER 89-3134) Copyright

Computer and information system security for the Space Station protects valuable life, resources, and technology. Access to information will be permitted over an extensive geographic area, through space and ground communications, by multiple users of varying disciplines. The Space Station data security and privacy approach is designed to prevent unauthorized attempts to access, alter, modify or destroy data objects of varying sensitivity levels within the Space Station Information system (SSIS). The four types of security and privacy mechanisms (protection, detection, containment, and recovery) implemented at key SSIS locations provide a secure, cost-effective, and operationally supportive environment. Author

A90-11659
FIBER OPTIC SYSTEMS FOR MOBILE PLATFORMS II; PROCEEDINGS OF THE MEETING, BOSTON, MA, SEPT. 6, 7, 1988
NORRIS E. LEWIS, ED. (Litton Industries, Poly-Scientific Div., Blacksburg, VA) and EMERY L. MOORE, ED. (Litton Industries, Guidance and Control Systems Div., Woodland Hills, CA) Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 989), 1989, 220 p. For individual items see A90-11660 to A90-11675.
(SPIE-989) Copyright

The papers contained in this volume provide an overview of recent research and development efforts in the fiber optic systems for mobile platforms. The applications discussed include aircraft, shipboard, automotive, and spacecraft, launch, and missile systems. Papers are presented on the performance of linear fiber optic data buses, military applications of fiber optic tethered vehicle technology, fiber optic switches for missile and space environments, and fiber optic data networks and components for space station applications. V.L.

A90-11668
MACROBEND FIBER OPTIC TRANSDUCER FOR AEROSPACE APPLICATIONS
BRUCE JOHNSON, DAVE BRODEUR, TOM LINDSAY, and RANDY MORTON (Eldec Corp., Bothell, WA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 68-77. refs
(Contract DAAJ02-85-C-0050)
Copyright

Intensity modulation induced by macrobending in multimode optical fibers is presented as a transduction mechanism for analog position sensing in harsh aerospace environments. The macrobend sensor described herein is most suitable for short stroke applications where an intrinsic sensor is desired and only moderate linearity is required. Macrobend sensors are built and tested with intensity referencing and modal conditioning. The latter allow for sensor replacement without in situ calibration. The theory, design tradeoffs, and test results of generic intrinsic macrobend position sensors are presented. Author

A90-11670
SPACE PLATFORM INFORMATION DISTRIBUTION SYSTEM - A FIBER OPTIC LAN APPROACH
RICHARD D. STEWART (SCI Technology, Inc., Huntsville, AL) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 162-167.
Copyright

This paper describes a design concept for a distributed system that is modular and provides a means of transferring analog signals, synchronous or asynchronous digital data (either bit serial or byte serial), and discrete status/control information in any mix. Maximum flexibility is a key feature. The system will accommodate a broad spectrum of operators and communication assets (both audio and digital), data acquisition/control system (analog or digital), and interconnection between multiple processors and peripheral devices. The architecture and protocol will accommodate both cable or optical fiber. Connectivities are established without using a central controller or switch. Analog signals can be distributed from one user to any number of other analog users without reduction in signal quality. Also, data can be distributed from any data terminal device to any other data terminal device. The flexible design allows for a wide variety of functional and operator interface capabilities with minimum impact to the hardware. Author

A90-11671
KNOWLEDGE BASED FO-LAN DESIGN ENVIRONMENT FOR THE HEALTH MONITORING AND CONTROL OF SPACE SYSTEMS
A. CHOUDRY (Alabama, University, Huntsville) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 168-172. refs
Copyright

The advantages offered by fiber-optic local area networks (FO-LAN) in avionics for advanced aerospace systems are briefly reviewed, and a design environment for avionics FO-LAN is proposed. The approach is based on the use of a layered design matrix which includes system performance requirements, component performance specifications, cost, weight, power, and other critical parameters. As a trial, a layered matrix has been developed for multimode fiber-optic networks. It has been used for designing an FO-LAN based intelligent sensor testbed for a propulsion and avionics module. V.L.

A90-11673
FIBER OPTIC DATA NETWORKS AND COMPONENTS FOR SPACE STATION APPLICATIONS
MARK E. CURRAN and ALAN A. JOSEPH (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA,

Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 183-192. refs
Copyright

The functional requirements and architecture for the fiber optic systems being developed for the Space Station are discussed with emphasis on the design and environmental concerns unique to the Space Station. In particular, attention is given to the data management subsystem, the communications and tracking system, and fiber optic sensors. The discussion covers the general design and performance characteristics of the system components, the problems involved in their development, and reliability and cost effectiveness factors. V.L.

A90-11674* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SIMULATION AND ANALYSIS OF AN INTERMEDIATE FREQUENCY (IF) DISTRIBUTION SYSTEM WITH APPLICATIONS FOR SPACE STATION
THOMAS A. COSTELLO (NASA, Johnson Space Center, Houston, TX) and C. MAITE BRANDT (Lockheed Engineering and Sciences Co., Houston, TX) IN: Fiber optic systems for mobile platforms II; Proceedings of the Meeting, Boston, MA, Sept. 6, 7, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 193-200. refs
Copyright

Simulation and analysis results are described for a wideband fiber optic intermediate frequency distribution channel for a frequency division multiple access (FDMA) system where antenna equipment is remotely located from the signal processing equipment. The fiber optic distribution channel accommodates multiple signals received from a single antenna with differing power levels. Performance parameters addressed are intermodulation degradations, laser noise, and adjacent channel interference, as they impact the overall system design. Simulation results showed that the laser diode modulation level can be allowed to reach 100 percent without considerable degradation. The laser noise must be controlled as to provide a noise floor of less than -90 dBW/Hz. The fiber optic link increases the degradation due to power imbalance yet diminishes the effects of the transmit amplifier nonlinearity. Overall, optimal operation conditions can be found to yield a degradation level of about .1 dB caused by the fiber optic link. Author

A90-12182
THE PACKET SPACE COMMUNICATIONS - A REALITY
J. C. BONNET (Schlumberger Industries, Velizy-Villacoublay, France) IN: ETC '87 - European Telemetry Conference, Aix-en-Provence, France, June 22-25, 1987, Proceedings. Paris, Societe des Electriciens et des Electroniciens, 1987, p. 41-48. refs
Copyright

Packet space communications can contribute to meeting five essential needs of such programs as the Hermes Spaceplane, and the Eureca, Soho, and Cluster missions. These needs are: (1) compliance with the requests of the whole community of users, defining modular products at very low prices; (2) confidence in providing perfect data transmission whatever the link budget; (3) proposing to station operators a high degree of visibility on entirely automatic systems; (4) maintenance providing the means to build up self-testing capabilities; and (5) evolution, permitting, through the utilization of the OSI standard, the implementation of multiple modifications. B.J.

A90-13273*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
INTELLIGENT COMPUTATIONAL SYSTEMS FOR SPACE APPLICATIONS
HENRY LUM, JR. and SONIE LAU (NASA, Ames Research Center, Moffett Field, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-044) Copyright

The evolution of intelligent computation systems is discussed starting with the Spaceborne VHSIC Multiprocessor System (SVMS). The SVMS is a six-processor system designed to provide at least a 100-fold increase in both numeric and symbolic processing over the i386 uniprocessor. The significant system performance parameters necessary to achieve the performance increase are discussed. K.K.

A90-13680#
SATCAV - A SPACE SYSTEM LIFE CYCLE COST AND AVAILABILITY MODEL
JOEL S. GREENBERG (Princeton Synergetics, Inc., NJ) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 15 p.
(IAF PAPER 89-694) Copyright

The launch and orbital operations of a generic space mission involving multiple satellite that carry multiple sensors can be simulated by the SATCAV dynamic stochastic life cycle cost and availability model. Either expendable or recoverable launch vehicles and upper stages may be treated, and account is taken of the consequences of a set of defined failures in terms of cost-incurring events and time delays. SATCAV encompasses alternative maintenance scenarios that include both ground and orbitally dormant or active spares; also, both launch-on-failure and launch-in-anticipation-of-wearout-failure alternatives are available. O.C.

A90-18042
A RAPID PROTOTYPING/ARTIFICIAL INTELLIGENCE APPROACH TO SPACE STATION-ERA INFORMATION MANAGEMENT AND ACCESS
RICHARD S. CARNAHAN, JR., STEPHEN M. COREY, and JOHN B. SNOW (Martin Marietta Information and Communications Systems, Denver, CO) (NASA, Bendix Field Engineering Corp., Computer Sciences Corp., et al., Annual Goddard Conference on Space Applications of Artificial Intelligence, Greenbelt, MD, May 16, 17, 1989) Telematics and Informatics (ISSN 0736-5853), vol. 6, no. 3-4, 1989, p. 273-297. Previously announced in STAR as N89-26600. refs
Copyright

Applications of rapid prototyping and Artificial Intelligence techniques to problems associated with Space-Station-era information management systems are described. In particular, the work is centered on issues related to: (1) intelligent man-machine interfaces applied to scientific data user support, and (2) the requirement that intelligent information management systems (IIMS) be able to efficiently process metadata updates concerning types of data handled. The advanced IIMS represents functional capabilities driven almost entirely by the needs of potential users. Space Station-era scientific data projected to be generated is likely to be significantly greater than data currently processed and analyzed. Information about scientific data must be presented clearly, concisely, and with support features to allow users at all levels of expertise efficient and cost-effective data access. Additionally, mechanisms for allowing more efficient IIMS metadata update processes must be addressed. The work reported covers the following IIMS design aspects: IIMS data and metadata modeling, including the automatic updating of IIMS-contained metadata, IIMS user-system interface considerations, including significant problems associated with remote access, user profiles, and on-line tutorial capabilities, and development of an IIMS query and browse facility, including the capability to deal with spatial information. A working prototype has been developed and is being enhanced. Author

A90-18048* Maryland Univ., College Park.
A CONNECTIONIST MODEL FOR DYNAMIC CONTROL
KEVIN C. WHITFIELD, SHARON M. GOODALL, and JAMES A. REGGIA (Maryland, University, College Park) (NASA, Bendix Field Engineering Corp., Computer Sciences Corp., et al., Annual Goddard Conference on Space Applications of Artificial Intelligence, Greenbelt, MD, May 16, 17, 1989) Telematics and Informatics (ISSN 0736-5853), vol. 6, no. 3-4, 1989, p. 375-390. Research supported by AT&T Information Systems. Previously announced

in STAR as N89-26604. refs
(Contract NAG1-885; NSF IRI-84-51430)
Copyright

The application of a connectionist modeling method known as competition-based spreading activation to a camera tracking task is described. The potential is explored for automation of control and planning applications using connectionist technology. The emphasis is on applications suitable for use in the NASA Space Station and in related space activities. The results are quite general and could be applicable to control systems in general. Author

A90-21535* Colorado Univ., Boulder.
ON DEVELOPING THE LOCAL RESEARCH ENVIRONMENT OF THE 1990S - THE SPACE STATION ERA
ROBERT CHASE and FRED ZIEL (Colorado, University, Boulder) IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989, p. 171-184. refs
(Contract NAGW-1191)
(AAS PAPER 89-014) Copyright

A requirements analysis for the Space Station's polar platform data system has been performed. Based upon this analysis, a cluster, layered cluster, and layered-modular implementation of one specific module within the Eos Data and Information System (EosDIS), an active data base for satellite remote sensing research has been developed. It is found that a distributed system based on a layered-modular architecture and employing current generation work station technologies has the requisite attributes ascribed by the remote sensing research community. Although, based on benchmark testing, probabilistic analysis, failure analysis and user-survey technique analysis, it is found that this architecture presents some operational shortcomings that will not be alleviated with new hardware or software developments. Consequently, the potential of a fully-modular layered architectural design for meeting the needs of Eos researchers has also been evaluated, concluding that it would be well suited to the evolving requirements of this multidisciplinary research community. Author

A90-22276
SPACECRAFT GROUND OPERATIONS AND DATA HANDLING; PROCEEDINGS OF THE CONFERENCE, LONDON, ENGLAND, FEB. 23, 1988
Conference sponsored by the Royal Aeronautical Society and Remote Sensing Society. London, Royal Aeronautical Society, 1988, 121 p. For individual items see A90-22277 to A90-22284.
Copyright

The present conference discusses the plans formulated for a UK spacecraft data processing system ground segment, the impact of the European Data Relay Satellite on the availability of remote-sensing data, and the usage and operational practices of the Columbus polar platform. Also discussed are the functions and services of the UK National Remote Sensing Center, the design of the Anglo-Norwegian Polar Platform ground segment, the role of ESOC in ERS-1 operations, the ground-segment architecture of ERS-1, and prospective data-processing, archiving, and dissemination practices for future remote sensing missions. O.C.

A90-22278
THE IMPACT OF THE EUROPEAN DATA RELAY SATELLITE ON THE PROVISION OF REMOTE SENSING DATA
A. DICKINSON (ESA, Paris, France) IN: Spacecraft ground operations and data handling; Proceedings of the Conference, London, England, Feb. 23, 1988. London, Royal Aeronautical Society, 1988, p. 2.1-2.9.
Copyright

ESA's Data Relay Satellite (DRS), scheduled for operation in the late 1990s, will furnish its users with a flexible system for data reception and transmission which can circumvent many of the limitations and constraints experienced with current systems. DRS's design will reduce or obviate the requirement for onboard data storage, reduce the delay between data-generation by a spaceborne sensor and its reception by an end user, and increase the flexibility of users' scheduling operations. In addition, DRS will significantly expand the coverage area over that furnished by conventional earth station networks. O.C.

A90-22281
ANGLO-NORWEGIAN POLAR PLATFORM GROUND SEGMENT DESIGN
D. C. FERNS (Logica Space and Defence Systems, Ltd., Cobham, England) IN: Spacecraft ground operations and data handling; Proceedings of the Conference, London, England, Feb. 23, 1988. London, Royal Aeronautical Society, 1988, p. 5.1-5.12.
Copyright

The joint UK-Norway Phase A-1 design study for a ground segment dedicated to the operation of such future spacecraft as the Columbus Polar-orbiting Platform has encompassed the control functions for the platform's telemetry, tracking and command, health monitoring, orbit control, and tracking scheduling. Ground terminals have been defined for X-band, S-band, and EDRS data reception, as well as for user operations/support functions allowing payload-data requests to be managed and processed to the point of eventual dissemination of operational and scientific data to users. Attention is given to systems architectures and facility locations considered. O.C.

A90-22284
DATA PROCESSING, ARCHIVING AND DISSEMINATION FOR FUTURE REMOTE SENSING MISSIONS
LEN BARLOW, RAY HARRIS, and PETER HAVER (Software Sciences, Ltd., Farnborough, England) IN: Spacecraft ground operations and data handling; Proceedings of the Conference, London, England, Feb. 23, 1988. London, Royal Aeronautical Society, 1988, p. 8.1-8.27. refs
Copyright

An evaluation is made of the current understanding of the system design tasks facing those concerned with the management of information from such prospective ESA remote sensing spacecraft as ERS-1 and Columbus. An account is given of the projected methods for collection and archiving, processing, and dissemination of data from these two spacecraft. It has been found difficult to extract definite trends in satellite remote sensing information management; for instance, while optical disk storage devices are expected to become standard in the 1990s, improvements in telecommunications may render them less useful than presently anticipated. O.C.

A90-27904
ATMOSPHERIC EFFECTS ON THE PROPAGATION OF VERY SHORT PULSES AT MILLIMETRIC WAVELENGTHS
C. J. GIBBINS (Rutherford Appleton Laboratory, Didcot, England) IN: International Conference on Antennas and Propagation (ICAP 89), 6th, Coventry, England, Apr. 4-7, 1989, Proceedings. Part 2. London, England and Piscataway, NJ, Institution of Electrical Engineers, 1989, p. 432-436. refs
Copyright

The Forrer (1958) solution of the Fourier integral in closed form, which assumes that the atmospheric channel transfer function can be approximated by a truncated Taylor frequency series, is presently extended in order to investigate absorptive and dispersive effects on pulses at carrier frequencies of 10-200 GHz and pulse widths of 0.1-2.0 nsec, over line-of-sight path lengths from 1-50 km as well as along earth-space paths. Interesting effects are noted to arise in regions of the spectrum where pulse-compression occurs. O.C.

A90-28826
ITC/USA/'89; PROCEEDINGS OF THE INTERNATIONAL TELEMETERING CONFERENCE, SAN DIEGO, CA, OCT. 30-NOV. 2, 1989
Conference sponsored by the International Foundation for Telemetering. Research Triangle Park, NC, Instrument Society of America (ITC Proceedings. Volume 25), 1989, 957 p. For individual items see A90-28827 to A90-28909.
Copyright

The present conference on the development status and performance capabilities of telemetry techniques discusses trends in range-instrumentation systems, future telemetry system designs, a GPS-disciplined rubidium clock, the Space Shuttle cardiograph experiment, the MIL-STD-1553 data acquisition system, measurements of the performance of telemetry video codecs, video-coding techniques, a fully digital antenna-control system, a high-speed miniature PCM system, subminiature telemetry systems for submunitions, small ICBM telemetry processing, and a high-performance optical disk for future telemetry applications. Also discussed are rotary-head recorders in telemetry systems, a digitized Doppler signal processor, Space Station-era ground data handling, advancements in real-time architecture for telemetry processing, next-generation signal conditioning, high speed VLSI systems for NASA's telemetry return link, and data standards for the Space Station Freedom. O.C.

A90-28853* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
STANDARD SERVICES FOR THE CAPTURE, PROCESSING, AND DISTRIBUTION OF PACKETIZED TELEMETRY DATA
WILLIAM H. STALLINGS (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 361-367.
Copyright

Standard functional services for the capture, processing, and distribution of packetized data are discussed with particular reference to the future implementation of packet processing systems, such as those for the Space Station Freedom. The major functions are listed under the following major categories: input processing, packet processing, and output processing. A functional block diagram of a packet data processing facility is presented, showing the distribution of the various processing functions as well as the primary data flow through the facility. V.L.

A90-28864*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
TELEMETRY DATA STORAGE SYSTEMS TECHNOLOGY FOR THE SPACE STATION FREEDOM ERA
JOHN T. DALTON (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 455-462. refs

This paper examines the requirements and functions of the telemetry-data recording and storage systems, and the data-storage-system technology projected for the Space Station, with particular attention given to the Space Optical Disk Recorder, an on-board storage subsystem based on 160 gigabit erasable optical disk units each capable of operating at 300 M bits per second. Consideration is also given to storage systems for ground transport recording, which include systems for data capture, buffering, processing, and delivery on the ground. These can be categorized as the first in-first out storage, the fast random-access storage, and the slow access with staging. Based on projected mission manifests and data rates, the worst case requirements were developed for these three storage architecture functions. The results of the analysis are presented. I.S.

A90-28877*# Mississippi State Univ., Mississippi State.
SIMULATED PERFORMANCE RESULTS OF THE OMV VIDEO COMPRESSION TELEMETRY SYSTEM
FRANK INGELS (Mississippi State University, Mississippi State), GLENN PARKER, and LEE ANN THOMAS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 591-598. refs

The control system of NASA's Orbital Maneuvering Vehicle (OMV) will employ range/range-rate radar, a forward command link, and a compressed video return link. The video data is compressed by sampling every sixth frame of data; a rate of 5 frames/sec is adequate for the OMV docking speeds. Further axial compression is obtained, albeit at the expense of spatial resolution, by averaging adjacent pixels. The remaining compression is achieved on the basis of differential pulse-code modulation and Huffman run-length encoding. A concatenated error-correction coding system is used to protect the compressed video data stream from channel errors. O.C.

A90-28878*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ADVANCED CONCEPTS FOR TELEMETRY DATA SYSTEMS
JAMES A. PRITCHARD (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 599-606. refs

The Consultative Committee for Space Data Standards (CCSDS) has defined Advanced Orbiting System (AOS) standards for the overall architectural framework of future packet telemetry systems. The standards encompass a CCSDS principal network covering the onboard space-link and ground systems, and furnishes an asynchronous (telemetry/internetworking) and isochronous (audio and video) data-transport services employing CCSDS packets and virtual channels. Attention is given to changes envisioned in ground telemetry processing systems currently in use, as well as to the application of CCSDS standards to future systems. O.C.

A90-28879*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
SPACE STATION-ERA GROUND DATA HANDLING
GENE A. SMITH (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 607-611.

Planning is underway for the handling of the peak return link data rates ranging from 300 to 1200 Mbps that are associated with the emerging Space Station orbital-systems era. Ground data handling services encompass the enhancement of on-board ancilliary data packets to furnish standard calibrations and transformations not available on-board; remote access to an interactive data base will allow users to select and withdraw specified parameters based on user-defined criteria. O.C.

A90-28882
SIMULATIONS OF SPACE STATION DATA LINKS AND GROUND PROCESSING
STEPHEN HORAN (New Mexico State University, Las Cruces) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 629-635.
Copyright

A program aimed at the study of the possibilities of using parallel processing configurations for the real-time processing of Space Station data is reviewed. The potential configurations are evaluated using a program based on discrete-event simulation models. The major near-term goals of the program include: simulation of specific configurations to verify the methodology of using the simulation packages; model development for the ground-based data processing components; model development for commercially available parallel architectures; and modeling of various data transport configurations to simulate the operation of parallel processing configurations. V.L.

A90-28898*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADVANCED ORBITING SYSTEMS - A STANDARD ARCHITECTURE FOR SPACE DATA COMMUNICATIONS
ADRIAN J. HOOKE (JPL, Pasadena, CA) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San

Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 825-833.

The standard data handling service architecture developed by the Consultative Committee for Space Data Systems is discussed. Special attention is given to the communications protocols that are recommended for the networked transfer of space mission data, with emphasis on the unique requirements of transmitting many different data types through the weak-signal noisy space channels at high rates (up to many hundreds of megabits per second). A user service model of a typical space mission data flow configuration, known as the 'pipe diagram', is described in detail. I.S.

A90-28899* NASA Space Station Program Office, Reston, VA.
DATA STANDARDS FOR THE SPACE STATION FREEDOM PROGRAM
RICHARD D. CARPER (NASA, Space Station Program Office, Reston, VA) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 835-840.
Copyright

The Space Station Freedom Program (SSFP) plans to utilize several of the Recommendations of the Consultative Committee for Space Data Systems (CCSDS). This paper discusses four aspects of the effect of the Advanced Orbiting Systems (AOS) within the SSFP which are of special interest. It is first noted that the AOS is a new Recommendation of the CCSDS, and the SSFP has been in the unique position of playing a major role in the development of the Recommendation. Interactions of the process by the Program and the CCSDS are shown. Second, the specific application of the CCSDS AOS Recommendation to each of the four SSFP flight elements and the resulting sets of services provided on each element are discussed. Third, the usefulness and importance of the AOS Recommendation within the context of the international nature of the SSFP and as part of the generation of interorganizational support agreements within NASA are discussed. Finally, the current status of baselining various CCSDS Recommendations, especially the AOS, into the SSFP requirements structure is given. R.E.P.

A90-28900
SPACE LINK ARQ PROCEDURE FOR RELIABLE, ROBUST COMMUNICATIONS
FRED M. BROSI, JR. IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 841-847. Research supported by NASA, ESA, and DLR.
Copyright

A protocol for data transfer across space-to-ground and space-to-space links has been developed. The protocol is known as the Space Link ARQ Protocol (SLAP). The SLAP requirements and constraints are listed and the SLAP operational concept is examined, including the organization of the SLAP sending and acceptance functions. The SLAP environment and flow control are discussed and possible SLAP applications for orbiting platforms or the Space Station are considered. R.B.

A90-28901
NETWORK MANAGEMENT AND SIGNALLING STANDARDS FOR CCSDS ADVANCED ORBITING SYSTEM COMMUNICATION SYSTEMS
JOHN PIETRAS (Mitre Corp., Greenbelt, MD) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 849-857. refs
Copyright

The Consultative Committee for Space Data Systems (CCSDS) is an international organization chartered to develop and adopt communications protocols and data processing standards suitable for use in space-related communication and data processing systems. This paper briefly describes the CCSDS network management environment and reviews the current status of CCSDS recommendations for network management functional capability, use of internal standard for network management, and composition of signaling systems in support of the advanced orbiting systems services typified by the international Space Station Freedom Program. A timetable for future work in this area is presented. C.D.

A90-28902*# Mitre Corp., McLean, VA.
ADVANCED ORBITING SYSTEMS TEST-BEDDING AND PROTOCOL VERIFICATION
JAMES NOLES (Mitre Corp., McLean, VA) and MELVIN DE GREE (NASA, Space Station Freedom Program Office, Reston, VA) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 859-864.

The Consultative Committee for Space Data Systems (CCSDS) has begun the development of a set of protocol recommendations for Advanced Orbiting Systems (SOS). The AOS validation program and formal definition of AOS protocols are reviewed, and the configuration control of the AOS formal specifications is summarized. Independent implementations of the AOS protocols by NASA and ESA are discussed, and cross-support/interoperability tests which will allow the space agencies of various countries to share AOS communication facilities are addressed. C.D.

A90-28905*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
HIGH SPEED VLSI SYSTEMS FOR NASA'S TELEMETRY RETURN LINK PROCESSOR
SARAH L. HAND, LUIS G. SALICHS, and JOHN K. STEEDMAN (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 881-892.

This paper describes the architecture of the Data Interface Facility, (DIF), a key element in NASA's advanced communications systems, and its core element, the Return Link Processor (RLP). Current activities to prototype some of the primary functions of the RLP are presented. It is shown how the prototype elements can be integrated into a full-performance DIF RLP. C.D.

A90-28909*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
PROTOTYPE ARCHITECTURE FOR A VLSI LEVEL ZERO PROCESSING SYSTEM
JIANFEI SHI (NASA, Goddard Space Flight Center; RMS Technologies, Inc., Greenbelt, MD), GERALD J. GREBOWSKY, WARD P. HORNER, and JAMES R. CHESNEY (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'89; Proceedings of the International Telemetering Conference, San Diego, CA, Oct. 30-Nov. 2, 1989. Research Triangle Park, NC, Instrument Society of America, 1989, p. 925-936. refs

The prototype architecture and implementation of a high-speed level zero processing (LZP) system are discussed. Due to the new processing algorithm and VLSI technology, the prototype LZP system features compact size, low cost, high processing throughput, and easy maintainability and increased reliability. Though extensive control functions have been done by hardware, the programmability of processing tasks makes it possible to adapt the system to different data formats and processing requirements. It is noted that the LZP system can handle up to 8 virtual channels and 24 sources with combined data volume of 15 Gbytes per orbit. For greater demands, multiple LZP systems can be configured in parallel, each called a processing channel and assigned a subset of virtual channels. The telemetry data stream will be steered into different processing channels in accordance with their virtual channel IDs. This super system can cope with a virtually unlimited number of virtual channels and sources. In the near future, it is expected that new disk farms with data rate exceeding 150 Mbps

will be available from commercial vendors due to the advance in disk drive technology. R.E.P.

A90-28945#
THE DATA-RELAY PREPARATORY PROGRAMME
A. DICKINSON (ESTEC, Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 61, Feb. 1990, p. 39-45.
Copyright

The data-relay preparatory program establishes and defines the preferred configuration for the data-relay system (DRS) space and ground segments, information-transmission, telemetry, telecommand and ranging sevices for foreseen European space programs, including Columbus, Ariane-5, Hermes and advanced earth-observation systems. This program has been conducted in two main areas: system studies and technological development. The system study has been divided in three main phases: (1) system design, i.e., configuration of the ground and spaceborne elements (1988); (2) definition of configuration and capacity of DRS satellites (1989); and (3) design of satellites and ground-segment facilities on the subsystem level (1990). As a result of the study, the DRS configuration will provide two operational satellites in geostationary orbit with orbital position of 44 deg W and 59 deg E which will allow almost full global coverage. The European DRS will be served by independent user earth terminals, with mission control center (MCC) in Darmstadt. The first system is planned to be fully operational in 1996. N.B.

N90-11451*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
CONSIDERATIONS FOR A DESIGN AND OPERATIONS KNOWLEDGE SUPPORT SYSTEM FOR SPACE STATION FREEDOM
JON D. ERICKSON, KENNETH H. CROUSE, DONALD B. WECHSLER, and DOUGLAS R. FLAHERTY (Mitre Corp., Houston, TX.) Oct. 1989 73 p
(NASA-TM-102156; S-596; NAS 1.15:102156) Avail: NTIS HC A04/MF A01 CSCL 09/2

Engineering and operations of modern engineered systems depend critically upon detailed design and operations knowledge that is accurate and authoritative. A design and operations knowledge support system (DOKSS) is a modern computer-based information system providing knowledge about the creation, evolution, and growth of an engineered system. The purpose of a DOKSS is to provide convenient and effective access to this multifaceted information. The complexity of Space Station Freedom's (SSF's) systems, elements, interfaces, and organizations makes convenient access to design knowledge especially important, when compared to simpler systems. The life cycle length, being 30 or more years, adds a new dimension to space operations, maintenance, and evolution. Provided here is a review and discussion of design knowledge support systems to be delivered and operated as a critical part of the engineered system. A concept of a DOKSS for Space Station Freedom (SSF) is presented. This is followed by a detailed discussion of a DOKSS for the Lyndon B. Johnson Space Center and Work Package-2 portions of SSF. Author

N90-13966*# Houston Univ., Clear Lake, TX. Research Inst. for Computing and Information Systems.
SOFTWARE ENGINEERING AND ADA (TRADEMARK) TRAINING: AN IMPLEMENTATION MODEL FOR NASA
SUE LEGRAND (Softech, Inc., Houston, TX.) and GLENN FREEDMAN 27 Jun. 1988 26 p Presented at the Washington Ada (Trademark) Symposium, Washington, DC, 27 Jun. 1988
(Contract NCC9-16)
(NASA-CR-186071; NAS 1.26:186071) Avail: NTIS HC A03/MF A01 CSCL 09/2

The choice of Ada for software engineering for projects such as the Space Station has resulted in government and industrial groups considering training programs that help workers become familiar with both a software culture and the intricacies of a new computer language. The questions of how much time it takes to learn software engineering with Ada, how much an organization should invest in such training, and how the training should be structured are considered. Software engineering is an emerging, dynamic discipline. It is defined by the author as the establishment and application of sound engineering environments, tools, methods, models, principles, and concepts combined with appropriate standards, guidelines, and practices to support computing which is correct, modifiable, reliable and safe, efficient, and understandable throughout the life cycle of the application. Neither the training programs needed, nor the content of such programs, have been well established. This study addresses the requirements for training for NASA personnel and recommends an implementation plan. A curriculum and a means of delivery are recommended. It is further suggested that a knowledgeable programmer may be able to learn Ada in 5 days, but that it takes 6 to 9 months to evolve into a software engineer who uses the language correctly and effectively. The curriculum and implementation plan can be adapted for each NASA Center according to the needs dictated by each project. J.P.S.

N90-14532*# DePaul Univ., Chicago, IL. Dept. of Computer Science.
AN IMAGE COMPRESSION ALGORITHM FOR A HIGH-RESOLUTION DIGITAL STILL CAMERA Final Technical Report, 15 Sep. 1988 - 31 Dec. 1989
ROSALEE NERHEIM 1989 9 p
(Contract NAG9-313)
(NASA-CR-185079; NAS 1.26:185079) Avail: NTIS HC A02/MF A01 CSCL 14/2

The Electronic Still Camera (ESC) project will provide for the capture and transmission of high-quality images without the use of film. The image quality will be superior to video and will approach the quality of 35mm film. The camera, which will have the same general shape and handling as a 35mm camera, will be able to send images to earth in near real-time. Images will be stored in computer memory (RAM) in removable cartridges readable by a computer. To save storage space, the image will be compressed and reconstructed at the time of viewing. Both lossless and loss-y image compression algorithms are studied, described, and compared. J.P.S.

N90-14784*# Southwest Research Inst., San Antonio, TX.
HIGH VOLUME DATA STORAGE ARCHITECTURE ANALYSIS Final Report
JAMES M. MALIK 19 Jan. 1990 39 p
(Contract NCC9-16; SWRI PROJ. 05-3269)
(NASA-CR-186239; NAS 1.26:186239) Avail: NTIS HC A03/MF A01 CSCL 09/2

A High Volume Data Storage Architecture Analysis was conducted. The results, presented in this report, will be applied to problems of high volume data requirements such as those anticipated for the Space Station Control Center. High volume data storage systems at several different sites were analyzed for archive capacity, storage hierarchy and migration philosophy, and retrieval capabilities. Proposed architectures were solicited from the sites selected for in-depth analysis. Model architectures for a hypothetical data archiving system, for a high speed file server, and for high volume data storage are attached. J.P.S.

N90-14786*# Houston Univ., Clear Lake, TX. Research Inst. for Computing and Information Systems.
TRANSFERRING DATA OBJECTS: A FOCUSED ADA INVESTIGATION
SUE LEGRAND (Softech, Inc., Houston, TX.) 30 Apr. 1988 15 p
(Contract NCC9-16)
(NASA-CR-186065; NAS 1.26:186065) Avail: NTIS HC A03/MF A01 CSCL 09/2

The use of the Ada language does not guarantee that data objects will be in the same form or have the same value after they have been stored or transferred to another system. There are too many possible variables in such things as the formats used and other protocol conditions. Differences may occur at many different levels of support. These include program level, object

level, application level, and system level. A standard language is only one aspect of making a complex system completely homogeneous. Many components must be standardized and the various standards must be integrated. The principal issues in providing for interaction between systems are of exchanging files and data objects between systems which may not be compatible in terms of their host computer, operating system or other factors. A typical resolution of the problem of invalidating data involves at least a common external form, for data objects and for representing the relationships and attributes of data collections. Some of the issues dealing with the transfer of data are listed and consideration is given on how these issues may be handled in the Ada language. Author

N90-14789*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SOFTWARE REUSE ISSUES
SUSAN J. VOIGT, ed. and KATHRYN A. SMITH, ed. Washington Dec. 1989 168 p Workshop held in Melbourne, FL, 17-18 Nov. 1988
(NASA-CP-3057; L-16667; NAS 1.55:3057) Avail: NTIS HC A08/MF A01 CSCL 09/2

NASA Langley Research Center sponsored a Workshop on NASA Research in Software Reuse on November 17-18, 1988 in Melbourne, Florida, hosted by Software Productivity Solutions, Inc. Participants came from four NASA centers and headquarters, eight NASA contractor companies, and three research institutes. Presentations were made on software reuse research at the four NASA centers; on Eli, the reusable software synthesis system designed and currently under development by SPS; on Space Station Freedom plans for reuse; and on other reuse research projects. This publication summarizes the presentations made and the issues discussed during the workshop.

N90-14796*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
JOHNSON SPACE CENTER SOFTWARE REUSE ACTIVITY
STEVE GORMAN *In* NASA, Langley Research Center, Software Reuse Issues p 61-63 Dec. 1989
Avail: NTIS HC A08/MF A01 CSCL 09/2

There is a strong operational interest in reuse and commonality at the Johnson Space Center (JSC). Although commonality and reuse were not emphasized in the Space Shuttle Orbiter Project, it is a major goal for Space Station Freedom and the Software Support Environment (SSE). Research activities at JSC are generally conducted through the Software Engineering Research Center (SERC) of the University of Houston at Clear Lake. The Life Cycle Model developed by SERC includes reuse at each phase, but reuse is not a principal theme. The SSE is a significant entry point for new reuse technology, and the SERC can provide consultation and possible prototypes. SERC is seen as an interface to other NISE reuse researchers. The AdaNET is managed at JSC through the University of Houston at Clear Lake for the NASA Office of Technology Utilization. It may also be a gateway for reuse research. Author

N90-14799*# National Aeronautics and Space Administration, Washington, DC.
SSFP APPROACH TO SOFTWARE REUSE
PEG SNYDER *In* NASA, Langley Research Center, Software Reuse Issues p 89-96 Dec. 1989
Avail: NTIS HC A08/MF A01 CSCL 09/2

This talk began by presenting the Space Station Freedom Program (SSFP) definitions of software commonality and software reuse. Software commonality is the use of identical, interchangeable, functionally compatible, or similar software items to satisfy different sets of functionally similar requirements. The Software Support Environment (SSE) and the Data Management System (DMS) of onboard computing facilities are examples of SSFP common software. Software reuse is the use of identical, compatible, or similar software items in either modified or unmodified form to satisfy development activities at any point in the software life cycle; in other words, taking an existing item and applying it to another development activity. Software commonality has been mandated in several critical areas (such as the SSE and DMS) and a policy directive is under review. A software reuse study group was established in May 1988 to gather background information (see Level 2 Software Reuse Study that follows by Scott Herman). The SSFP Program Definition and Requirements Document contains requirements for SSE support in the area of software reuse. The SSE is a collection of tools and rules, and provides the common environment to be used for the life cycle management of all SSFP operational software. Author

N90-14800*# Grumman Technical Services, Inc., Reston, VA.
LEVEL 2 SOFTWARE REUSE STUDY
SCOTT E. HERMAN *In* NASA, Langley Research Center, Software Reuse Issues p 97-103 Dec. 1989
Avail: NTIS HC A08/MF A01 CSCL 09/2

The Space Station Freedom Program (SSFP) Level 2 Software Reuse Study group was formed by Bob Nelson (NASA SSFP) from members of the Information Systems Program Support Contract (PSC) team. The objectives of the study were to identify existing software reuse libraries, to identify existing reusability processes and experiences, to identify reusability analysis tools and users, and to provide recommendations for a software reusability process for the SSFP. To date the following have been delivered: (1) definitions of commonality and reuse, (2) a report on existing software reuse libraries and library management systems, (3) a report on reuse process and methodology gleaned from software reuse experts, and (4) a report on software attributes for measuring commonality and reusability. Three implementation alternatives for a repository of reusable components were identified: centralized at the SSE Development Facility (SSEDF), a distributed approach across the network of Software Production Facilities, and a directory approach. A number of findings from the reuse study and several reuse strategy considerations were presented. Author

N90-14802*# Planning Research Corp., Houston, TX.
SUPPORT FOR LIFE-CYCLE PRODUCT REUSE IN NASA'S SSE
CHARLES SHOTTON *In* NASA, Langley Research Center, Software Reuse Issues p 111-118 Dec. 1989
Avail: NTIS HC A08/MF A01 CSCL 09/2

The Software Support Environment (SSE) is a software factory for the production of Space Station Freedom Program operational software. The SSE is to be centrally developed and maintained and used to configure software production facilities in the field. The PRC product TTCQF provides for an automated qualification process and analysis of existing code that can be used for software reuse. The interrogation subsystem permits user queries of the reusable data and components which have been identified by an analyzer and qualified with associated metrics. The concept includes reuse of non-code life-cycle components such as requirements and designs. Possible types of reusable life-cycle components include templates, generics, and as-is items. Qualification of reusable elements requires analysis (separation of candidate components into primitives), qualification (evaluation of primitives for reusability according to reusability criteria) and loading (placing qualified elements into appropriate libraries). There can be different qualifications for different installations, methodologies, applications and components. Identifying reusable software and related components is labor-intensive and is best carried out as an integrated function of an SSE. Author

N90-16106# Department of the Air Force, Washington, DC.
SEQUENTIAL RAPID COMMUNICATION VISUAL DISPLAYS Patent
ETHEL MATIN, inventor (to AF) and KENNETH R. BOFF, inventor (to AF) 4 Jul. 1989 12 p Filed 28 Aug. 1987 Supersedes US-Patent-Appl-SN-090500
(AD-D014282; US-PATENT-4,845,645; US-PATENT-APPL-SN-090500) Avail: US Patent and Trademark Office CSCL 14/2

The rapid communication (RAP-COM) microprocessor controlled

memory display system and method operates by presenting real-time data in rapid temporal succession at one spatial location. It can be embodied as a stand-alone instrument or as a small display window within a larger integrated display. It can be incorporated, for example, within larger display configurations in military crew stations, nuclear power plants, air-traffic control centers, space stations, or industrial process control plants. RAP-COM has two advantages over conventional display formats. First, it reduces the amount of required display space by presenting information in sequentially in one location rather than simultaneously in several locations. Second it speeds the rate of system-to-operator information transfer by eliminating the time needed for the scanning saccadic eye movements that access information from conventional spatially separated displays. GRA

N90-16204*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
VISUAL INFORMATION PROCESSING FOR TELEVISION AND TELEROBOTICS
FRIEDRICH O. HUCK, ed. and STEPHEN K. PARK, ed. (College of William and Mary, Williamsburg, VA.) Washington Nov. 1989 263 p Workshop held in Williamsburg, VA, 10-12 May 1989
(NASA-CP-3053; L-16665; NAS 1.55:3053) Avail: NTIS HC A12/MF A02 CSCL 14/2

This publication is a compilation of the papers presented at the NASA conference on Visual Information Processing for Television and Telerobotics. The conference was held at the Williamsburg Hilton, Williamsburg, Virginia on May 10 to 12, 1989. The conference was sponsored jointly by NASA Offices of Aeronautics and Space Technology (OAST) and Space Science and Applications (OSSA) and the NASA Langley Research Center. The presentations were grouped into three sessions: Image Gathering, Coding, and Advanced Concepts; Systems; and Technologies. The program was organized to provide a forum in which researchers from industry, universities, and government could be brought together to discuss the state of knowledge in image gathering, coding, and processing methods.

N90-16212*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DATA COMPRESSION FOR THE MICROGRAVITY EXPERIMENTS
KHALID SAYOOD, WAYNE A. WHYTE, JR., KAREN S. ANDERSON, MARY JO SHALKHAUSER, and ANNE M. SUMMERS (Nebraska Univ., Lincoln.) *In* NASA, Langley Research Center, Visual Information Processing for Television and Telerobotics p 93-107 Nov. 1989 Sponsored in part by NASA, Goddard Space Flight Center
(Contract NAG3-806; NAG5-916)
Avail: NTIS HC A12/MF A02 CSCL 14/2

Researchers present the environment and conditions under which data compression is to be performed for the microgravity experiment. Also presented are some coding techniques that would be useful for coding in this environment. It should be emphasized that researchers are currently at the beginning of this program and the toolkit mentioned is far from complete. Author

N90-16220*# Odetics, Inc., Anaheim, CA.
KNOWLEDGE-BASED IMAGING-SENSOR FUSION SYSTEM
GEORGE WESTROM *In* NASA, Langley Research Center, Visual Information Processing for Television and Telerobotics p 215-229 Nov. 1989
(Contract NAS1-18816; NAS1-18664)
Avail: NTIS HC A12/MF A02 CSCL 14/2

An imaging system which applies knowledge-based technology to supervise and control both sensor hardware and computation in the imaging system is described. It includes the development of an imaging system breadboard which brings together into one system work that we and others have pursued for LaRC for several years. The goal is to combine Digital Signal Processing (DSP) with Knowledge-Based Processing and also include Neural Net processing. The system is considered a smart camera. Imagine that there is a microgravity experiment on-board Space Station Freedom with a high frame rate, high resolution camera. All the data cannot possibly be acquired from a laboratory on Earth. In fact, only a small fraction of the data will be received. Again, imagine being responsible for some experiments on Mars with the Mars Rover: the data rate is a few kilobits per second for data from several sensors and instruments. Would it not be preferable to have a smart system which would have some human knowledge and yet follow some instructions and attempt to make the best use of the limited bandwidth for transmission. The system concept, current status of the breadboard system and some recent experiments at the Mars-like Amboy Lava Fields in California are discussed. Author

N90-16687*# California State Univ., Fresno. Dept. of Computer Science.
FORMALISMS FOR USER INTERFACE SPECIFICATION AND DESIGN
BRENT J. AUERNHEIMER *In* University of Central Florida, NASA/ASEE Summer Faculty Fellowship Program p 1-23 Oct. 1989
Avail: NTIS HC A18/MF A03 CSCL 09/2

The application of formal methods to the specification and design of human-computer interfaces is described. A broad outline of human-computer interface problems, a description of the field of cognitive engineering and two relevant research results, the appropriateness of formal specification techniques, and potential NASA application areas are described. Author

N90-18178# Naval Ocean Systems Center, San Diego, CA.
KAPSE INTERFACE TEAM (KIT) PUBLIC REPORT, VOLUME 8, PART 2 Final Report, May - Oct. 1985
D. L. HAYWARD Oct. 1989 393 p
(AD-A215840; NOSC/TD-552-VOL-8-PT-2) Avail: NTIS HC A17/MF A03 CSCL 12/5

Topics addressed include: A Distributed CAIS; NASA Space Station Software Requirements; Applying Denotational Semantics to Specifying Kernel Interfaces; Quality Assurance Guidelines; Ada Interoperability Survey; An Investigation of the Common APSE Interface Set (CAIS) on and IBM S/370 Running VM/CMS Implementation of a Prototype CAIS Environment; and PCTE - A Basic for a Portable Common Tool Environment. GRA

N90-19411*# Mississippi State Univ., Mississippi State. Dept. of Electrical Engineering.
EVALUATION AND ANALYSIS OF THE ORBITAL MANEUVERING VEHICLE VIDEO SYSTEM
ROBERT J. MOORHEAD, II *In* Alabama Univ., Research Reports: 1989 NASA/ASEE Summer Faculty Fellowship Program 27 p Dec. 1989
(Contract NGT-01-008-021)
Avail: NTIS HC A99/MF E06 CSCL 17/2

The work accomplished in the summer of 1989 in association with the NASA/ASEE Summer Faculty Research Fellowship Program at Marshall Space Flight Center is summarized. The task involved study of the Orbital Maneuvering Vehicle (OMV) Video Compression Scheme. This included such activities as reviewing the expected scenes to be compressed by the flight vehicle, learning the error characteristics of the communication channel, monitoring the CLASS tests, and assisting in development of test procedures and interface hardware for the bit error rate lab being developed at MSFC to test the VCU/VRU. Numerous comments and suggestions were made during the course of the fellowship period regarding the design and testing of the OMV Video System. Unfortunately from a technical point of view, the program appears at this point in time to be trouble from an expense prospective and is in fact in danger of being scaled back, if not cancelled altogether. This makes technical improvements prohibitive and cost-reduction measures necessary. Fortunately some cost-reduction possibilities and some significant technical improvements that should cost very little were identified. Author

N90-19757*# Houston Univ., Clear Lake, TX. Research Inst. for Computing and Information Systems.
DEVELOPMENT OF AN ADA PROGRAMMING SUPPORT ENVIRONMENT DATABASE SEAD (SOFTWARE ENGINEERING AND ADA DATABASE) ADMINISTRATION MANUAL
MORRIS LIAW and DONNA EVESSON (GHG Corp., Houston, TX.) Dec. 1988 161 p
(Contract NCC9-16)
(NASA-CR-186064; NAS 1.26:186064) Avail: NTIS HC A08/MF A01 CSCL 09/2

Software Engineering and Ada Database (SEAD) was developed to provide an information resource to NASA and NASA contractors with respect to Ada-based resources and activities which are available or underway either in NASA or elsewhere in the worldwide Ada community. The sharing of such information will reduce duplication of effort while improving quality in the development of future software systems. SEAD data is organized into five major areas: information regarding education and training resources which are relevant to the life cycle of Ada-based software engineering projects such as those in the Space Station program; research publications relevant to NASA projects such as the Space Station Program and conferences relating to Ada technology; the latest progress reports on Ada projects completed or in progress both within NASA and throughout the free world; Ada compilers and other commercial products that support Ada software development; and reusable Ada components generated both within NASA and from elsewhere in the free world. This classified listing of reusable components shall include descriptions of tools, libraries, and other components of interest to NASA. Sources for the data include technical newletters and periodicals, conference proceedings, the Ada Information Clearinghouse, product vendors, and project sponsors and contractors. Author

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LIFE SCIENCES/HUMAN FACTORS/SAFETY

Studies, models, planning, analyses and simulations of habitability issues. Includes the performance and well-being of the crew and crew rescue.

A90-11024*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTEGRATED LAUNCH AND EMERGENCY ENTRY VEHICLE CONCEPT
JAMES A. MARTIN (NASA, Langley Research Center, Hampton, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Sept.-Oct. 1989, p. 391, 392.
Copyright

This paper describes the design of an integrated launch and emergency entry vehicle (EEV) that can satisfy the need for an advanced manned vehicle, a heavy-lift launch vehicle, and the Space Station. It is pointed out that, because only one small entry vehicle would need to be developed, the development costs should be relatively low. The EEV would have reasonable operating costs because its expendable tank would be smaller than that of the Space Shuttle and all expensive parts would be reusable. Schematic diagrams are included. I.S.

A90-11091* Krug International, San Antonio, TX.
DETERMINING A BENDS-PREVENTING PRESSURE FOR A SPACE SUIT
R. W. KRUTZ, JR., J. T. WEBB (Krug International, Technology Services Div., San Antonio, TX), and G. A. DIXON (USAF, School of Aerospace Medicine, Brooks AFB, TX) SAFE Journal, vol. 19, Fall 1989, p. 20-24. Research sponsored by USAF. refs
(Contract NASA ORDER T-82170)
Copyright

Research conducted to determine the proper pressure for preventing bends during EVA without preoxygenation is examined. Male and female subjects with different breathing gas mixtures and pressures are studied in order to define the pressure. Visual and auditory Doppler ultrasonic signals are utilized to monitor intravascular gas bubbles. The workload, which simulates EVA, consists of a handturned bicycle ergometer, a torque wrench operation, and a rope pull. The experimental data reveal that the minimum space suit pressure needed to prevent decompression sickness is 9.5 psi. I.F.

A90-12792
ADVANCED LIFE SUPPORT IN LUNAR AND MARS MISSIONS
Aerospace Engineering (ISSN 0736-2536), vol. 9, Oct. 1989, p. 23-27.
Copyright

The technology-development requirements that must be addressed in order to allow extensive lunar and Martian manned exploration encompass closed-loop life support systems, EVA, surface transportation systems, long-duration medical support, physiological deconditioning and psychological environments, and reliability enhancement. Lunar scenarios stressing science will probably emphasize long-range mobility, requiring pressurized mobile systems able to furnish life support for crews and to support telerobotic apparatus. Early Mars exploration would by contrast stress limited EVA. O.C.

A90-13259*# National Aeronautics and Space Administration, Washington, DC.
MEDICAL AND TECHNOLOGY REQUIREMENTS FOR HUMAN SOLAR SYSTEM EXPLORATION MISSIONS
ARNAULD NICOGOSSIAN, LEONARD HARRIS, LANA COUCH, FRANK SULZMAN (NASA, Washington, DC), and KAREN GAISER (Lockheed Engineering and Sciences Co., Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. refs
(IAF PAPER 89-024)

Measures that need to be taken to cope with the health problems posed by zero gravity and radiation in manned solar system exploration missions are discussed. The particular systems that will be used aboard Space Station Freedom are addressed, and relevant human factors problems are examined. The development of a controlled ecological life support system is addressed. C.D.

A90-13261#
INNOVATIVE APPROACHES TO THE DESIGN OF BIOREGENERATIVE LIFE SUPPORT SYSTEMS FOR ADVANCED MISSIONS
S. H. SCHWARTZKOPF, T. M. OLCOTT, and E. F. LAURSEN (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-026) Copyright

The design requirements and applications of innovative bioregenerative life support technologies and hybrid bioregenerative/physicochemical technologies to advanced manned missions are considered. The processing of atmosphere, water, and waste is discussed. Food production and the integration of biological systems on advanced manned missions are addressed. C.D.

A90-13267#
TELESCIENCE TESTBED FOR PHYSIOLOGICAL EXPERIMENTS
MASAMICHI YAMASHITA (Institute of Space and Astronautical Science, Sagamihara, Japan), SATORU WATANABE, TADAAKI MANO, NOBUO MATUI (Nagoya University, Japan), FLEMMING BONDE-PETERSEN (Danish Aerospace Medical Centre of Research, Denmark) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p.
(IAF PAPER 89-034) Copyright

A telescience system for studying human physiology was simulated using a water immersion laboratory (weightlessness simulator). Electrocardiography, blood pressure, skin flowmetry,

blood analyses, and echocardiography were conducted by operators at a remote location. The quality of the data is evaluated, and their relevance for the critical issues concerning operational management of telescience are addressed. C.D.

A90-13301*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
HUMAN FACTORS AND PRODUCTIVITY ON SPACE STATION FREEDOM
C. S. LEACH, J. W. BROWN, and P. A. SANTY (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. refs
(IAF PAPER 89-087) Copyright

Three main facets of man systems are investigated with reference to the Space Station Freedom program: specific hardware systems that focus on the human element; requirements definition for man-systems integration; and crew interface and operations analysis. Three key criteria have been identified for selecting individuals to constitute the human system or crew for Space Station Freedom missions: aptitude for mission specific skills, motivation, and sensitivity to self and others. Integration of the human system into the complex engineering and science systems planned on Space Station Freedom will require the close collaboration of engineers, physicians, psychologists, and human factors experts. Ground-based research and experiments on the KC-135 aircraft are providing information about how human systems will function on a space station and how to design other systems to interact with the crew. A laboratory for further research will be provided onboard Space Station Freedom. C.E.

A90-13305#
STUDIES ON HABITATION MODULE AND INTERCONNECTING ELEMENTS FOR A FUTURE EUROPEAN SPACE STATION
U. RIEDEL and J. EWALD (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 20 p.
(IAF PAPER 89-092)

This paper describes the design concepts of the Habitation Module (HAB) of a future European space station and the Interconnecting Element (ICE), which will allow the architectural built-up of several elements forming the configuration of an orbital station. Special attention is given to the key requirements for the HAB and ICE designs and to their overall configurations, with special attention given to the human factors and safety aspects of the system. Consideration is also given to the HAB and the ICE subsystems; the internal architecture of HAB; the development, test, and ground support of HAB; and the key technologies involved in the HAB/ICE. Design diagrams of the HAB and ICE are included. I.S.

A90-13389*# National Aeronautics and Space Administration, Washington, DC.
PROGRESS TOWARD AN INTEGRATED ADVANCED TRANSPORTATION SYSTEM
DARRELL R. BRANSCOME (NASA, *Office of Space Flight*, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p. refs
(IAF PAPER 89-230) Copyright

Long term mission and payload mass requirements have been inventoried in NASA's Civil Needs Data Base, thereby establishing a framework for the analysis of launch vehicle requirements as well as time-frame requirements for the availability of specific launch vehicle and orbit-transfer vehicle capabilities. The Next Manned Transportation System studies conducted within this framework focus on the definition of options for manned flight operations beyond current Space Shuttle capabilities. Also under way are Assured Crew Return Capability studies for the Space Station Freedom, and Space Transfer Vehicle studies for a space-based aerobraking spacecraft. O.C.

A90-13401#
ESCAPE VEHICLE CONCEPTS FOR MANNED SPACE STATIONS
MAX GRIMARD and GILLES DEBAS (Aerospatiale, Les Mureaux, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p.
(IAF PAPER 89-245) Copyright

A conceptual study has been conducted by ESA into the matching of space launch emergency scenarios with crew escape facilities. Attention is given to three escape vehicle (EV) concepts: (1) a 'minimum' EV, describable as a virtual ejection seat, entailing the lowest cost but furnishing the lowest levels of performance; (2) a 'reference' EV, with greater performance than the minimum EV in order to improve such factors as postlanding safety; and (3) an 'ambulance' EV, which is optimized for medical emergencies. The likelihood of medical emergencies is identified as the most powerful of the determinants of a specific EV system. O.C.

A90-13402*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LIFTING-BODY OPTION FOR A SPACE STATION RESCUE VEHICLE
W. RAY HOOK and DELMA C. FREEMAN, JR. (NASA, Langley Research Center, Hampton, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p.
(IAF PAPER 89-246) Copyright

With the proposed development of the Space Station Freedom, the need for an assured crew return capability (ACRC) has been identified. During the past 2 years within NASA, there has been an ongoing activity to establish the design requirements for such a vehicle and to identify candidate vehicle concepts that can satisfy these requirements. From this activity, three primary design reference missions and four candidate vehicle concepts have been identified. In support of this activity, the emphasis at Langley has been to assess the potential application of a lifting-body concept derived from work on the HL-10 and X-24 programs in the late sixties. A vehicle systems analysis has been completed including wind-tunnel tests, aerodynamic heating predictions, six-degree-of-freedom entry simulations, and a global landing opportunities assessment. This report summarizes the results of work at Langley over the past 2 years to define the candidate lifting-body ACRC vehicle and provides insight into potential benefits of the higher cross range of this concept in accomplishing the Space Station rescue mission. Author

A90-13612#
THE BASIC HEALTH CARE SYSTEM FOR THE CREW LUNAR BASE
MINORU TERAI (Tokyo Metropolitan Institute of Technology, Hino, Japan) and KEIJI NITTA (National Aerospace Laboratory, Chofu, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p.
(IAF PAPER 89-573) Copyright

The basic health care system for the crew of the lunar base is presented, noting its two subsystems. The first is the daily health care system containing mainly the same care menu as in some biochemical and ordinary medical examinations on earth. The second system is a periodic medical inspection of the crew's bones and the determination of natural radioisotopes in the body. Both health care systems run automatically including complete examinations and data recordings. Examinations and data files of the results are controlled by computer. Daily examinations' results are compared with the filed data. In case of any discrepancy, a computerized message is sent for a close reexamination by a medical doctor or if a recheck of the same submenu is needed. The automatic health care systems and the life support monitoring system are kept in daily contact. C.E.

A90-13613#
OXYGEN SEPARATION SYSTEM OF RESIDENTIAL SPACE AT THE LUNAR BASE
YASUFUMI UEDA, NAOAKI IZUTANI, and HIROYASU YAMAMOTO (Daikin Industries, Ltd., Mechanical Engineering

Laboratory, Sakai, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-574) Copyright

With the aim of developing the lunar resources, helium-3, the scheme to build a lunar base has been advanced. The development of the Closed Ecological Life Support System (CELSS) is important for this scheme of building a lunar base. The investigations of the oxygen separation methods, selection of the suitable oxygen separation methods, and the determination of the equipment specifications are presented in this paper. Author

A90-13626#
MEDICAL RESULTS OF THE FLIGHT OF THE SECOND PRIME CREW ON THE ORBITAL STATION MIR
O. G. GAZENKO, A. I. GRIGORIEV, S. A. BUGROV, V. V. BOGOMOLOV, A. D. EGOROV (Institut Mediko-Biologicheskikh Problem, Moscow, USSR) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p. refs
(IAF PAPER 89-594) Copyright

An analysis of the medical results of the second prime crew flown aboard the Mir station, and in particular of Yuri V. Romanenko, who remained in orbit for 326 days, is presented. Data are reported which show that Romanenko retained good health and high work capacity throughout the flight. This achievement is credited to concerted efforts of the crew and mission control center, and to adequate environment, work-rest cycle, and countermeasures, primarily regular and active exerçise. C.D.

A90-13643#
AN HISTORICAL PERSPECTIVE ON CREW RESCUE AND THE ROLE OF THE ASSOCIATION OF SPACE EXPLORERS
JOHN FABIAN (Association of Space Explorers, San Francisco, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-618) Copyright

The Association of Space Explorers has actively encouraged the development of an international space rescue capability. Space treaties and recent studies concerning this issue are reviewed. International meetings on space safety and rescue have been conducted or are planned for the immediate future. The difficulties of launch readiness, limitations imposed by orbital mechanics, and practical implications of international cooperation have been and are being addressed. It is noted that responsiveness, compatibility, and mutual support are key ingredients of any international rescue plan. B.J.

A90-13646#
SPACE VEHICLE CREW RESCUE - UNIFICATION OF PARAMETERS FOR PERSONAL LIFE SUPPORT AND AIRLOCK SYSTEMS
G. I. SEVERIN, I. P. ABRAMOV, V. I. SVERSCHEK, and R. KN. SHARIPOV (AN SSSR, Sovet Interkosmos, Moscow, USSR) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-621) Copyright

Methods of the emergency evacuation of crew members onto a rescue vehicle and their return to earth are analyzed. It is noted that, when rescue operations involve EVA and the use of different types of space vehicles, the effectiveness of the rescue missions will depend on the compatibility of the EVA suits and the individual life support systems with the corresponding systems of the rescue vehicle. It is proposed that the parameters of the Mir space suit and airlock systems be taken as a basis for a unified approach, making the systems compatible. Specific proposals on the system parameters to be unified are given. B.J.

A90-13723#
VARIABLE GRAVITY RESEARCH FACILITY - AN INTERNATIONAL SPACE UNIVERSITY DESIGN PROJECT
ALICE EICHOLD and ERIC VIIRRE IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER ST-89-005)

NASA's Variable Gravity Research Facility (VGRF) is an innovative spacecraft design development effort aimed at the generation of artificial gravity at various levels, as required for the training and conditioning of manned planetary mission crews. Students participating in the International Space University will undertake a comprehensive study of this spacecraft's various problems in 1989, with a view to the compilation of a report supporting the VGRF's feasibility and requisite implementation methods. The project is considered an important support for a 1000-day manned Mars exploration journey. O.C.

A90-16532* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SPACE STATION ACCOMMODATION OF LIFE SCIENCES IN SUPPORT OF A MANNED MARS MISSION
BARRY D. MEREDITH, KELLI F. WILLSHIRE, JANE A. HAGAMAN (NASA, Langley Research Center, Hampton, VA), and RHEA M. SEDDON (NASA, Johnson Space Center, Houston, TX) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 95-106.
(AAS PAPER 87-233) Copyright

Results of a life science impact analysis for accommodation to the Space Station of a manned Mars mission are discussed. In addition to addressing such issues as on-orbit vehicle assembly and checkout, the study also assessed the impact of a life science research program on the station. A better understanding of the effects on the crew of long duration exposure to the hostile space environment and to develop controls for adverse effects was the objective. Elements and products of the life science accommodation include: the identification of critical research areas; the outline of a research program consistent with the mission timeframe; the quantification of resource requirements; the allocation of functions to station facilities; and a determination of the impact on the Space Station program and of the baseline configuration. Results indicate the need at the Space Station for two dedicated life science lab modules; a pocket lab to support a 4-meter centrifuge; a quarantine module for the Mars Sample Return Mission; 3.9 man-years of average crew time; and 20 kilowatts of electrical power. C.E.

A90-16533
A DIAGNOSTIC AND ENVIRONMENTAL MONITORING SYSTEM (DEMS) CONCEPT TO SUPPORT MANNED MARS IN -FLIGHT AND SURFACE OPERATIONS
CORINNE M. BUONI, MARK S. KOTUR, LARRY S. MILLER, and BENJAMIN BARTILSON (Battelle Memorial Institute, Columbus, OH) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 107-127. refs
(AAS PAPER 87-234) Copyright

A microbiological assay concept for both in-flight and Martian surface application is discussed. The Diagnostic and Environmental Monitoring System (DEMS), which combines state-of-the-art colorimetric and immunoassay technology is proposed. The advantages include the DEMS ability to conduct a large number of biological assay for a variety of samples (liquids, solids, and atmosphere), eliminate time-consuming culturing techniques, provide a high degree of selectivity and sensitivity, respond rapidly, meet the requirement for small size, and use commercially available reagents and assay techniques. The advantages and disadvantages of current and improved microbiological diagnostic and monitoring systems for a manned Mars mission are reviewed. The scientific basis of DEMS and the overall design and operational requirements are identified and discussed, including an engineering development strategy to create an initial version of DEMS available for Space Station applications. C.E.

A90-16534
A ZERO-G CELSS/RECREATION FACILITY FOR AN EARTH/MARS CREW SHUTTLE
ALICE EICHOLD (California, University, Berkeley) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 129-138. refs
(AAS PAPER 87-235) Copyright

This paper presents a zero-gravity architectural design for a

module on an earth/Mars crew shuttle. Although in the early stages of development and of uncertain immediate cost-effectiveness, Controlled Ecological Life Support (CELSS) promises the most synergetic long-term means for providing food, air and water as well as accommodating 'homesickness'. In this project, plant growth units have been combined with recreation facilities to ensure that humans have daily opportunities to view their gardens. Furthermore, human exercise contributes toward powering the mechanical systems for growing the plants. The solution was arrived at by the traditional architectural design process with an empirical emphasis. The solution consists of smaller volumes for exercise facilities and plant growth units contained within a large geometrical sphere. Moisture and heat-generating activities thus share facilities and favorable gas exchanges are exploited. Author

A90-16539
INDIVIDUAL DIFFERENCES, MISSION PARAMETERS, AND SPACEFLIGHT ENVIRONMENT HABITABILITY
ALBERT A. HARRISON, NANCY J. STRUTHERS, and BERNARD J. PUTZ (California, University, Davis) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 191-199. refs
(AAS PAPER 87-240) Copyright

Preliminary results of empirical tests of a Three Factor Model of environmental habitability are discussed. The impact of individual differences, environmental attributes and mission parameters on the rated acceptability of space habitat attributes is analyzed. The individual differences include gender, age, occupational preferences, and preferred levels of activity. Environmental attributes include interior space availability, food and other nutritional quality, availability of good hygiene facilities, and protection against radiation, bone decalcification, cardiac deconditioning, and other medical or health risks. Mission parameters such as mission destination and crew size are manipulated experimentally. Both individual differences and mission parameters affected rated acceptability. It is concluded that spaceflight environment is considered equally acceptable for either a Mars or a moon base. C.E.

A90-16625* National Aeronautics and Space Administration, Washington, DC.
SPACE PHYSIOLOGY AND MEDICINE (2ND EDITION)
ARNAULD E. NICOGOSSIAN, ED. (NASA, Washington, DC), CAROLYN LEACH HUNTOON, ED., and SAM L. POOL, ED. (NASA, Johnson Space Center, Houston, TX) Philadelphia, PA, Lea and Febiger, 1989, 414 p. No individual items are abstracted in this volume.
Copyright

The fundamental biomedical issues involved in manned space flight are examined in review chapters contributed by leading U.S. experts. Sections are devoted to the history of manned space flight, the space environment, space-flight systems and procedures, physiological adaptation to space flight, health maintenance of space crewmembers, and medical problems of space flight. Extensive diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

A90-16656 Life Systems, Inc., Cleveland, OH.
LIFE SUPPORT SYSTEM CONSIDERATIONS AND CHARACTERISTICS FOR A MANNED MARS MISSION
FEROLYN T. POWELL (Life Systems, Inc., Cleveland, OH) IN: The case for Mars III: Strategies for exploration - General interest and overview. San Diego, CA, Univelt, Inc., 1989, p. 135-155. Research supported by NASA and Life Systems, Inc. refs
(AAS PAPER 87-188) Copyright

Both the Low Earth Orbit (LEO) Space Station and future manned space missions require Environmental Control and Life Support Systems (ECLSS) that provide safe, comfortable environments in which humans can live and work. The ECLSS functions and requirements (performance and design load) for these missions are defined. Options for closing the ECLSS cycle are discussed and the level of closure planned for the initial orbital capability (IOC) Space Station are quantified. The impacts of the remaining ECLSS expendables on advanced missions are discussed. Also discussed are the new ECLSS requirements related to generation of food (via plants, animals and/or fish). The paper focuses on the ECLSS design drivers associated with a manned Mars mission. These drivers include environmental, operational and interface drivers. Characteristics of the IOC Space Station ECLSS are given to provide a quantitative feeling of the magnitude of the ECLSS for a Mars mission. Author

A90-17712
WORKING IN ORBIT AND BEYOND: THE CHALLENGES FOR SPACE MEDICINE
VICTORIA GARSHNEK, ED. (George Washington University, Washington, DC), CLAUDE CADOUX, ED. (Union Memorial Hospital, Baltimore, MD), and DAVID B. LORR, ED. San Diego, CA, Univelt, Inc. (Science and Technology Series. Volume 72), 1989, 185 p. For individual items see A90-17713 to A90-17722.
Copyright

Papers on space medicine are presented, covering topics such as the direction of the NASA life science program, vestibular factors influencing biomedical support for humans in space, biomedical research on reduced gravity, medical aspects of the Space Phoenix Program, and bone and muscle maintenance during long-term spaceflight. Other topics include cardiovascular responses to microgravity, space medicine and the Soviet space program, the efficacy of medical countermeasures in space, health maintenance on the Space Station, and radiation hazards in LEO, polar orbit, GEO, and deep space. Additional subjects include solar system exploration, spaceflight and the cardiopulmonary system, simulation facilities of the Soviet space program, and postflight recovery measures and long-duration spaceflight. R.B.

A90-17713* National Aeronautics and Space Administration, Washington, DC.
CURRENT STATUS AND FUTURE DIRECTION OF NASA'S SPACE LIFE SCIENCES PROGRAM
RONALD J. WHITE and BARBARA F. LUJAN (NASA, Life Sciences Div., Washington, DC) IN: Working in orbit and beyond: The challenges for space medicine. San Diego, CA, Univelt, Inc., 1989, p. 1-7.
(AAS PAPER 87-152) Copyright

The elements of the NASA Life Sciences Program that are related to manned space flight and biological scientific studies in space are reviewed. Projects included in the current program are outlined and the future direction of the program is discussed. Consideration is given to issues such as long-duration spaceflight, medical support in space, readaptation to the gravity field of earth, considerations for the Space Station, radiation hazards, environmental standards for space habitation, and human operator interaction with computers, robots, and telepresence systems. R.B.

A90-17717
SOVIET MANNED SPACE FLIGHT - PROGRESS THROUGH SPACE MEDICINE
VICTORIA GARSHNEK (George Washington University, Washington, DC) IN: Working in orbit and beyond: The challenges for space medicine. San Diego, CA, Univelt, Inc., 1989, p. 45-57. refs
(AAS PAPER 87-158) Copyright

An historical overview of the Soviet space program is given, focusing on the role of space medicine in manned spaceflight. Consideration is given to biomedical studies conducted on the Salyut and Mir space stations. Current topics of Soviet research in space medicine are listed. The countermeasures used by the Soviet space program during long-term spaceflight are examined, including exercise programs, the Penguin suit for maintaining the musculoskeletal system, the Chibis vacuum suit, salt water loading, nutritional countermeasures and the use of drugs. Also, consideration is given to postflight recovery activities. R.B.

A90-17718* National Aeronautics and Space Administration, Washington, DC.
RADIATION HAZARDS IN LOW EARTH ORBIT, POLAR ORBIT, GEOSYNCHRONOUS ORBIT, AND DEEP SPACE
PERCIVAL D. MCCORMACK (NASA, Life Sciences Div., Washington, DC) IN: Working in orbit and beyond: The challenges for space medicine. San Diego, CA, Univelt, Inc., 1989, p. 59-78. refs
(AAS PAPER 87-159) Copyright

The predicted doses to the blood forming organs and skin of spacecraft crews in low inclination at high inclination and polar orbits, in LEO and in free space are reviewed. Doses from trapped solar radiation and galactic cosmic radiation are covered, and also those to be expected from anomalous, large solar particle events. They are compared with the maximum annual and career doses laid down by the National Council on Radiation protection (1987). The effect of spacecraft and space suit shielding is also considered. Space Shuttle flights have allowed extensive comparison of predicted doses with those measured experimentally. This has revealed some defects in the radiation and magnetic fields models used and has led to extensive reexamination of these models. Author

A90-17877
GUIDANCE ON RADIATION RECEIVED IN SPACE ACTIVITIES
Bethesda, MD, National Council on Radiation Protection and Measurements (NCRP Report, No. 98), 1989, 237 p. refs
Copyright

The potential effects of radiation on the crews of planned space missions are analyzed on the basis of compiled U.S. and Soviet measurement data, and specific recommendations are presented. Topics addressed include the history of space radiation guidelines and the reasons for the present reappraisal, the space radiation environment (radiation belts, Galactic cosmic rays, and solar-particle events), radiation exposure to personnel, radiobiological features of the space radiation environment, and radiation protection standards. Diagrams, drawings, graphs, and extensive tables of numerical data are provided. T.K.

A90-19743*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ASSURED CREW RETURN VEHICLE FLOWFIELD AND AERODYNAMIC CHARACTERISTICS
K. JAMES WEILMUENSTER, ROBERT E. SMITH, and FRANCIS A. GREENE (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 16 p. refs
(AIAA PAPER 90-0229)

A lifting body has been proposed as a candidate for the Assured Crew Return Vehicle which will serve as crew rescue vehicle for the Space Station. The focus of this work is on body surface definition, surface and volume grid definition, and the computation of inviscid flowfields about the vehicle at wind-tunnel conditions. Very good agreement is shown between the computed aerodynamic characteristics of the vehicle at a freestream Mach number of 10 and those measured in wind-tunnel tests. Author

A90-19987#
NUMERICAL CALCULATIONS OF MASS DIFFUSION AND CONVECTION OF SMOKE IN SPACELAB
J. ALEX WANG, K. C. SHIH, and R. L. HOLLAND (McDonnell Douglas Space Systems Co., Huntsville, AL) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs
(AIAA PAPER 90-0717) Copyright

The study documented in this paper uses a Navier-Stokes flow solver (INS3D) together with an independent Smoke Diffusion and Convection (SDC) program to assess the smoke detection capability inside the Spacelab module. The flow solver INS3D is used to calculate the airflow field within the habitable area of the module, and the trace of smoke particles is determined by the SDC program which utilizes the calculated airflow field as convection mechanism for smoke. The present SDC program has been used for parametric studies of smoke traces inside Spacelab. Numerical results of this study indicates that the location of smoke initiation is critical to smoke detection. The methodology used in this study can be extended to assess smoke detection for the Space Station. Author

A90-20391
POTENTIAL ROLE OF RABBITS AS A SUSTAINABLE ECOLOGICAL COMPONENT IN SPACE STATION VOYAGES
S. D. LUKEFAHR (Alabama Agricultural and Mechanical University, Huntsville) Huntsville Association of Technical Societies, Annual Technical and Business Exhibition and Symposium, 5th, Huntsville, AL, May 16, 17, 1989. 18 p. refs
(TABES PAPER 89-1516) Copyright

The biological potential of the rabbit as a meat-producing animal for long-term space missions is discussed. It is emphasized that rabbit is more efficient in forage protein utilization than most livestock, is in a constant state of reproduction, has a rapid growth rate, exhibits high degree of genetic diversity, is well suited to either large or small colonies, and that its meat is highly nutritious; the nonedible byproducts of the rabbit are rich in nutrient quality for plant culture and/or recycling. Data are presented on the nutrient requirements of the rabbit; the contents of minerals in urine; physiological parameters, including water and oxygen consumption; housing and environmental requirements; and possible human infection sources transmitted by rabbits. I.S.

A90-21632
THE RESCUE OF SALYUT 7
SAUNDERS B. KRAMER Air and Space (ISSN 0886-2257), vol. 4, Feb.-Mar. 1990, p. 54-59.
Copyright

In February 1985, the Soviet space station Salyut 7 suddenly stopped responding to ground control. A cosmonaut crew trained for three months, simulating repair procedures that might be required by Salyut 7 after their Soyuz spacecraft docked at the disabled space station and their inspection had been completed. This mission, Soyuz T-13, ascertained that the Salyut electrical power batteries were dead and proceeded with the neccessary repairs. On September 18, 1985, Soyuz T-14 arrived to resume routine experimentation and earth remote sensing tasks aboard Salyut 7. O.C.

A90-23264*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PERFORMANCE ASSESSMENT OF A SPACE STATION RESCUE AND PERSONNEL/LOGISTICS VEHICLE
J. CHRIS NAFTEL, RICHARD W. POWELL, and THEODORE A. TALAY (NASA, Langley Research Center, Hampton, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 76-81. Previously cited in issue 09, p. 1302, Accession no. A89-25503.
Copyright

A90-23703#
COMBUSTION IN MICROGRAVITY - OPPORTUNITIES, CHALLENGES, AND PROGRESS
C. K. LAW (Princeton University, NJ) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 16 p. refs
(AIAA PAPER 90-0120) Copyright

The present paper discusses the opportunities provided by the microgravity environment for fundamental combustion research, emphasizes the potential of fire hazards in space (and the challenges to devise rational fire prevention and control strategies), and reports on recent progress in microgravity combustion research. Specific microgravity combustion phenomena discussed include flammability limits and near-limit flame propagation, flamefront instabilities, jet diffusion flames, flame stabilization, flame spreading over solid and liquid surfaces, droplet vaporization and combustion, flame propagation in particle suspensions, and fire safety in space environments. Experimental facilities and instrumentation which are either currently available or are being planned for microgravity combustion research are briefly discussed,

and the need to conduct some of the combustion experiments onboard the Space Station Freedom is emphasized. Author

A90-24437* Utah Univ., Salt Lake City.
MEDICAL IMPACT ANALYSIS FOR THE SPACE STATION
BRENT D. NELSON (LDS Hospital, Salt Lake City, UT), REED M. GARDNER, DAVID V. OSTLER, JOHN M. SCHULZ, and JAMES S. LOGAN (NASA, Johnson Space Center; Krug International, Houston, TX; LDS Hospital, Salt Lake City, UT) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, Feb. 1990, p. 169-175. refs
(Contract NAS9-17425)
Copyright

In this study, Space Station medical care priorities were determined by a medical impact analysis of two analog populations, U.S. Army and U.S. Navy personnel. Diseases and injuries in the International Classification of Disease, 9th Revision, Clinical Modification (ICD-9-CM) were ranked, using a Medical Impact Score (MIS) combining modified incidence rate and a function of disease outcome. The validity of the analysis method was tested by measuring rank order correlation between the two analog populations. Despite virtually identical age and sex distributions, Army and Navy incidence rates differed significantly for half of the ICD-9-CM categories, p less than 0.05. Disability rates differed for 76 percent, p less than 0.05. Nevertheless, Army and Navy MIS rank orders for categories and sections were not significantly different, p less than 0.001. In critical ways, the Space Station will be a safer environment than earth. Cardiac events, musculoskeletal injuries, affective psychoses, and renal calculi were among the highest scoring categories. Author

A90-24769
HUMANS IN SPACE - MEDICAL CHALLENGES
JAMES W. HUMPHREYS, JR. IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 125-134.
Copyright

The biomedical aspects of human space activity are examined. An overview of the history of the study of biomedical problems associated with space flight is given. Consideration is given to determining the optimal atmosphere for the cabin of a spacecraft, the effect of microgravity on physiologic functions, the effects of radiation and isolation, and problems associated with the lack of the usual cycles of light and darkness. Also, the problems of nourishment and the elimination of body wastes are discussed. R.B.

A90-24817*# National Aeronautics and Space Administration, Washington, DC.
ARTIFICIAL GRAVITY AS A COUNTERMEASURE IN LONG-DURATION MANNED SPACE FLIGHT
JAMES W. WOLFE and FRANK M. SULZMAN (NASA, Washington, DC) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 309-311.
Copyright

The physiological problems caused by prolonged weightlessness are briefly discussed. Prolonged bed rest is examined as a simulant of prolonged microgravity exposure. The rotation of a spacecraft is considered as a means to counteract the problems caused by prolonged weightlessness. C.D.

A90-24820*# National Aeronautics and Space Administration, Washington, DC.
SPACE IMMUNOLOGY - PAST, PRESENT AND FUTURE
GARY R. COULTER (NASA, Washington, DC), GERALD R. TAYLOR (NASA, Johnson Space Center, Houston, TX), and GERALD SONNENFELD (Louisville, University, KY) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 337, 338. refs
Copyright

Research results on the causes and mechanisms of change in immune systems during spaceflight are briefly reviewed. The most reliable conclusion from the sparse existing data is that postflight crew members exhibit a transient neutrophilia, eosinopenia, monocytopenia, reduced numbers of circulating T cells, and an often pronounced decrease in the ability of their T cells to respond to mitogen stimulation. Clinically, no direct predictive relationship between any of these measurements and increased health risk or disease has been established. Future areas of research are suggested in light of NASA's emerging requirements to support long-duration missions. C.D.

A90-25333
THE PROTONS OF SPACE AND BRAIN TUMORS. II - CELLULAR AND MOLECULAR CONSIDERATIONS
W. A. NAGLE, A. J. MOSS, JR., G. V. DALRYMPLE (John L. McClellan Veterans Hospital; Arkansas, University, Little Rock), A. B. COX, J. F. WIGLE (USAF, School of Aerospace Medicine, Brooks AFB, TX) et al. IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 412-431. refs
Copyright

An increased incidence of highly malignant gliomas, (glioblastoma multiforme) has been observed in Rhesus monkeys irradiated with 55-MeV protons, and in humans treated with therapeutic irradiation to the head. The results suggest a radiation etiology for these tumors. This paper reviews briefly some characteristics of glioma tumors and summarizes the genetic changes associated with malignant gliomas in experimental animals and in humans. The genetic abnoramlities include cytogenetic alterations and changes in the structure and expression of specific oncogenes. Also reviewed are some recent data concerning the molecular nature of radiation-induced somatic-cell mutation and oncogene activation. Finally, some implications of these results are discussed in relation to human radiation exposure in space. Author

A90-25334
PROMOTION OF A NEW RADIOPROTECTIVE ANTIOXIDATIVE AGENT
J. MATSUBARA, A. IKEDA, and T. KINOSHITA (Tokyo, University, Japan) IN: High-energy radiation background in space. New York, American Institute of Physics, 1989, p. 434-441. refs
Copyright

The mechanisms involved in radioprotective pre- or posttreatments with Zn, Mn, or biological-response modifiers (BRMs) were investigated experimentally in 7-week-old mice exposed to whole-body X-ray irradiation of 6.5 or 7.5 Gy. The focus was on the role of the heavy-metal-binding protein metallothionein (MT), produced in the liver, in the development of a tolerance to radiation damage. The experimental protocols are described in detail, and the results are presented in tables and graphs. It is shown that administration of Mn, Zn, or BRMs (and especially a combination of metallic salt and BRM) prior to or even after irradiation significantly increased MT production and also protected the mice against lethal damage. The potential benefits of this type of therapy for space crews are briefly considered. T.K.

A90-26020
ADVANTAGES OF A LOW-OXYGEN ENVIRONMENT IN SPACE CABINS
E. SHVARTZ (Rockwell International Corp., Space Transportation Systems Div., Downey, CA) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 61, March 1990, p. 272-276. refs
Copyright

The advantages of having a low-oxygen environment in space cabins are discussed. The major advantage is a sharply reduced fire hazard, which is a major threat in manned space flights. At 1 atm, for example, 15 percent O2 (9000 ft altitude equivalent) would

not support most fires and could accommodate the crew with respect to hypoxia, decompression sickness (DCS), and other requirements. Chronic exposure to such a hypoxic environment (altitude acclimatization) could imporve major areas of crew health and safety, including alleviating deconditioning effects, decreasing susceptibility to DCS, and improving tolerance to severe hypoxia. Author

A90-27403* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
RADIOLOGICAL HEALTH RISKS
D. STUART NACHTWEY (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 5 p. refs
(SAE PAPER 891432) Copyright

The crew of a manned Mars mission will be unavoidably exposed to galactic cosmic ray (GCR) flux. The Mars mission crew shielded by 2 g/sq cm Al could receive about 0.7 Sv in a 460-day mission at solar minimum. However, three-fourths of this dose-equivalent in free space is contributed by high LET heavy ions (Z 3 or greater) and target fragments with average Q of 10.3 and 20, respectively. Such high quality factors for these particles may be inappropriate. Moreover, in a 460-day mission, less than half of the nuclei in the body of an astronaut will have been traversed by a single heavy particle. The entire concept of absorbed dose/quality factors/dose-equivalents as applied to GCR must be reconsidered. Author

A90-27405
PERIODIC ACCELERATION STIMULATION IN SPACE
RUSSELL R. BURTON (USAF, School of Aerospace Medicine, Brooks AFB, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 6 p. refs
(SAE PAPER 891434; AD-A221337) Copyright

The need to provide acceleration in space for astronauts to prevent the physiologic debilitating effects of weightlessness termed the weightless adaptation syndrome (WAS), is discussed. The use of a short-radius 1.5-1.8 m centrifuge to provide short-duration (less than 2 hrs) periodic (perhaps daily or less frequent) exposures of 1 G or greater to prevent WAS is proposed. This approach is termed periodic acceleration stimulation in a weightless environment (PAS-WE). Four human-use studies are described that are considered necessary to validate the usefulness of PAS-WE to prevent WAS and to provide the necessary information for aerospace engineers to design and build the proper centrifuge for Space Station. Author

A90-27413* Umpqua Research Co., Myrtle Creek, Ore.
APPLICATION OF BIOCATALYSTS TO SPACE STATION ECLSS AND PMMS WATER RECLAMATION
CLIFFORD D. JOLLY (UMPQUA Research Co., Myrtle Creek, OR) and ROBERT M. BAGDIGIAN (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 7 p. refs
(Contract NAS8-37642)
(SAE PAPER 891442) Copyright

Immobilized enzyme reactors have been developed and tested for potential water reclamation applications in the Space Station Freedom Environmental Control and Life Support System (ECLSS) and Process Materials Management System (PMMS). The reactors convert low molecular weight organic contaminants found in ECLSS and PMMS wastewaters to compounds that are more efficiently removed by existing technologies. Demonstration of the technology was successfully achieved with two model reactors. A packed bed reactor containing immobilized urease was found to catalyze the complete decomposition of urea to by-products that were subsequently removed using conventional ion exchange results. A second reactor containing immobilized alcohol oxidase showed promising results relative to its ability to convert methanol and ethanol to the corresponding aldehydes for subsequent removal. Preliminary assessments of the application of biocatalysts to ECLSS and PMMS water reclamation sytems are presented. Author

A90-27414* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
TEST RESULTS ON REUSE OF RECLAIMED SHOWER WATER - A SUMMARY
CHARLES E. VEROSTKO, RAFAEL GARCIA, RICHARD SAUER (NASA, Johnson Space Center, Houston, TX), RICHARD P. REYSA (Boeing Aerospace and Electronics, Houston, TX), ARTHUR T. LINTON (Hamilton Standard Management Services, Inc., Houston, TX) et al. SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 17 p.
(SAE PAPER 891443) Copyright

Results are presented from tests to evaluate a microgravity whole body shower and waste water recovery system design for possible use on the Space Station. Several water recovery methods were tested, including phase change distillation, a thermoelectric hollow fiber membrane evaporation subsystem, and a reverse osmosis dynamic membrane system. Consideration is given to the test hardware, the types of soaps evaluated, the human response to showering with reclaimed water, chemical treatment for microbial control, the procedures for providing hygienic water, and the quality of water produced by the systems. All three of the waste water recovery systems tested successfully produced reclaimed water for reuse. R.B.

A90-27415
WATER RECOVERY BY VAPOR COMPRESSION DISTILLATION
ROBERT N. SCHMIDT (Life Systems, Inc., Cleveland, OH) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p. refs
(SAE PAPER 891444) Copyright

The use of vapor compression distillation (VCD) as the water recovery procedure for the Space Station is examined. This method is proposed for the Ultrapure Water System of the Space Station. The VCD procedure is described. The applicability of the VCD is evaluated and compared with a thermoelectrically integrated membrane evaporation subsystem. The data reveal that the VCD provides better quality product water, higher water recovery rates, higher capacity, and is cost effective. I.F.

A90-27416* Umpqua Research Co., Myrtle Creek, Ore.
RECOVERY OF HYGIENE WATER BY MULTIFILTRATION
DAVID F. PUTNAM, CLIFFORD D. JOLLY, GERALD V. COLOMBO (UMPQUA Research Co., Myrtle Creek, OR), and DON PRICE (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p.
(Contract NAS9-17523)
(SAE PAPER 891445) Copyright

A multifiltration hygiene water reclamation process that utilizes adsorption and particulate filtration techniques is described and evaluated. The applicability of the process is tested using a simulation of a 4-man subsystem operation for 240 days. It is proposed the process has a 10 year life, weighs 236 kg, and uses 88 kg of expendable filters and adsorption beds to process 8424 kg of water. The data reveal that the multifiltration is an efficient nonphase change technique for hygiene water recovery and that the chemical and microbiological purity of the product water is within the standards specified for the Space Station hygiene water. I.F.

A90-27417* Bend Research, Inc., OR.
A NOVEL MEMBRANE-BASED WATER-RECLAMATION POSTTREATMENT UNIT
JANE KUCERA GLENGER, RODERICK J. RAY, SCOTT B. MCCRAY (Bend Research, Inc., OR), and DAVID PUTNAM (UMPQUA Research Co., Myrtle Creek, OR) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p. refs
(Contract NAS9-17611)
(SAE PAPER 891446) Copyright

This paper describes the development of an advanced membrane/sorption-bed hybrid subsystem to posttreat humidity

condensate and phase-change distillate generated during space missions. Discussed are the design and construction of a breadboard hybrid subsystem, and data showing the performance of this subsystem operating for more than 90 days. The purpose of this program was to reduce the number of sorption beds required by this subsystem by using membranes to concentrate the contaminants. Tests show that the breadboard hybrid subsystem presented here uses 50 percent fewer sorption beds than a stand-alone multifiltration process. Author

A90-27419
SPACE STATION FREEDOM CARBON DIOXIDE REMOVAL ASSEMBLY
ROBERT KAY and LORI WOODWARD (Allied-Signal Aerospace Co., Torrance, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p.
(SAE PAPER 891449) Copyright

Carbon dioxide removal from the Space Station Freedom atmosphere is an essential part of the overall life support and oxygen reclamation process. The system must selectively remove carbon dioxide from an air supply stream, then concentrate it for downstream processing in a carbon dioxide reduction system where oxygen is eventually recovered. Space Station Freedom will utilize a four-bed molecular sieve system for the carbon dioxide removal assembly. This system uses the principle of adsorption to selectively remove and concentrate carbon dioxide. The technology required for the four-bed system is well established and was proven in space flight during the Skylab program. This paper describes the four-bed molecular sieve carbon dioxide removal system, its operation, and its key components. Author

A90-27420
PRELIMINARY EVALUATION OF A MEMBRANE GAS SEPARATION UNIT FOR SPACE STATION FREEDOM ATMOSPHERE REVITALIZATION SUBSYSTEM
RONALD J. KUSE (Boeing Aerospace and Electronics, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 19 p. refs
(SAE PAPER 891450) Copyright

A study was initiated to investigate the potential of integrating a membrane gas separation unit into the Space Station Atmosphere Revitalization Subsystem to remove inert impurities in the carbon dioxide stream fed to the Bosch reduction reactor. Removal of the inerts eliminates the need for a reactor bleed stream and subsequent treatment. Preliminary calculations indicate that under normal operating conditions, inclusion of the membrane unit reduces Atmosphere Revitalization power consumption and heat rejection by 388 and 300 watts, respectively, and causes only small weight and space penalties to be incurred. According to current cost factors, an annual net savings of $0.76 million (in 1989 dollars) excluding separator hardware costs is realized. Although based on preliminary data and estimates, there appears to be reasons for cautious optimism in the proposed design modification and continuation of the study to obtain more detailed data. Author

A90-27421
ATMOSPHERIC COMPOSITION MONITOR ASSEMBLY FOR SPACE STATION FREEDOM ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM
MARY A. ROTHERAM (Perkin-Elmer Corp., Applied Science Div., Pomona, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p.
(SAE PAPER 891451) Copyright

The Atmospheric Composition Monitor Assembly (ACMA) is an instrument for monitoring the composition of the atmosphere in Space Station Freedom. The ACMA is composed of the following major instruments: Major Constituent Analyzer (MCA); Carbon Monoxide Monitor (COM); Trace Contaminant Monitor (TCM); and Particle Counter Monitor (PCM). the MCA is a mass spectrometer based system that provides continuous monitoring of major atmospheric constituents (O2, CO2, N2, H2O) and of hydrogen and ethane. The COM is a nondispersive infrared instrument for the continuous monitoring of trace levels of carbon monoxide. The TCM is a gas chromatograph-mass spectrometer for monitoring trace levels of contaminants. The PCM monitors the concentration of particulates in the 0.5 to 100 micron range using a light scattering technique. Author

A90-27423*
VACUUM RESOURCE PROVISION FOR SPACE STATION FREEDOM
KENNETH J. LASKEY, THEODORE G. MORDFIN, and THOMAS W. RUSS (Grumman Corp., Reston, VA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 17 p. refs
(Contract NASW-4300)
(SAE PAPER 891453) Copyright

The use of vacuum resources is integral to a number of proposed concepts for gas disposal from Space Staton Freedom. These include both direct overboard venting and onboard collection and storage of waste gases. A methodology is presented for determining flowrates through proposed vacuum lines. The flowrates through overboard vents are used to calculate number column densities, which are compared with current Freedom program requirements. The results are combined with discussions about the relative merits of some proposed and alternate concepts for providing vacuum resources. Author

A90-27439* Lockheed Engineering and Sciences Co., Houston, TX.
ENABLING HUMAN EXPLORATION OF SPACE - A LIFE SCIENCES OVERVIEW
KAREN K. GAISER (Lockheed Engineering and Sciences Co., Washington, DC) and FRANK M. SULZMAN (NASA, Life Sciences Div., Washington, DC) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 6 p.
(SAE PAPER 891471) Copyright

In the transition from the short-duration missions of the Space Shuttle era to long-duration exploration missions, the health and safety of crewmembers must be ensured. The body undergoes many complex physiological changes as a result of its adaptation to a microgravity environment and U.S. and Soviet experiences have shown that time is required for readaptation to gravity. The consequences of these changes for the extended exploration missions envisioned for the future are unknown. A Mars mission may require crewmembers to spend many months in microgravity, and then work effectively in a one-third gravity environment. Other problems may arise when returning crewmembers must readapt to earth's gravity. Life Sciences activities are being planned to systematically address the physiological issues involved with long-term manned exploration missions, through ground-based studies and flight investigations on the Shuttle and Space Station Freedom. The areas of focus are artificial gravity, radiation, health care, and space human factors. Author

A90-27440* Grumman Aerospace Corp., Bethpage, NY.
A HUMAN FACTORS EVALUATION OF EXTRAVEHICULAR ACTIVITY GLOVES
JOHN M. O'HARA, MICHAEL BRIGANTI (Grumman Space Systems, Bethpage, NY), JOHN CLELAND, and DAN WINFIELD (Research Triangle Institute, Research Triangle Park, NC) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p.
(Contract NAS9-17702)
(SAE PAPER 891472) Copyright

One of the major problems faced in Extravehicular Activity (EVA) glove development has been the absence of concise and reliable methods to measure the effects of EVA gloves on human-hand capabilities. NASA has sponsored a program to develop a standardized set of tests designed to assess EVA-gloved hand capabilities in six performance domains: Range of Motion, Strength, Tactile Perception, Dexterity, Fatigue, and Comfort. Based upon an assessment of general human-hand functioning and EVA task

requirements, several tests within each performance domain were developed to provide a comprehensive evaluation. All tests were designed to be conducted in a glove box with the bare hand, an EVA glove without pressure, an EVA glove at operation pressure. Thus, the differential effect on performance of the glove with and without pressure was tested. Bare hand performance was used to 'calibrate' the effects. Ten subjects participated in the test setup as a repeated-measures experimental design. The paper will report the results of the test program. Author

A90-27442
EVOLUTION OF SPACE STATION - LIFE SCIENCES PROGRAM AND FACILITIES
SJOERD L. BONTING (SETI Institute, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p. refs
(SAE PAPER 891474) Copyright

The needs for life sciences research and facilities on Space Station in Phase 2, based on future space exploration and utilization plans, are discussed. The assumed scenario involves a Lunar Base, manned missions to Mars, and an orbiting Space Colony for the production of Solar Power Satellites permitting replacement of fossil fuels by the middle of the next century. From this scenario, the contours of a life sciences program for the period after 1998 are derived. Based on the main elements of such a program, the major new life sciences facilities needed in Phase 2 are identified. It is concluded that a full-length dedicated life sciences module and an attached short module with large centrifuge and animal research facilities, as well as a man-rated variable research facility and other attached facilities are needed. A proposed deployment schedule for these facilities is presented. Should replacement of fossil fuels by space-derived solar power not be necessary, then the same elements and facilities will be needed, but the schedule can be relaxed. Author

A90-27443* NASA Space Station Program Office, Reston, VA.
SPACE STATION FREEDOM (SSF) CREW SYSTEMS SE&I
FRANK H. AUSTIN, JR. (NASA, Space Station Freedom Program Office, Reston, VA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 6 p. refs
(SAE PAPER 891475) Copyright

Space Station program office planning and requirements activity has accelerated during the past year to bring the Space Station Freedom Program (SSF) through the program requirements review phase during 1988. The preliminary design review cycle began in Jan. 89, and is now planned for completion, with formal preliminary design reviews between Apr. and Sept., 1990. This paper briefly describes the PROGRAMMATIC aspects of the engineering and integration management of the SSF crew systems. Emphasis is given to the Crew Health Care System, which includes the Health Maintenance Facility, the Exercise Countermeasure Facility, and the Environmental Health System; all managed within the Man-Systems, one of the twelve 'distributed systems.' Medical and engineering requirements to meet the needs of the mature Space Station operations environment and highlights of critical technologies and equipment in development will be reviewed. Author

A90-27444
OUTFITTING OF THE CREW HEALTH CARE SYSTEM FOR THE SPACE STATION FREEDOM
JOHN J. NAGEL, RICHARD A. SMITH, MICHAEL F. STOLLE, and JOHN B. TROWBRIDGE (McDonnell Douglas Space Systems Co., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 15 p.
(SAE PAPER 891476) Copyright

Crew medical care will be one of the most essential provisions of the Space Station of the 1990s. Increased duration in space, reduced crew selectivity, and reduced return to earth capability all speak strongly for a complete set of medical instrumentation and supplies, countermeasures for space adaptation syndrome, and the capability to closely monitor the total environment in which the crew live and work. Foreseeing these needs, NASA has committed to the development of a Crew Health Care Element for Space Station Freedom. It consists of three systems: Health Maintenance Facility, Exercise Countermeasures Facility, and Environmental Health System. For the majority of the equipment to outfit these systems, space flight ready instruments do not exist. Therefore, commercial off the shelf items will have to be converted to flight certification levels and some will even have to be modified to accommodate the microgravity conditions of Space Station Freedom. Still other capabilities will have to be developed from the ground up. The development of the CHeC element will provide many challenges to the project engineers and scientists. Author

A90-27446
PERFORMANCE SIMULATION OF ENVIRONMENTAL CONTROL SYSTEMS WITH INTERFACE ORIENTED MODELLING TECHNIQUE
MARKUS ROTHMEYER and RALF SIMON (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. refs
(SAE PAPER 891478) Copyright

The use of an interface oriented modeling technique for the assembly, subsystem, and system simulation of the Enviromental Control and Life Support System (ECLSS) is examined. The modular nature of the basic concept and the use of several numerical solution techniques are discussed. As an example, the simulation of a simplified ECLS subsystem, the related input data, and the computed results are presented. Areas of further developments aimed at the creation of a knowledge based simulation tool are outlined. V.L.

A90-27447
ON THE REPRESENTATION OF LIFE-SUPPORT SYSTEM MODELS
HEINZ A. PREISIG, TAE YEONG LEE, FRANK LITTLE, and BRUCE WRIGHT (Texas A & M University, College Station) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 15 p. refs
(SAE PAPER 891479) Copyright

A canonical decomposition of models describing physical-chemical-biological systems is described which is based on Newtonian physics and axiomatic thermodynamics. The resulting hierarchical representation of complex models prepares for an object oriented modeling support tool which will readily interface to knowledge-based tools. It also approaches the documentation problem for large systems and has the structure that allows multiple user interfaces to be implemented each of which is specific for a certain group of researchers in the interdisciplinary team. Author

A90-27448* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DAWN (DESIGN ASSISTANT WORKSTATION) FOR ADVANCED PHYSICAL-CHEMICAL LIFE SUPPORT SYSTEMS
MARY R. RUDOKAS, ELIZABETH R. CANTWELL (NASA, Ames Research Center, Moffett Field, CA), PETER I. ROBINSON, and TIMOTHY W. SHENK (RECOM Software, Inc., Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p. refs
(SAE PAPER 891481) Copyright

This paper reports the results of a project supported by the National Aeronautics and Space Administration, Office of Aeronautics and Space Technology (NASA-OAST) under the Advanced Life Support Development Program. It is an initial attempt to integrate artificial intelligence techniques (via expert systems) with conventional quantitative modeling tools for advanced physical-chemical life support systems. The addition of artificial intelligence techniques will assist the designer in the definition and simulation of loosely/well-defined life support processes/problems as well as assist in the capture of design knowledge, both quantitative and qualitative. Expert system and conventional modeling tools are integrated to provide a design

workstation that assists the engineer/scientist in creating, evaluating, documenting and optimizing physical-chemical life support systems for short-term and extended duration missions. Author

A90-27449
THE IMPACT OF THE WATER RECOVERY AND MANAGEMENT (WRM) SUBSYSTEM WASTEWATER RECOVERY EFFICIENCY UPON THE SPACE STATION FREEDOM ECLSS WATER BALANCE
JAMES ROCKTOFF (Grumman Corp., Space Station Program Support Div., Reston, VA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 23 p. refs
(SAE PAPER 891482) Copyright

A parametric study of the impact of the ECLSS water recovery subsystem wastewater processing efficiency upon the overall Space Station Freedom water balance was performed. A representative range of recovery efficiencies was used for each of the three different water recovery processes. The recovery efficiency associated with the hygiene wastewater reclamation process proved to be particularly significant in determining the overall Space Station Freedom ECLSS water balance because of the relatively large volume of fluid treated within this loop. The analysis also indicated that a positive ECLSS water balance depended upon the ability to double process the concentrated brine discharged from the reverse osmosis waste-hygiene-water processor. Implications of the WRM subsystem sensitivity analysis results for the Space Station Freedom ECLSS as well as the effects upon the propulsion and fluid management systems are discussed. R.E.P.

A90-27450* McDonnell-Douglas Space Systems Co., Huntsville, AL.
MICROGRAVITY SENSITIVITIES FOR SPACE STATION ECLS SUBSYSTEMS
M. E. BANGHAM, T. W. CARROLL (McDonnell Douglas Space Systems Co., Huntsville, AL), and W. R. HUMPHRIES (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p.
(SAE PAPER 891483) Copyright

This report presents a review of the Space Station Environmental Control and Life Support subsystems (ECLSS) for sensitivity to low gravity environments. The object of this review is to categorize sensitivity areas and to quantify the risks. This review addresses all processes from a top level view and then examines in more detail those areas which were considered potential risks. The study has concentrated on the primary function of the subsystems which may be significant to the performance of the particular component and does not address integration of the subsystem and/or the mechanical aspects of the designs. The areas of primary concern were the Atmosphere Revitalization (AR), Water Recovery and Management (WRM), and the Waste Management (WM) subsystems. Author

A90-27451
FEASIBILITY OF A COMMON ELECTROLYZER FOR SPACE STATION FREEDOM
DONALD H. SARGENT (Grumman Corp., Space Station Program Support Div., Reston, VA) and GEORGE R. SCHMIDT (Booz-Allen and Hamilton, Inc., Bethesda, MD) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p. refs
(SAE PAPER 891484) Copyright

The Baseline Space Station Freedom architecture calls for separate and independent water electrolysis subsystems in ECLSS and in Propulsion. A study to assess the potential benefits and impacts of electrolyzer commonality evaluated fifteen sets of ECLSS and Propulsion architectural options with graduated levels of commonality, first by quantifying the electrical power, weight, volume, and heat rejection requirements; and then qualitatively according to safety and redundancy, reliability and maintainability, integration and verification, and assembly. There were no compelling quantitative or qualitative advantages of the options incorporating commonality which would drive a decision to alter the Baseline. The options were also compared with respect to estimated program costs. The maximum projected savings were less than five per cent, likely within the uncertainty of the estimation process. The overall conclusion reached was that the Baseline, of independent unit design and subsystem architectures, should be retained. Author

A90-27452* Texas A&M Univ., College Station.
COMPARISON OF WASTE COMBUSTION AND WASTE ELECTROLYSIS - A SYSTEMS ANALYSIS
MARK T. HOLTZAPPLE and FRANK E. LITTLE (Texas A & M University, College Station) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 36 p. refs
(Contract NAG9-253)
(SAE PAPER 891485) Copyright

A steady state model of a closed environmental system has been developed which includes higher plant growth for food production, and is designed to allow wastes to be combusted or electrolyzed. The stoichiometric equations have been developed to evaluate various trash compositions, food items (both stored and produced), metabolic rates, and crew sizes. The advantages of waste electrolysis versus combustion are: (1) oxygen is not required (which reduces the load on the oxygen producing system); (2) the CO2 and H2 products are produced in pure form (reducing the load on the separators); and (3) nitrogen is converted to nitrate (which is directly usable by plants). Weight tradeoff studies performed using this model have shown that waste electrolysis reduces the life support weight of a 4-person crew by 1000 to 2000 kg. R.E.P.

A90-27457
POTENTIAL FOR REDUCTION OF DECOMPRESSION SICKNESS BY PREBREATHING WITH 100 PERCENT OXYGEN WHILE EXERCISING
JAMES T. WEBB, JANET F. WIEGMAN (Krug International Corp., San Antonio, TX), and GENE A. DIXON (USAF, School of Aerospace Medicine, Brooks AFB, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 6 p. refs
(Contract F33615-85-C-4503; F33615-89-C-0603)
(SAE PAPER 891490) Copyright

Exercise performed for at least 30 min while prebreathing 100 percent oxygen prior to decompression has been reported to increase efficiency of denitrogenation by 100-500 percent. The incidence of decompression sickness following such a prebreathe was decreased by 50 percent compared to resting prebreathe. This article provides background and recommends parameters for a test to determine the operational feasibility of prebreathing with exercise. Author

A90-27458* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
ECOLOGY OF MICRO-ORGANISMS IN A SMALL CLOSED SYSTEM - POTENTIAL BENEFITS AND PROBLEMS FOR SPACE STATION
E. B. RODGERS (NASA, Marshall Space Flight Center, Huntsville, AL), D. B. SEALE, M. E. BORAAS, and C. V. SOMMER (Wisconsin, University, Milwaukee) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(SAE PAPER 891491) Copyright

The probable sources and implications of microbial contamination on the proposed Space Station are discussed. Because of the limited availability of material, facilities and time on the Space Station, we are exploring the feasibility of replacing traditional incubation methods for assessing microbial contamination with rapid, automated methods. Some possibilities include: ATP measurement, microscopy and telecommunications, and molecular techniques such as DNA probes or monoclonal

antibodies. Some of the important ecological factors that could alter microbes in space include microgravity, exposure to radiation, and antibiotic resistance. Author

A90-27459* Wisconsin Univ., Milwaukee.
THE USE OF MODELS TO PREDICT POTENTIAL CONTAMINATION ABOARD ORBITAL VEHICLES
MARTIN E. BORAAS and DIANNE B. SEALE (Wisconsin, University, Milwaukee) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p. refs
(Contract NAS8-37914)
(SAE PAPER 891492) Copyright

A model of fungal growth on air-exposed, nonnutritive solid surfaces, developed for utilization aboard orbital vehicles is presented. A unique feature of this testable model is that the development of a fungal mycelium can facilitate its own growth by condensation of water vapor from its environment directly onto fungal hyphae. The fungal growth rate is limited by the rate of supply of volatile nutrients and fungal biomass is limited by either the supply of nonvolatile nutrients or by metabolic loss processes. The model discussed is structurally simple, but its dynamics can be quite complex. Biofilm accumulation can vary from a simple linear increase to sustained exponential growth, depending on the values of the environmental variable and model parameters. The results of the model are consistent with data from aquatic biofilm studies, insofar as the two types of systems are comparable. It is shown that the model presented is experimentally testable and provides a platform for the interpretation of observational data that may be directly relevant to the question of growth of organisms aboard the proposed Space Station. R.E.P.

A90-27466
PRELIMINARY G189A COMPUTER PROGRAM MODELING OF THE SPACE STATION ECLSS
ROBERT S. BARKER and ROGER VON JOUANNE (Boeing Aerospace and Electronics, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 19 p.
(SAE PAPER 891499) Copyright

The G189A computer model of the baseline Space Station ECLSS is described, and some modeling results are examined. The model is at an early stage of refinement and, at present, used primarily to obtain detailed fluid-interface mass flows and other mass-balance information, while thermal exchange and interrelationships are simplified. The discussion covers the general configuration of ECLSS and key design requirements; modeling of the Temperature and Humidity Control and Atmosphere Revitalization subsystems; modeling of potable and hygiene water systems; and an example of G189A Space Station model performance analyses. V.L.

A90-27467* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SYSTEM LEVEL DESIGN ANALYSES FOR THE SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM
A. S. BACSKAY and J. C. KNOX (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 19 p. refs
(SAE PAPER 891500) Copyright

The development and verification of a computer model for the design and analysis of the current Space Station ECLSS configuration are discussed. The model is used to resolve system-level design issues, such as sizing accumulators and assessing flow control techniques. Actual component verification efforts are outlined, and technical aspects of each component model are identified. The results obtained to date and plans for future analytical efforts are summarized. V.L.

A90-27469* McDonnell-Douglas Space Systems Co., Houston, TX.
MASS ANALYSIS FOR THE SPACE STATION ECLSS USING THE BALANCE SPREADSHEET METHOD
WEN-HO CHU (McDonnell Douglas Space Systems Co., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. Research supported by NASA. refs
(SAE PAPER 891502) Copyright

The balance spreadsheet method is applied to mass analysis of the Environmental Control and Life Support System (ECLSS). The spreadsheet layout reduces the complexity of the ECLSS analysis by concisely defining the sources, sinks, and net changes in mass for each fluid. The analysis method is illustrated by using information from the latest Space Station ECLSS Architectural Control Documents and a given Space Station assembly sequence. The analysis results are plotted and discussed. Author

A90-27470
ARTIFICIAL INTELLIGENCE APPLICATION TO ADVANCED ECLS SYSTEMS
BENJAMIN E. BISHOP, JR. and ALBERT M. BOEHM (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 11 p. refs
(SAE PAPER 891503) Copyright

The role of advanced automation and artificial intelligence in facilitating ECLSS control and diagnostics is reviewed with reference to the preliminary design of the Space Station. In particular, the possible role of advanced computer capabilities in advanced missions, such as the growth station and moon and Mars exploration, is examined. The benefits of artificial intelligence are discussed from both the expert system and learned system perspectives. V.L.

A90-27471
APPLICATION OF BIOREGENERATIVE SUBSYSTEMS TO AN ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM FOR A MANNED MARS SPRINT MISSION
S. R. GUSTAVINO and M. M. MANKAMYER (McDonnell Douglas Space Systems Co., Space Station Div., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p. refs
(SAE PAPER 891504) Copyright

This paper describes the application of bioregenerative subsystems to an environmental control and life support system (ECLSS) for long-duration manned Mars missions. Special attention is given to the integration of new bioregenerative subsystems into a computer model of an ECLSS for such a mission. The model is being developed using both the existing physicochemical computer simulations and new bioregenerative component simulations, along with a plant growth unit (PGU) which simulates the growth cycle for white potatoes. The ECLSS configuration and the PGU structure are discussed, and diagrams of both are presented. I.S.

A90-27472* Boeing Aerospace Co., Seattle, WA.
LIFE SUPPORT SYSTEM DEFINITION STUDY FOR LONG DURATION PLANETARY MISSIONS
T. SLAVIN, P. MEYER (Boeing Aerospace and Electronics, Seattle, WA), and R. REYSA (Boeing Aerospace and Electronics, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p.
(Contract NAS9-18040)
(SAE PAPER 891505) Copyright

The development of a mission planners life support systems (LSS) guidebook for providing data on the impact of various LSS on mission parameters such as mass, power, and volume is discussed. The factors utilized to define LSS case study mission drivers, and driver and mission impact parameter definitions are described. An example of a guidebook table for a specific set of LSS drivers is provided. Four approaches for physical/chemical closed-loop LSS are examined. A preliminary LSS guidebook for a lunar base is presented. I.F.

A90-27473* Westinghouse Research and Development Center, Pittsburgh, PA.
CARBON DIOXIDE AND WATER VAPOR HIGH TEMPERATURE ELECTROLYSIS
ARNOLD O. ISENBERG (Westinghouse Research and Development Center, Pittsburgh, PA) and CHARLES E. VEROSTKO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 18 p.
(Contract NAS9-17590)
(SAE PAPER 891506) Copyright

The design, fabrication, breadboard testing, and the data base obtained for solid oxide electrolysis systems that have applications for planetary manned missions and habitats are reviewed. The breadboard tested contains sixteen tubular cells in a closely packed bundle for the electrolysis of carbon dioxide and water vapor. The discussion covers energy requirements, volume, weight, and operational characteristics related to the measurement of the reactant and product gas compositions, temperature distribution along the electrolyzer tubular cells and through the bundle, and thermal energy losses. The reliability of individual cell performance in the bundle configuration is assessed. V.L.

A90-27474* Bend Research, Inc., OR.
INVESTIGATION OF HUMIDITY CONTROL VIA MEMBRANE SEPARATION FOR ADVANCED EXTRAVEHICULAR MOBILITY UNIT (EMU) APPLICATION
D. D. NEWBOLD, R. J. RAY, W. A. PLEDGER, S. B. MCCRAY (Bend Research, Inc., OR), and M. F. BROWN (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(Contract NAS9-17983)
(SAE PAPER 891507) Copyright

This paper describes the development of a membrane-based process for dehumidifying the Extravehicular Mobility Unit (EMU). The membrane process promises to be smaller, lighter, and more energy efficient than the other technologies for dehumidification. The dehydration membranes were tested for 90 days at conditions expected to be present in the EMU. The results of these tests indicate that membrane-based technology can effectively control humidity in the EMU. Author

A90-27475* Photo Catalytics, Inc., Boulder, CO.
PHOTOCATALYTIC POST-TREATMENT IN WASTE WATER RECLAMATION SYSTEMS
GERALD COOPER, MATTHEW A. RATCLIFF (Photo-Catalytics, Inc., Boulder, CO), and CHARLES E. VEROSTKO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p. refs
(Contract NAS9-17983)
(SAE PAPER 891508) Copyright

A photocatalytic water purification process is described which effectively oxidizes organic impurities common to reclaimed waste waters and humidity condensates to carbon dioxide at ambient temperatures. With this process, total organic carbon concentrations below 500 ppb are readily achieved. The temperature dependence of the process is well described by the Arrhenius equation and an activation energy barrier of 3.5 Kcal/mole. The posttreatment approach for waste water reclamation described here shows potential for integration with closed-loop life support systems. V.L.

A90-27476* Texas A&M Univ., College Station.
PERFORMANCE CHARACTERIZATION OF WATER RECOVERY AND WATER QUALITY FROM CHEMICAL/ORGANIC WASTE PRODUCTS
W. M. MOSES, T. D. ROGERS, H. CHOWDHURY (Texas A & M University, College Station), and H. S. CULLINGFORD (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(Contract NAG9-251; NAG9-253)
(SAE PAPER 891509) Copyright

The water reclamation subsystems currently being evaluated for the Space Shuttle Freedom are briefly reviewed with emphasis on a waste water management system capable of processing wastes containing high concentrations of organic/inorganic materials. The process combines low temperature/pressure to vaporize water with high temperature catalytic oxidation to decompose volatile organics. The reclaimed water is of potable quality and has high potential for maintenance under sterile conditions. Results from preliminary experiments and modifications in process and equipment required to control reliability and repeatability of system operation are presented. V.L.

A90-27477* Texas A&M Univ., College Station.
ELECTROCHEMICAL INCINERATION OF WASTES
L. KABA, G. D. HITCHENS, and J. O'M. BOCKRIS (Texas A & M University, College Station) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 17 p. refs
(Contract NAG9-192)
(SAE PAPER 891510) Copyright

A low temperature electrolysis process has been developed for the treatment of solid waste material and urine. Experiments are described in which organic materials are oxidized directly at the surface of an electrode. Also, hypochlorite is generated electrochemically from chloride component of urine. Hypochlorite can act as a strong oxidizing agent in solution. The oxidation takes place at 30-60 C and the gaseous products from the anodic reaction are carbon dioxide, nitrogen, oxygen. Hydrogen is formed at the cathode. Carbon monoxide, and nitrogen oxides and methane were not detected in the off gases. Chlorine was evolved at the anode in relatively low amounts. Author

A90-27478
THE CHALLENGE OF INTERNAL CONTAMINATION IN SPACECRAFT, STATIONS, AND PLANETARY BASES
JON R. SCHULZ (Martin Marietta Corp., Astronautics Group, Denver, CO) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p. refs
(SAE PAPER 891512) Copyright

The problem of internal contamination is examined with emphasis on a contamination assessment and management program based on a graphic model of potential contaminant sources, flow paths, and sensitive receptors. The model provides a basis for systematically identifying issues, assessing risk, identifying where the knowledge base must evolve, and mitigating significant effects. Potential solutions to internal contamination problems are discussed. V.L.

A90-27479
SPACE STATION FREEDOM GASEOUS TRACE CONTAMINANT LOAD MODEL DEVELOPMENT
MARK I. LEBAN and PHILLIP A. WAGNER (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p. refs
(SAE PAPER 891513) Copyright

A Space Station Freedom gaseous contaminant load model has been developed. It consists of 214 contaminants with their Spacecraft Maximum Allowable Concentrations, and their estimated generation rates. The Space Station Freedom load model is based on load models developed for previous space missions. It should be considered a preliminary, not a final load model, as it is continually being expanded and updated as new data on Space Station Freedom becomes available. Author

A90-27480* Houston Univ., Clear Lake, TX.
A RATIONALE FOR ATMOSPHERIC MONITORING ON SPACE STATION FREEDOM
DENNIS M. CASSERLY (Houston, University, Clear Lake, TX) and DANE M. RUSSO (NASA, Johnson Space Center, Houston, TX)

SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p. refs
(SAE PAPER 891514) Copyright

The atmosphere monitoring needs for the Space Station Freedom are identified by examining the monitoring requirements for supplied breathing air in confined spaces, as in the case of submarines and the Shuttle. Some other factors influencing the monitoring requirements for Space Station Freedom are also identified. These include: the experience of past missions and ground based tests; the proposed experimental and manufacturing processes and their hazards; and limitations of the life support systems. V.L.

A90-27481
BIOISOLATION TESTING OF SPACE STATION FREEDOM MODULAR HABITATS
PAUL WARD-DOLKAS and TERI SCHNEPP (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p.
(SAE PAPER 891516) Copyright

Previous testing verified that bioisolation between animal specimens and a spacecraft crew can be provided at the level of the individual specimen's living quarters (modular habitat) by the use of microbial air filters. As a follow-on effort, a long term experiment was performed to (1) determine the effective lifetime of the microbial filters and (2) collect and analyze condensate from the heat exchanger. This paper presents results showing that the filters provided effective microbial isolation throughout the 58 day tests. Condensate data analysis is also presented. The experiment was repeated for a two week period without filters to serve as a control. Author

A90-27482* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE RODENT RESEARCH ANIMAL HOLDING FACILITY AS A BARRIER TO ENVIRONMENTAL CONTAMINATION
P. D. SAVAGE, JR., G. C. JAHNS, B. P. DALTON, R. P. HOGAN (NASA, Ames Research Center, Moffett Field, CA), and A. E. WRAY (GE Government Services Co., Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. Previously announced in STAR as N90-12151.
(SAE PAPER 891517) Copyright

The rodent Research Animal Holding Facility (RAHF), developed by NASA Ames Research Center (ARC) to separately house rodents in a Spacelab, was verified as a barrier to environmental contaminants during a 12-day biocompatibility test. Environmental contaminants considered were solid particulates, microorganisms, ammonia, and typical animal odors. The 12-day test conducted in August 1988 was designed to verify that the rodent RAHF system would adequately support and maintain animal specimens during normal system operations. Additional objectives of this test were to demonstrate that: (1) the system would capture typical particulate debris produced by the animal; (2) microorganisms would be contained; and (3) the passage of animal odors was adequately controlled. In addition, the amount of carbon dioxide exhausted by the RAHF system was to be quantified. Of primary importance during the test was the demonstration that the RAHF would contain particles greater than 150 micrometers. This was verified after analyzing collection plates placed under exhaust air ducts and and rodent cages during cage maintenance operations, e.g., waste tray and feeder changeouts. Microbiological testing identified no additional organisms in the test environment that could be traced to the RAHF. Odor containment was demonstrated to be less than barely detectable. Ammonia could not be detected in the exhaust air from the RAHF system. Carbon dioxide levels were verified to be less than 0.35 percent. Author

A90-27489
SPACE STATION FREEDOM DISTRIBUTED SYSTEMS - AN OVERVIEW
WAYNE L. NEALE and RICHARD L. OLSON (Boeing Aerospace Co., Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p.
(SAE PAPER 891524) Copyright

The distributed systems located within the pressurized volume of Space Station Freedom are described with emphasis on the environmental control and life support systems and the test plan to qualify these systems for flight. The discussion covers the Habitation and U.S. Laboratory element layouts, the structures and mechanisms subsystem, the Electrical Power Distribution system, the Data Management System, the Internal Audio/Video system, Thermal Control System, and Man-Systems hardware. The functions of the main subsystems of the Environmental Control and Life Support System are briefly reviewed, with reference to temperature and humidity control, atmosphere control and supply, fire detection and suppression, water recovery management, and waste management. V.L.

A90-27494* National Aeronautics and Space Administration, Washington, DC.
CREW SYSTEM DYNAMICS - COMBINING HUMANS AND AUTOMATION
MARY CONNORS (NASA, Washington, DC) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(SAE PAPER 891530) Copyright

Some of the human factor issues involved in effectively combining human and automated systems are examined with particular reference to spaceflights. The concepts of the crew system and crew systems dynamics are defined, and the present status of crew systems is summarized. The possibilities and potential problems aasociated with the use of automated systems are discussed, as are unique capabilities and possible errors introduced by human participants. It is emphasized that the true integration of human and automated systems must allow for the characteristics of both. V.L.

A90-27495
DESIGN OF THE ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS FOR THE COLUMBUS PRESSURIZED MODULES
K.-O. HIENERWADEL and G. KRING (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p.
(SAE PAPER 891531) Copyright

For the long duration mission intended for the Columbus pressurized modules as used in former applications like Spacelab had to be advanced. The development encompasses modifications of assemblies/functions which have been part of existing systems as well as the implementation of new features like the trace gas contamination monitoring assembly. All functions which form a part of one of the two ECLSSs are listed and described with their status at the beginning of Phase C/D. Special emphasis is given to the air loops. Author

A90-27497
DEVELOPMENT OF THE CATALYTIC OXIDIZER TECHNOLOGY FOR THE EUROPEAN SPACE PROGRAMME
KLAUS AMMANN (Draegerwerk AG, Luebeck, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p.
(SAE PAPER 891533) Copyright

The development of a technological breadboard for a catalytic oxidizer assembly is described. The assembly was designed to remove the light-weight hydrocarbons, H, and CO from a Space Station atmosphere. With regard to the necessary flow rate, CO turned out to be the design driver while methane governed the thermal design. A concept was selected consisting of a high flow/low temperature catalyst for CO oxidation and a low flow/high temperature catalyst for the removal of the more stable contaminants. Test results on both assembly and ECLSS-subsystem level, including experiments with selected catalyst poisons, are presented. Author

A90-27498
MICROBIOLOGICAL CONTAMINATION CONTROL IN THE COLUMBUS PROJECT
JACQUELINE BAUNE and MANFRED BAUNE (MBB-ERNO, Bremen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 6 p.
(SAE PAPER 891534) Copyright

Microbiological contamination is likely to be a problem on long duration space missions. Therefore a study was performed to establish preliminary requirements and control plan. The major findings are that manned pressurized modules should be delivered into orbit virtually free of microbes, be designed to inhibit microbial growth and be easy to clean. Author

A90-27499
BAF - AN ADVANCED ECOLOGICAL CONCEPT FOR AIR QUALITY CONTROL
ROGER A. BINOT (ESTEC, Noordwijk, Netherlands) and P. G. PAUL (Comprimo, Netherlands) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(SAE PAPER 891535) Copyright

A preliminary study has been initiated to evaluate the feasibility of a self-regenerating biological air filter (BAF) onboard future inhabited space stations to alleviate the disdvantages and limitations of the physicochemical systems. The discussion focuses on the biodegradability of the various contaminants that are likely to be found in spacecraft and their production rates and allowed concentrations versus the kinetic and equilibrium constants for their degradation that are needed for the sizing of the system. V.L.

A90-27501
AIR LOOP CONCEPTS FOR ENVIRONMENTAL CONTROL AND LIFE SUPPORT
H. P. LEISEIFER, B. PATTI (ESTEC, Noordwijk, Netherlands), and K. O. HIENERWADEL (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. refs
(SAE PAPER 891537) Copyright

The relation between air loops and the ECLSS of manned spacecraft is studied. Air loop functions in laboratory modules and design implementation for various conceptual approaches are discussed. Particular consideration is given to centralized and decentralized ECLSS; separated and combined air loops; free and nonfree subfloor architecture; cabin loop ventilation; and rack cooling. The use of air loops in the Columbus project is examined. I.F.

A90-27502* Krug International, Houston, TX.
AN OVERVIEW OF THE SPACE STATION FREEDOM ENVIRONMENTAL HEALTH SYSTEM
ELIZABETH E. RICHARD (Krug International Corp., Houston, TX) and DANE RUSSO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 6 p. refs
(SAE PAPER 891538) Copyright

The proposed environmental health system (EHS) designed for the closed environment of the Space Station is examined. The internal contamination control and environmental health considerations for the Space Station are discussed. The microbiology, toxicology, water quality, radiological health, vibroacoustics, and barothermal physiology subsystems of the EHS are described. Proposed capabilities of the EHS are: the environmental sample collection, processing, and analysis of the breathing atmosphere, potable and hygiene water, and internal surfaces. I.F.

A90-27503* Alabama Univ., Huntsville.
PROBLEMS IN WATER RECYCLING FOR SPACE STATION FREEDOM AND LONG DURATION LIFE SUPPORT
D. S. JANIK, W. J. CRUMP (Alabama, University, Huntsville), B. A. MACLER, T. WYDEVEN, JR. (NASA, Ames Research Center, Moffett Field, CA), and R. L. SAUER (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p. refs
(SAE PAPER 891539) Copyright

A biologically-enhanced, physical/chemical terminal water treatment testbed for the Space Station Freedom is proposed. Recycled water requirements for human, animal, plant and/or combined crews for long duration space missions are discussed. An effective terminal treatment method for recycled water reclamation systems that is based on using granular activated carbon as the principal active agent and the controls of microbial contamination and growth within recycled water systems are examined. The roles of plants in water recycling within CELSS is studied. I.F.

A90-27504* Krug International, Houston, TX.
MICROBIAL IDENTIFICATION SYSTEM FOR SPACE STATION FREEDOM
HARLAN D. BROWN, JANIE B. SCARLETT, JOYCE A. SKWERES (Krug International Corp., Houston, TX), RUSSELL L. FORTUNE, JOHN L. STAPLES (Vitek Systems, Inc., Hazelwood, MO), and DUANE L. PIERSON (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p. refs
(SAE PAPER 891540) Copyright

The Environmental Health System (EHS) and Health Maintenance Facility (HMF) on Space Station Freedom will require a comprehensive microbiology capability. This requirement entails the development of an automated system to perform microbial identifications on isolates from a variety of environmental and clinical sources and, when required, to perform antimicrobial sensitivity testing. The unit currently undergoing development and testing is the Automated Microbiology System II (AMS II) built by Vitek Systems, Inc. The AMS II has successfully completed 12 months of laboratory testing and evaluation for compatibility with microgravity operation. The AMS II is a promising technology for use on Space Station Freedom. Author

A90-27505* Alabama Univ., Huntsville.
DEFINITION OF A NEAR REAL-TIME MICROBIOLOGICAL MONITOR FOR APPLICATION IN SPACE VEHICLES
MELVIN V. KILGORE, JR., ROBERT J. ZAHORCHAK, WILLIAM F. ARENDALE (Alabama, University, Huntsville), SAMUEL S. WOODWARD (Boeing Aerospace and Electronics, Seattle, WA), and DUANE L. PIERSON (Boeing Co., Biomedical Laboratories; NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p. refs
(SAE PAPER 891541) Copyright

The concepts and methodologies for microbiological monitoring in space are examined, focusing on the determination of the requirements of a near real-time microbiological monitor. Results are presented from the technical evaluation of five microbiological monitor concepts, including cultural methods, single cell detection, biomolecular detection, specific product detection, and general molecular composition. Within these concepts, twenty-eight specific methodolgies were assessed and the five candidate methodologies with the highest engineering and feasibility scores were selected for further evaluations. The candidate methodologies are laser light scattering, primary fluorescence, secondary fluorescence, volatile product detection, and electronic particle detection. The advantages and disadvantages of these five candidate methodologies are discussed. R.B.

A90-27507* Krug International, Houston, TX.
BIOFILM FORMATION AND CONTROL IN A SIMULATED SPACECRAFT WATER SYSTEM - INTERIM RESULTS
JOHN R. SCHULTZ, ROBERT D. TAYLOR, DAVID T. FLANAGAN, RANDALL E. GIBBONS, HARLAN D. BROWN (Krug International Corp., Houston, TX), RICHARD L. SAUER (NASA, Johnson Space

Center, Houston, TX) et al. SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p. refs
(SAE PAPER 891543) Copyright

The ability of iodine to control microbial contamination and biofilm formation in spacecraft water distribution systems is studied using two stainless steel water subsystems. One subsystem has an iodine level of 2.5 mg/L maintained by an iodinated ion-exchange resin. The other subsystem has no iodine added. Stainless steel coupons are removed from each system to monitor biofilm formation. Results from the first six months of operation indicate that 2.5 mg/L of iodine has limited the number of viable bacteria that can be recovered from the iodinated subsystem. Epifluorescence microscopy of the coupons taken from this subsystem, however, indicates some evidence of microbial colonization after 15 weeks of operation. Numerous bacteria have been continually removed from both the water samples and the coupons taken from the noniodinated subsystem after only 3 weeks of operation. Author

A90-27509
DECOMPRESSION SICKNESS RISKS FOR EUROPEAN EVA
LORENZ VOGT, JUERGEN WENZEL (DLR, Institut fuer Flugmedizin, Cologne, Federal Republic of Germany), STEPHEN LUCK (Dornier GmbH, Friedrichshafen, Federal Republic of Germany), and BENGT SVENSSON (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(SAE PAPER 891546) Copyright

The design of a European space suit with a design pressure of 500 hPa requires a reevaluation of the protective procedures for space-suit decompression. An R factor of 1.2 and a tissue half-time of 360 minutes in a single-tissue model have been identified as appropriate operational values. On the basis of an acceptable risk level of approximately 1 percent, oxygen prebreathing times are proposed for (1) direct pressure reduction from 1013 hPa to a suit pressure of 500 hPa and (2) staged decompression using a 700-hPa intermediate stage in the spacecraft cabin. In addition, factors which influence individual susceptibility to DCS are identified. Author

A90-27511
CO2 PROCESSING AND O2 RECLAMATION SYSTEM SELECTION PROCESS FOR FUTURE EUROPEAN SPACE PROGRAMMES
M. ARLOW and G. TRAXLER (Oesterreichische Raumfahrt- und Systemtechnik Gesellschaft mbH, Vienna, Austria) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. Research supported by ESTEC.
(SAE PAPER 891548) Copyright

The process used to select the regenerative CO2 processing and O2 reclamation system for the AOC phase of the Columbus program is discussed. The system requirements are outlined, including the metabolic gas exchange ratio and specified cabin leakage rates. Candidate system configurations are described and compared in terms of interface, technology availability, water quantity and quality requirements and oxygen, carbon, and hydrogen loop closure considerations. The process of preselecting eight candidate system configurations from sixty-four candidates and the final selection of the final baseline configuration are discussed. R.B.

A90-27512
LIFE SUPPORT - FUTURE TRENDS AND DEVELOPMENTS
ROBIN C. HUTTENBACH and JAMES D. H. RADFORD (Nelson Space Services, Ltd., London, England) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 18 p. refs
(SAE PAPER 891549) Copyright

Design trends in life support systems currently under consideration for prospective manned space missions are discussed, with a view to the development status of the regenerative, 'closed-loop' systems required for permanent microgravity orbit stations, long-duration transports, and ultimately even lunar and planetary bases. While such regenerative systems will in the medium term employ physicochemical methods in such tasks as the recovery of oxygen from exhaled CO2, and resort of open-loop methods in the matters of food supply and waste disposal, there will eventually be a resort to a combination of biological and physicochemical processes to recycle organic nutrients and grow food. O.C.

A90-27513
WASTE MANAGEMENT ABOARD MANNED SPACECRAFT
CHRISTOPHER A. LAMBE, DENISE L. OAKLEY, ALAN ROSEVEAR (Atomic Energy Research Establishment, Harwell Laboratory, England), CLAUDE CHIPAUX (Matra, S.A., Velizy-Villacoublay, France), and ROGER A. BINOT (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p.
(SAE PAPER 891550) Copyright

The reasons for dealing with waste, the main treatment options, and the available technologies are discussed. Recommendations are then proposed about those technologies which will need to be developed. Waste management aims to make a change of form which is both advantageous in terms of volume and hazard reduction and which does not compromise crew health and safety. A broad overview of the waste management strategies required to treat wastes from missions of increasing length is presented. In conclusion, the basic philosophy behind any successful waste management strategy will involve the exclusion of microbial activity and, thus, waste stabilization, and/or the inclusion of microbial degradation processes for the treatment of biodegradable wastes leading to element recycle within a closed environmental life support system. R.E.P.

A90-27514
VAPOR COMPRESSION DISTILLATION SUBSYSTEM EVALUATION - MICROBIOLOGICAL ANALYSIS OF SYSTEM HARDWARE, PRETREATMENT SOLUTIONS AND PRODUCT WATER
JOSEPH L. ZELIBOR, TIMOTHY L. HUFF, MELVIN V. KILGORE, JR. (Alabama, University, Huntsville), MARY S. TRAWEEK, GERALD A. WHITMAN (Boeing Aerospace and Electronics, Seattle, WA) et al. SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 11 p. refs
(SAE PAPER 891551) Copyright

A Space Station Freedom life-support system candidate component, the urine water-recovery function Vapor Compression Distillation Subsystem (VCDS), has undergone testing; its hardware, urine pretreatment solution, brine-solution, and product tank water have all been sampled for microbiological analysis. The largest bacterial populations were collected from product tank water. It is judged that bacteria, especially those producing either spores or extracellular polymeric substances, are able to survive pretreatment and VCDS operation, rendering product water unacceptable. O.C.

A90-27515* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
CMIF ECLS SYSTEM TEST FINDINGS
RICHARD G. SCHUNK, ROBYN L. CARRASQUILLO, KATHYRN Y. OGLE, PAUL O. WIELAND, and ROBERT M. BAGDIGIAN (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p.
(SAE PAPER 891552) Copyright

During 1987 three Space Station integrated Environmental Control and Life Support System (ECLSS) tests were conducted at the Marshall Space Flight Center (MSFC) Core Module Integration Facility (CMIF) as part of the MSFC ECLSS Phase II test program. The three tests ranged in duration from 50 to 150 hours and were conducted inside of the CMIF module simulator. The Phase II partial integrated system test configuration consisted

of four regenerative air revitalization subsystems and one regenerative water reclamation subsystem. This paper contains a discussion of results and lessons learned from the Phase II test program. The design of the Phase II test configuration and improvements made throughout the program are detailed. Future plans for the MSFC CMIF test program are provided, including an overview of planned improvements for the Phase III program. Author

A90-27535
PRELIMINARY DESIGN OF JEM ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM
K. SHIRAKI, H. HASHIMOTO, K. MANABE (NASDA, Tokyo, Japan), A. HATTORI, and H. HAMA (Kawasaki Heavy Industries, Ltd., Kobe, Japan) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(SAE PAPER 891574) Copyright

This paper outlines the current status of the preliminary design study of the JEM ECLSS, one of the subsystems in JEM which is attached to the Space Station core. ECLSS functions, the design concepts for ECLSS function allocation between FEM and the Space Station core, and JEM ECLSS function/hardware distribution are established. The design approach emphasizes the JEM emergency system concept with respect to contamination control and monitoring and to fire detection and suppression, which must be standardized throughout all modules in Space Station. Author

A90-27536
STUDY OF ADVANCED SYSTEM FOR AIR REVITALIZATION
H. ISHIDA, H. YAMASHIRO, S. FUJITA, K. MASUYAMA, S. KONDO (Kawasaki Heavy Industries, Ltd., Kobe, Japan) et al. SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. refs
(SAE PAPER 891575) Copyright

A feasibility study of the Space Station Air Revitalization System (ARS) is presented. Tests of the CO2 Removal/Concentration Subsystem (CRC), the O2 Generation Subsystem (OGS), and the Trace Contaminant Control Subsystem (TCCS) are discussed. The components of an advanced ARS are described. C.D.

A90-27537
STUDY OF AIR REVITALIZATION SYSTEM FOR SPACE STATION
M. MINEMOTO, T. ETOH, H. IDA, S. HATANO, N. KAMISHIMA (Mitsubishi Heavy Industries, Ltd., Kobe, Japan) et al. SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. refs
(SAE PAPER 891576) Copyright

The results are reported of various test and simulation calculations performed on a system to remove from the air the CO2 produced by human metabolisms in closed environments such as space stations, and to regenerate O2 from the CO2. Design data are presented on an adsorption/desorption system using solid amine for removing and concentrating CO2 and on a Bosch reaction system for obtaining solid carbon and water by reducing concentrated CO2. Optimum conditions for operating the device are described. C.D.

A90-27538
APPLICABILITY OF MEMBRANE DISTILLATION METHOD TO SPACE EXPERIMENTAL WASTE WATER TREATMENT
HIROSHI OKAZAKI, HIROYO MATSUMOTO, AKIRA KAKIMOTO, and HIROAKI MATSUMOTO (Mitsubishi Heavy Industries, Ltd., Kobe, Japan) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 9 p. refs
(SAE PAPER 891578) Copyright

Consideration is given to the possible use of membrane distillation combined with conventional water treatment processes for water reclamation for the Space Station. Emphasis is given to a study of the water reclamation system designed for the Life Science Experiment for the JEM. The evacuating method for membrane distillation is tested using a spiral wound element-type module and a hollow-fiber element-type module. Results are presented from evaluations of the water quality of products obtained from the treatment of an algae culture solution and rat urine. R.B.

A90-27539* Lockheed Engineering and Sciences Co., Houston, TX.
DEVELOPMENT OF A PREPROTOTYPE ADVANCED EXTRAVEHICULAR MOBILITY UNIT (AEMU) REGENERABLE LIFE SUPPORT SUBSYSTEM - A PROGRESS REPORT
NORMAN C. ALLEN (Lockheed Engineering and Sciences Co., Houston, TX) and B. MICHAEL LAWSON (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 20 p.
(SAE PAPER 891579) Copyright

Regenerable life support (RLS) technologies are being developed for use in the Advanced Extravehicle Mobility Unit (AEMU) aboard Space Station Freedom. This report describes the requirements that these RLS technologies must satisfy in the Space Station application and the significant features of the technologies now being evaluated. Who is developing the equipment and how the subsystems will be integrated are addressed. An overview of the planned test program schedule is given. C.D.

A90-27544* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A TELESCIENCE MONITORING AND CONTROL CONCEPT FOR A CELSS PLANT GROWTH CHAMBER
DARYL N. RASMUSSEN and ARSHAD MIAN (NASA, Ames Research Center; General Electric Co., Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 12 p. refs
(SAE PAPER 891585) Copyright

Consideration is given to the use of telescience to monitor and control a Space Station CELSS plant growth chamber (PGC). The proposed telescience control system contains controllers for PGC subsystems, a local master controller, and remote controllers. The benefits of telescience are discussed and the functional requirements of the PGC are outlined. A typical monitoring and control scenario is described. It is suggested that the proposed concept would provide remote access to a ground-based CELSS research facility, Space Station plant growth facilities, lunar-based CELSS facilities, and manned interplanetary spacecraft. R.B.

A90-27546* Life Systems, Inc., Cleveland, OH.
ATMOSPHERE CONTROL FOR PLANT GROWTH FLIGHT EXPERIMENTS
FEROLYN T. POWELL, MARTIN SUDAR (Life Systems, Inc., Cleveland, OH), MARC TIMM, and BRUCE YOST (Bionetics Corp., Cocoa Beach, FL) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 11 p. Research sponsored by NASA, Bionetics Corp., and Life Systems, Inc.
(SAE PAPER 891587) Copyright

An atmosphere exchange system (AES) has been designed to provide a conditioned atmosphere supply to plant specimens in flight without incurring the large weight and volume associated with bottled gases. The paper examines the atmosphere filter cartridge (AFC) designed to remove trace organic atmosphere contaminants from the Space Shuttle cabin and to condition the cabin atmosphere prior to exposure to plant specimens. The AES and AFC are described and illustrated. The AFC design requirements are discussed and results are presented from tests on the performance of the AFC. Also, consideration is given to the potential applications of the AFC and future design concepts for atmosphere control. R.B.

A90-27554* Allied-Signal Aerospace Co., Torrance, CA.
METAL OXIDE REGENERABLE CARBON DIOXIDE REMOVAL SYSTEM FOR AN ADVANCED PORTABLE LIFE SUPPORT SYSTEM
MAURENA S. NACHEFF (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., Torrance, CA), CRAIG H. CHANG (Allied-Signal Engineered Materials Research Center, Des Plaines, IL), GERALD

V. COLOMBO (Umpqua Research Co., Myrtle Creek, OR), and ROBERT J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p. refs
(Contract NAS9-17836)
(SAE PAPER 891595) Copyright

The development of a CO2 removal system for an astronaut portable life support system to meet the EVA requirements for the Space Station is discussed, focusing on the factors important in the selection of the metal oxide absorbent for CO2 removal. Results from laboratory tests on metal oxide absorbent materials are given, including characterization studies and dynamic CO2 uptake and regeneration measurements. The preliminary design of the breadboard system to perform both the absorption and regeneration functions is presented. R.B.

A90-28716
REPLACING NASA'S SHUTTLE
DONALD F. ROBERTSON Interavia Space Markets (ISSN 0258-4212), vol. 6, Jan.-Feb. 1990, p. 42-47.
Copyright

The latest NASA Shuttle II proposal for an Advanced Manned Launch System (AMLS) is reviewed. It could achieve total reusability, with a glide-back booster stage and no solid rockets. The propellant load would be divided between the booster and orbiter stages. The AMLS payload of just over nine tons will be limited to crew and 'high-value' cargo, carried in the dorsal pod. Bulky freight and satellites will rely on expendable launchers. AMLS will be a Space Station ferry only and would not be used for on-orbit experiments. The operational history of the Space Shuttle program is shown, as well as its programmed future undertakings. Beyond the proposed Shuttle II, some insight is offered on the conceptual vehicle named Shuttle Z that could be the mainstay of Lunar-Base or Mars expeditions. Needed technologies and key features of a proposed AMLS orbiter are also mentioned. In addition, NASA proposals for a rescue vehicle for Space Station Freedom that will serve to return stranded or injured astronauts to earth is presented. One such proposed crew rescue vehicle would carry four people plus 450 kg of supplies, for a gross mass of 7146 kg. R.E.P.

A90-28950#
THE ESA ASTRONAUT SLEEP RESTRAINT - ITS DEVELOPMENT AND USE ONBOARD SPACELAB AND MIR
W. OCKELS and H. STOEWER (ESTEC, Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 61, Feb. 1990, p. 71-76. In French.
Copyright

The necessity to provide an astronaut with comfortable sleeping conditions prompted the development of a new astronaut sleep restraint which could produce some kind of spring-like pressure and feedback over body and limbs. In its final concept the device, as designed by two Dutch scientists for ESA, presents a sleeping bag which provides a feedback pressure roughly proportional to the degree of stretching, and varies with sleeping positions. It consists of two sheets of Nomex cloth stretched by a tubular tensioning device: a system of peripheral pressure tubes and valves. The astronaut sleep restraint has been tested in orbit in two space missions: spacelab-D1 and MIR, and found acceptable for future space missions, especially the longer ones. N.B.

A90-29151
A MODEL OF HUMAN METABOLIC MASSFLOW RATES FOR AN ENGINEERED CLOSED ECOSYSTEM
M. J. CONDRAN, W. Z. SADEH, D. W. HENDRICKS (Colorado State University, Fort Collins), and M. E. BRZECZEK (Martin Marietta Corp., Astronautics Group, Denver, CO) Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p. refs
(SAE PAPER 891486) Copyright

A computer simulation model of the human metabolic system describing the massflow rates of the input and output metabolic elements was developed. The input metabolic elements consist of oxygen, dry food, and water, while the output elements include carbon dioxide, feces, urine and insensible water. Energy expenditure rate was introduced as the fundamental quantity, and its dependence upon the body mass and energy activity category was modeled. Four energy activity categories, i.e., work, exercise, leisure, and sleep, were considered. All the metabolic massflow rates were expressed in terms of the energy expenditure rate by means of linear relations. Integration and demonstration of the model of the metabolic system was accomplished using a scenario of daily distribution of energy activity categories and dry food composition for a given body mass. The results indicate the sensitivity of the calculated input/output metabolic massflow rates to the body mass and the selected scenario. Author

A90-31354* Brookhaven National Lab., Upton, NY.
THE EFFECT OF PRESSURE SUIT GLOVES ON HAND PERFORMANCE
JOHN M. O'HARA (Brookhaven National Laboratory, Upton, NY) IN: Human Factors Society, Annual Meeting, 33rd, Denver, CO, Oct. 16-20, 1989, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1989, p. 139-143.
(Contract NAS9-17702)
Copyright

The effects of pressure gloves on human hand capabilities is a major concern in the performance of extravehicular activity (EVA) for space maintenance and construction missions. The effects of EVA gloves on six hand performance domains was investigated in this NASA sponsored research. They were range of motion, strength, tactile perception, dexterity, fatigue, and comfort. All tests were designed to be performed in a glove box using the barehand as well as the glove at 0 and 4.3 pressure differentials. Ten subjects participated in the test in a repeated measures design. The results of the experiments are summarized in this paper. Author

A90-31361* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
CREW QUARTERS FOR SPACE STATION
F. E. MOUNT (NASA, Johnson Space Center, Houston, TX) IN: Human Factors Society, Annual Meeting, 33rd, Denver, CO, Oct. 16-20, 1989, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1989, p. 531-535. refs
Copyright

The only long-term U.S. manned space mission completed has been Skylab, which has similarities as well as differences to the proposed Space Station. With the exception of Skylab missions, there has been a dearth of experience on which to base the design of the individual Space Station Freedom crew quarters. Shuttle missions commonly do not have sleep compartments, only 'sleeping arrangements'. There are provisions made for each crewmember to have a sleep restraint and a sleep liner, which are attached to a bulkhead or a locker. When the Shuttle flights began to have more than one working shift, crew quarters became necessary due to noise and other disturbances caused by crew task-related activities. Shuttle missions that have planned work shifts have incorporated sleep compartments. To assist in gaining more information and insight for the design of the crew quarters for the Space Station Freedom, a survey was given to current crewmembers with flight experience. The results from this survey were compiled and integrated with information from the literature covering space experience, privacy, and human-factors issues. Author

N90-11799# Technische Hogeschool, Delft (Netherlands). Faculty of Aerospace Engineering.
PROJECT AENEAS: A FEASIBILITY STUDY FOR CREW EMERGENCY RETURN VEHICLE
H. BUNING Jul. 1988 252 p
(PB89-217020; LR-558) Avail: NTIS HC A12/MF A02 CSCL 22/2

The goal of Project AENEAS was to design a Crew Emergency Return Vehicle for the International Space Station. This vehicle has to be able to perform the following Mission Definitions: a non-time critical retreat from Space Station, in case the Space

Shuttle is not available for a long time; a time critical retreat to Earth in case of a Space Station contingency; and an ambulance return under medical tolerant conditions. In order to cover the different aspects of the design, the 29 participating engineering students were divided into eight groups, which in their turn were assembled into three major divisions: a spacecraft engineering division. Topics covered in the report include the following: Systems requirements; space station interface; human factors; power and communication; propulsion; spacecraft integration; orbital operations; reentry; landing and recovery; limits of design and cost aspects. GRA

N90-11801# Aerospace Corp., El Segundo, CA. Chemistry and Physics Lab.
PHOTOLYSIS OF SPACECRAFT CONTAMINANTS
THOMAS B. STEWART, GRAHAM S. ARNOLD, DAVID F. HALL, and H. D. MARTEN 1 Jul. 1989 68 p
(Contract F04701-85-C-0086)
(AD-A211715; TR-0086(6403-01)-1; SD-TR-89-45) Avail: NTIS HC A04/MF A01 CSCL 22/2

Self-contamination of sensitive spacecraft surfaces has long been recognized as potentially limiting the performance, and even the useful life, of a spacecraft. It has become clear that photochemical reactions, induced by solar vacuum ultraviolet (VUV) illumination, play a substantial role in contaminant deposition. A series of laboratory measurements of the absolute rates of adsorption, desorption, and VUV-induced deposition of contaminants under simulated spacecraft conditions are described in this report. The rates measured are sufficient to explain anomalous radiator degradation on the Satellite Data Systems spacecraft radiator. The dependence of the deposition rate on substrate identity and temperature and on contaminant identity and flux is discussed, and a simple kinetic model that describes most experimental observations is presented. GRA

N90-12151*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE RODENT RESEARCH ANIMAL HOLDING FACILITY AS A BARRIER TO ENVIRONMENTAL CONTAMINATION
P. D. SAVAGE, JR., G. C. JAHNS, B. P. DALTON, R. P. HOGAN, and A. E. WRAY (General Electric Co., Moffett Field, CA.) Sep. 1989 11 p Presented at the 19th Intersociety Conference on Environmental Systems, San Diego, CA, 24-26 Jul. 1989
(NASA-TM-102237; A-89183; NAS 1.15:102237) Avail: NTIS HC A03/MF A01 CSCL 06/3

The rodent Research Animal Holding Facility (RAHF), developed by NASA Ames Research Center (ARC) to separately house rodents in a Spacelab, was verified as a barrier to environmental contaminants during a 12-day biocompatibility test. Environmental contaminants considered were solid particulates, microorganisms, ammonia, and typical animal odors. The 12-day test conducted in August 1988 was designed to verify that the rodent RAHF system would adequately support and maintain animal specimens during normal system operations. Additional objectives of this test were to demonstrate that: (1) the system would capture typical particulate debris produced by the animal; (2) microorganisms would be contained; and (3) the passage of animal odors was adequately controlled. In addition, the amount of carbon dioxide exhausted by the RAHF system was to be quantified. Of primary importance during the test was the demonstration that the RAHF would contain particles greater than 150 micrometers. This was verified after analyzing collection plates placed under exhaust air ducts and rodent cages during cage maintenance operations, e.g., waste tray and feeder changeouts. Microbiological testing identified no additional organisms in the test environment that could be traced to the RAHF. Odor containment was demonstrated to be less than barely detectable. Ammonia could not be detected in the exhaust air from the RAHF system. Carbon dioxide levels were verified to be less than 0.35 percent. Author

N90-12645*# Wyle Labs., Inc., Huntsville, AL.
ADVANCED SPACECRAFT FIRE SAFETY: PROPOSED PROJECTS AND PROGRAM PLAN Final Report
WALLACE W. YOUNGBLOOD and M. VEDHA-NAYAGAM Oct. 1989 176 p
(Contract NAS3-25367)
(NASA-CR-185147; NAS 1.26:185147; WYLE-60300-1) Avail: NTIS HC A09/MF A01 CSCL 22/2

A detailed review identifies spacecraft fire safety issues and the efforts for their resolution, particularly for the threats posed by the increased on-orbit duration, size, and complexity of the Space Station Freedom. Suggestions provided by a survey of Wyle consultants and outside fire safety experts were combined into 30 research and engineering projects. The projects were then prioritized with respect to urgency to meet Freedom design goals, status of enabling technology, cost, and so on, to yield 14 highest priority projects, described in terms of background, work breakdown structure, and schedule. These highest priority projects can be grouped into the thematic areas of fire detection, fire extinguishment, risk assessment, toxicology and human effects, and ground based testing. Recommendations for overall program management stress the need for NASA Headquarters and field center coordination, with information exchange through spacecraft fire safety oversight committees. Author

N90-13013*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CARDIOVASCULAR, RENAL, ELECTROLYTE, AND HORMONAL CHANGES IN MAN DURING GRAVITATIONAL STRESS, WEIGHTLESSNESS, AND SIMULATED WEIGHTLESSNESS: LOWER BODY POSITIVE PRESSURE APPLIED BY THE ANTIGRAVITY SUIT Thesis - Oslo Univ.
STEIN E. KRAVIK Oct. 1989 142 p Sponsored in part by NAS-NRC, Washington, DC; Joint Medical Service, HQ Defense Command, Norway and the Norwegian Research Council for Science and the Humanities
(NASA-TM-102232; A-89084; NAS 1.15:102232) Avail: NTIS HC A07/MF A01 CSCL 06/19

Because of their erect posture, humans are more vulnerable to gravitational changes than any other animal. During standing or walking man must constantly use his antigravity muscles and his two columns, his legs, to balance against the force of gravity. At the same time, blood is surging downward to the dependent portions of the body, draining blood away from the brain and heart, and requiring a series of complex cardiovascular adjustments to maintain the human in a bipedal position. It was not until 12 April 1961, when Yuri Gagarin became the first human being to orbit Earth, that we could confirm man's ability to maintain vital functions in space -- at least for 90 min. Nevertheless, man's adaptation to weightlessness entails the deconditioning of various organs in the body. Muscles atrophy, and calcium loss leads to loss of bone strength as the demands on the musculoskeletal system are almost nonexistent in weightlessness. Because of the lack of hydrostatic pressures in space, blood rushes to the upper portions of the body, initiating a complex series of cardioregulatory responses. Deconditioning during spaceflight, however, first becomes a potentially serious problem in humans returning to Earth, when the cardiovascular system, muscles and bones are suddenly exposed to the demanding counterforce of gravity -- weight. One of the main purposes of our studies was to test the feasibility of using Lower Body Positive Pressure, applied with an antigravity suit, as a new and alternative technique to bed rest and water immersion for studying cardioregulatory, renal, electrolyte, and hormonal changes in humans. The results suggest that Lower Body Positive Pressure can be used as an analog of microgravity-induced physiological responses in humans. Author

N90-13036*# Auburn Univ., AL. Dept. of Aerospace Engineering.
PROPOSAL FOR A ZERO-GRAVITY TOILET FACILITY FOR THE SPACE STATION Final Report
EDGAR L. FLERI, JR., PAUL A. GALLIANO, MARK E. HARRISON, WILLIAM B. JOHNSON, and GREGORY J. MEYER Jun. 1989 56 p Sponsored by USRA
(Contract NASW-4435)

(NASA-CR-183151; NAS 1.26:183151) Avail: NTIS HC A04/MF A01 CSCL 06/11

This proposed toilet facility has a straightforward design. It has few moving parts and is easily maintained. Air and water flow provide sanitary movement of the waste. The toilet's chambers are coated with Teflon which, along with the water flow, makes it self-cleaning. An added disinfectant called Betadiene kills any bacteria that may form on the chamber walls. The chair is contoured to take into account the neutral body position and the necessary strain position for defecation. Restraints at the ankles, knees, and midsection hold the body in the chair. The waste is stored in discs of Gortex material which are inside a replaceable storage chamber. This chamber can be removed, capped and stored until eventual return to earth. Author

N90-13926*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

EXERCISE COUNTERMEASURES FOR BED REST DECONDITIONING

JOHN GREENLEAF, ed. Oct. 1989 58 p

(NASA-TM-101045; A-88315; NAS 1.15:101045) Avail: NTIS HC A04/MF A01 CSCL 06/19

The major objectives were to evaluate the efficiency of different modes of exercise (isotonic and isokinetic) for countering the effects of bed rest deconditioning on work capacity (peak oxygen uptake), muscular strength, orthostatic tolerance, posture, equilibrium and gait; and to collect additional data of a more fundamental nature to help understand how these deconditioning responses occur. These data will be used for writing prescriptions for exercise to be utilized by astronauts for maintaining work capacity and well-being on Freedom Station, and to determine what exercise devices should be place in the station. Author

N90-13931*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

FUNCTIONAL DECOR IN THE INTERNATIONAL SPACE STATION: BODY ORIENTATION CUES AND PICTURE PERCEPTION

RICHARD G. COSS, YVONNE A. CLEARWATER, CHRISTOPHER G. BARBOUR, and STEVEN R. TOWERS (California Univ., Davis.) Nov. 1989 29 p

(NASA-TM-102242; A-89260; NAS 1.15:102242) Avail: NTIS HC A03/MF A01 CSCL 05/9

Subjective reports of American astronauts and their Soviet counterparts suggest that homogeneous, often symmetrical, spacecraft interiors can contribute to motion sickness during the earliest phase of a mission and can also engender boredom. Two studies investigated the functional aspects of Space Station interior aesthetics. One experiment examined differential color brightnesses as body orientation cues; the other involved a large survey of photographs and paintings that might enhance the interior aesthetics of the proposed International Space Station. Ninety male and female college students reclining on their backs in the dark were disoriented by a rotating platform and inserted under a slowly rotating disk that filled their entire visual field. The entire disk was painted the same color but one half had a brightness value that was about 69 percent higher than the other. The effects of red, blue, and yellow were examined. Subjects wearing frosted goggles opened their eyes to view the rotating, illuminated disk, which was stopped when they felt that they were right-side up. For all three colors, significant numbers of subjects said they felt right-side up when the brighter side of the disk filled their upper visual field. These results suggest that color brightness could provide Space Station crew members with body orientation cues as they move about. It was found that subjects preferred photographs and paintings with the greatest depths of field, irrespective of picture topic. Author

N90-13934*# Life Systems, Inc., Cleveland, OH.

REFURBISHMENT OF ONE-PERSON REGENERATIVE AIR REVITALIZATION SYSTEM Final Report, 22 Jul. 1985 - 3 Apr. 1989

FEROLYN T. POWELL Mar. 1989 24 p

(Contract NAS8-36435)

(NASA-CR-183757; NAS 1.26:183757; LSI-TR-875-9) Avail: NTIS HC A03/MF A01 CSCL 05/8

Regenerative processes for the revitalization of spacecraft atmospheres and reclamation of waste waters are essential for making long-term manned space missions a reality. Processes studied include: static feed water electrolysis for oxygen generation, Bosch carbon dioxide reduction, electrochemical carbon dioxide concentration, vapor compression distillation water recovery, and iodine monitoring. The objectives were to: provide engineering support to Marshall Space Flight Center personnel throughout all phases of the test program, e.g., planning through data analysis; fabricate, test, and deliver to Marshall Space Flight Center an electrochemical carbon dioxide module and test stand; fabricate and deliver an iodine monitor; evaluate the electrochemical carbon dioxide concentrator subsystem configuration and its ability to ensure safe utilization of hydrogen gas; evaluate techniques for recovering oxygen from a product oxygen and carbon dioxide stream; and evaluate the performance of an electrochemical carbon dioxide concentrator module to operate without hydrogen as a method of safe haven operation. Each of the tasks were related in that all focused on providing a better understanding of the function, operation, and performance of developmental pieces of environmental control and life support system hardware. Author

N90-14213# Committee on Science, Space and Technology (U.S. House).

REVIEW OF THE AEROSPACE SAFETY ADVISORY PANEL REPORT FOR NASA FISCAL YEAR 1990 AUTHORIZATION

1989 113 p Hearing before the Subcommittee on Space Science and Applications of the Committee on Science, Space, and Technology, 101st Congress, 1st Session, no. 69, 28 Sep. 1989

(GPO-24-234) Avail: Subcommittee on Space Science and Applications, Washington, D.C. 20510 HC free; SOD HC $3.50 as 552-070-07499-6

The Panel identified five main categories of findings under the National Space Transportation System (NSTS), including management structure, safety enhancements, advanced solid rocket motor, logistics and support, and space shuttle elements. The Panel found that the NSTS management structure has been clarified and strengthened, and that the safety, reliability, maintainability, and quality assurance function is now stronger, more visible, better staffed, and better funded. It was recommended that these funds be protected to maintain safety. It was also recommended that lists of safety enhancements that are maintained be kept current and prioritized. NASA's decision to develop an advanced solid rocket motor was questioned. Implementation should be deferred until other alternatives have been evaluated. The NSTS logistics and support systems showed a satisfactory trend, but an improvement in overhaul and repair turnaround time was recommended. A program to improve solid rocket motors and boosters was also recommended, as well as tests to determine design corrections to meet original requirements for the booster aft skirt. The Panel recommended continued emphasis on developing and using strong risk assessment and management procedures. The Space Station Freedom Program is ungoing a complete review to accommodate anticipated reduced funding levels. Flight safety procedures for all NASA Centers are to be reviewed to determine their adequacy. J.P.S.

N90-14262*# California Univ., Los Angeles. Dept. of Mechanical, Aerospace, and Nuclear Engineering.

RISK-BASED FIRE SAFETY EXPERIMENT DEFINITION FOR MANNED SPACECRAFT Final Report

G. E. APOSTOLAKIS, V. S. HO, E. MARCUS, A. T. PERRY (American Space Technology, Inc., Santa Monica, CA.), and S. L. THOMPSON Oct. 1989 191 p

(Contract NAS8-37750)

(NASA-CR-183835; NAS 1.26:183835; UCLA-ENG-90-11) Avail: NTIS HC A09/MF A02 CSCL 22/2

Risk methodology is used to define experiments to be conducted in space which will help to construct and test the models required for accident sequence identification. The development of

accident scenarios is based on the realization that whether damage occurs depends on the time competition of two processes: the ignition and creation of an adverse environment, and the detection and suppression activities. If the fire grows and causes damage faster than it is detected and suppressed, then an accident occurred. The proposed integrated experiments will provide information on individual models that apply to each of the above processes, as well as previously unidentified interactions and processes, if any. Initially, models that are used in terrestrial fire risk assessments are considered. These include heat and smoke release models, detection and suppression models, as well as damage models. In cases where the absence of gravity substantially invalidates a model, alternate models will be developed. Models that depend on buoyancy effects, such as the multizone compartment fire models, are included in these cases. The experiments will be performed in a variety of geometries simulating habitable areas, racks, and other spaces. These simulations will necessitate theoretical studies of scaling effects. Sensitivity studies will also be carried out including the effects of varying oxygen concentrations, pressures, fuel orientation and geometry, and air flow rates. The experimental apparatus described herein includes three major modules: the combustion, the fluids, and the command and power modules. Author

N90-14778*# National Aeronautics and Space Administration, Washington, DC.
EXPLORING THE LIVING UNIVERSE: A STRATEGY FOR SPACE LIFE SCIENCES
Jun. 1988 231 p Original contains color illustrations
(NASA-TM-101891; NAS 1.15:101891) Avail: NTIS HC A11/MF A02 CSCL 06/3

The status and goals of NASA's life sciences programs are examined. Ways and mean for attaining these goals are suggested. The report emphasizes that a stronger life sciences program is imperative if the U.S. space policy is to construct a permanently manned space station and achieve its stated goal of expanding the human presence beyond earth orbit into the solar system. The same considerations apply in regard to the other major goal of life sciences: to study the biological processes and life in the universe. A principal recommendation of the report is for NASA to expand its program of ground- and space-based research contributing to resolving questions about physiological deconditioning, radiation exposure, potential psychological difficulties, and life support requirements that may limit stay times for personnel on the Space Station and complicate missions of more extended duration. Other key recommendations call for strengthening programs of biological systems research in: controlled ecological life support systems for humans in space, earth systems central to understanding the effects on the earth's environment of both natural and human activities, and exobiology. J.P.S.

N90-15937*# Boeing Aerospace Co., Kent, WA.
CREW EMERGENCY RETURN VEHICLE AUTOLAND FEASIBILITY STUDY
J. A. BOSSI, M. A. LANGEHOUGH, and K. L. LEE Dec. 1989 168 p
(Contract NAS1-18762)
(NASA-CR-181940; NAS 1.26:181940) Avail: NTIS HC A08/MF A01 CSCL 22/2

The crew emergency return vehicle (CERV) autoland feasibility study focused on determining the controllability of the NASA Langley high lift over drag CERV for performing an automatic landing at a prescribed runway. An autoland system was developed using integral linear quadratic Gaussian (LQG) design techniques. The design was verified using a nonlinear 6 DOF simulation. Simulation results demonstrate that the CERV configuration is a very flyable configuration for performing an autoland mission. Adequate stability and control was demonstrated for wind turbulence and wind shear. Control surface actuator requirements were developed. Author

N90-15974# European Space Agency, Paris (France).
CREW SAFETY AND RESCUE IN SPACE: AN INTERNATIONAL APPROACH
VALERIE DAVID, ed. and T. DUC GUYENNE, ed. Aug. 1989 70 p Workshop held in Le Bourget, France, 7 Jun. 1989; sponsored by NASA, Agenzia Spaziale Italiana, Canadian Space Agency, CNES, DFVLR, Glavkosmos, and the National Space Development Agency
(ESA-SP-300; ISBN-92-9029-042-4; ISSN-0379-6566; ETN-90-96196) Copyright Avail: NTIS HC A04/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 30 Dutch guilders

The 1989 workshop on crew safety and rescue operations in space are presented. The safety and rescue during space transportation and orbit activities and the interoperability between manned space systems are the main topics. The workshop provided the opportunity of exchanging space technology knowledge. A consensus on the need of implementing international safety and rescue operations emerged. The goals and limitations of space rescue, concerning launch, reentry and orbital phases are underlined. It is pointed out that the same infrastructure needed to support in-space international rendezvous and docking must also be put into place to enhance terrestrial capabilities for rescue of astronauts and cosmonauts returning from space under emergency conditions. ESA

N90-15977*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ASSURED CREW RETURN CAPABILITY ARCHITECTURE
J. W. CRAIG *In* ESA, Crew Safety and Rescue in Space: An International Approach p 21-26 Aug. 1989
Copyright Avail: NTIS HC A04/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 30 Dutch guilders CSCL 22/1

The fundamental elements of the spacecraft Assured Crew Return Capability (ACRC) are discussed. These elements are access, response time, crew transfer, and the availability of landing sites. The use of an embedded operations concept identified as an essential element of the ACRC architecture. Several rescue assets are identified and evaluated as primary elements of an overall ACRC architecture. The investigation results lead to the following conclusions: optimum on-orbit rescue capability is provided by a rescue system integral to the operational vehicle; ground based rescue provides the most practical coverage for stranded transportation vehicles; and due to infrequent and unexpected use of ACRC, crew operations must be kept simple. ESA

N90-15980# Glavkosmos, Moscow (USSR).
CREW SAFETY AND RESCUE AIDS
YURI P. SEMYENOV *In* ESA, Crew Safety and Rescue in Space: An International Approach p 37-42 Aug. 1989
Copyright Avail: NTIS HC A04/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 30 Dutch guilders

The Soviet program concerning crew safety and rescue aids is summarized. Complex procedures to ensure safety in all phases of the mission are envisaged. The program includes the steps of orbit insertion with the help of booster, orbital flight and recovery. The possibility to expand feasibilities for crew rescue by using spacecraft of different countries in orbital flight phases are considered. The problem of manned spacecraft/stations systems compatibility is analyzed. It involves radiocommunication systems, orbital rendezvous control systems, docking units, internal atmospheres. In this case, spacecraft additional equipping and technical decisions changes are needed. ESA

N90-15981# National Space Development Agency, Tokyo (Japan).
NASDA'S APPROACH TO THE INTEROPERABILITY OF SAFETY AND RESCUE IN SPACE
MASANORI HOMMA *In* ESA, Crew Safety and Rescue in Space: An International Approach p 43-45 Aug. 1989

 Avail: NTIS HC A04/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 30 Dutch guilders

The present status of the National Space Development Agency of Japan (NASDA) activity, is described. The future plans concerning the issue of First National Processing (FMPT) and Japanese Experiment Module (JEM) which are manned space activities in development phase in Japan, are discussed. In the design of JEM, the safety and rescue has the high priority. The future programs research consists of rendezvous docking, data relay satellite network and reentry vehicle. It is shown that the requirement of interoperability can not be neglected. ESA

N90-16398# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.). Dept. of Environmental Control and Life Support Systems.
DNSS: GERMAN/NORWEGIAN WORK TEAM SPACE SUBSEA. ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEMS (TECHNICAL MATTERS), PHASE 2 Final Report
INGO BORCHERS, INGO DATHE, JOSEF HACKSTEIN, ANDREAS KREIS, HELMUT PREISS, MARION STIEB-STABEL, and RAINER STOEPLER Oct. 1987 12 p In GERMAN; ENGLISH summary
(Contract BMFT-FE-01-TQ-8602-AK/PA1)
(ETN-90-95905) Avail: NTIS HC A03/MF A01

Monitoring and control methods used to avoid microbiological contamination in the Hermes and Columbus programs are discussed. A critical analysis of the components of the environmental control and life support subsystem is presented. Components of the environmental control and life support system were the main noise sources in the Spacelab project. Analytical investigations concerning noise production for a variable speed fan are presented. Primary and secondary noise sources are taken into account in optimizing noise reduction. A universal test bench used to verify the analytical data is presented. ESA

N90-17308*# Southern California Inst. of Architecture, Santa Monica.
SPACE STATION WARDROOM HABITABILITY AND EQUIPMENT STUDY
DAVID NIXON, CHRISTOPHER MILLER, and REGIS FAUQUET Washington NASA Dec. 1989 142 p
(Contract NCC2-356)
(NASA-CR-4246; NAS 1.26:4246) Avail: NTIS HC A07/MF A01 CSCL 06/11

Experimental designs in life-size mock-up form for the wardroom facility for the Space Station Habitability Module are explored and developed. In Phase 1, three preliminary concepts for the wardroom configuration are fabricated and evaluated. In Phase 2, the results of Phase 1 are combined with a specific range of program design requirements to provide the design criteria for the fabrication of an innovative medium-fidelity mock-up of a wardrobe configuration. The study also focuses on the design and preliminary prototyping of selected equipment items including crew exercise compartments, a meal/meeting table and a portable workstation. Design criteria and requirements are discussed and documented. Preliminary and final mock-ups and equipment prototypes are described and illustrated. Author

N90-17560*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUPERSONIC AERODYNAMIC CHARACTERISTICS OF A PROPOSED ASSURED CREW RETURN CAPABILITY (ACRC) LIFTING-BODY CONFIGURATION
GEORGE M. WARE Nov. 1989 75 p
(NASA-TM-4136; L-16627; NAS 1.15:4136) Avail: NTIS HC A04/MF A01 CSCL 01/1

An investigation was conducted in the Langley Unitary Plan Wind Tunnel at Mach numbers from 1.6 to 4.5. The model had a low-aspect-ratio body with a flat undersurface. A center fin and two outboard fins were mounted on the aft portion of the upper body. The outboard fins were rolled outboard 40 deg from the vertical. Elevon surfaces made up the trailing edges of the outboard fins, and body flaps were located on the upper and lower aft fuselage. The center fin pivoted about its midchord for yaw control. The model was longitudinally stable about the design center-of-gravity position at 54 percent of the body length. The configuration with undeflected longitudinal controls trimmed near 0 deg angle of attack at Mach numbers from 1.6 to 3.0 where lift and lift-drag ratio were negative. Longitudinal trim was near the maximum lift-drag ratio (1.4) at Mach 4.5. The model was directionally stable over Mach number range except at angles of attack around 4 deg at M = 2.5. Pitch control deflection of more than -10 deg with either elevons or body flaps is needed to trim the model to angles of attack at which lift becomes positive. With increased control deflection, the lifting-body configuration should perform the assured crew return mission through the supersonic speed range. Author

N90-17595*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FIRE SAFETY APPLICATIONS FOR SPACECRAFT
ROBERT FRIEDMAN and SANDRA I. OLSON *In* AGARD, Aircraft Fire Safety 15 p Oct. 1989 Previously announced as N89-24413
 Avail: NTIS HC A18/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01/3

Fire safety for spacecraft is reviewed by first describing current practices, many of which are adapted directly from aircraft. Then, current analyses and experimental knowledge in low-gravity combustion, with implications for fire safety are discussed. In orbiting spacecraft, the detection and suppression of flames are strongly affected by the large reduction in buoyant flows under low gravity. Generally, combustion intensity is reduced in low gravity. There are some notable exceptions, however, one example being the strong enhancement of flames by low-velocity ventilation flows in space. Finally, the future requirements in fire safety, particularly the needs of long-duration space stations in fire prevention, detection, extinguishment, and atmospheric control are examined. The goal of spacecraft fire-safety investigations is the establishment of trade-offs that promote maximum safety without hampering the useful human and scientific activities in space. Author

N90-17674*# Boeing Aerospace Co., Seattle, WA.
SPACE STATION CONTAMINATION CONTROL STUDY: INTERNAL COMBUSTION, PHASE 1 Final Report, Jun. 1985 - Sep. 1986
ROBERT T. RUGGERI 9 Feb. 1987 299 p
(Contract NAS8-36432)
(NASA-CR-179323; NAS 1.26:179323) Avail: NTIS HC A13/MF A02 CSCL 22/2

Contamination inside Space Station modules was studied to determine the best methods of controlling contamination. The work was conducted in five tasks that identified existing contamination control requirements, analyzed contamination levels, developed outgassing specification for materials, wrote a contamination control plan, and evaluated current materials of offgassing tests used by NASA. It is concluded that current contamination control methods can be made to function on the Space Station for up to 1000 days, but that current methods are deficient for periods longer than about 1000 days. Author

N90-18460# *European Space Agency. European Space* Research and Technology Center, ESTEC, Noordwijk (Netherlands). Product Assurance and Safety Dept.
SYSTEM SAFETY REQUIREMENTS FOR ESA SPACE SYSTEMS AND ASSOCIATED EQUIPMENT
Sep. 1988 68 p
(ESA-PSS-01-40-ISSUE-2; ISSN-0379-4059; ETN-90-96301)
 Avail: NTIS HC A04/MF A01

A specification defining the system safety requirements which implement the ESA safety policy and which are applicable to ESA space systems and associated equipment is presented. Safety program requirements are detailed under the following headings: general, safety organization and management, safety personnel access and authority, system safety program plan, safety program

tasks, project technical safety specification, and safety assurance. Technical system safety requirements are detailed under the following headings: general system design, manned system safety, launcher systems, payload safety, and ground equipment and facilities. ESA

N90-19294# Pacific Northwest Lab., Richland, WA.
TECHNOLOGY EVALUATION FOR SPACE STATION ATMOSPHERIC LEAKAGE
D. K. LEMON, M. A. FRIESEL, J. W. GRIFFIN, J. R. SKORPIK, C. L. SHEPARD, Z. I. ANTONIAK, and R. J. KURTZ Feb. 1990 110 p
(Contract DE-AC06-76RL-01830)
(DE90-007844; PNL-7269) Avail: NTIS HC A06/MF A01

A concern in operation of a space station is leakage of atmosphere through seal points and through the walls as a result of damage from particle (space debris and micrometeoroid) impacts. This report describes a concept for a monitoring system to detect atmosphere leakage and locate the leak point. The concept is based on analysis and testing of two basic methods selected from an initial technology survey of potential approaches. DOE

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ORBITS & ORBITAL TRANSFER

Maintenance of space station or other large structures in their orbits, as well as transfer between orbits. Includes docking with servicing or transfer vehicles.

A90-13250#
TETHER-ASSISTED SERVICING OF THE COLUMBUS FREE FLYING LABORATORY BY HERMES
ALEXANDER HORNIK (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany) and WOLFGANG SEBOLDT (DLR, Cologne, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-012) Copyright

The tether-assisted servicing of the Free Flyer by Hermes is studied. A trajectory analysis is included to calculate propellant mass requirements as a function of different mission parameters to compare the present mission design with the tether-assisted servicing. It is found that, for the present data, the application of a tether for the servicing promises an increase of 1220 Hg in the Hermes payload capability. K.K.

A90-13255#
IN-ORBIT DEMONSTRATION CONCEPT FOR THE SPACE PLATFORM IN NASDA - RENDEZVOUS AND DOCKING SYSTEM
I. KAWANO, Y. WAKABAYASHI, H. NAKAMURA, H. ANEGAWA, K. OHTA (National Space Development Agency of Japan, Tsukuba Space Center, Japan) et al. IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p. refs
(IAF PAPER 89-017) Copyright

A Japanese rendezvous and docking (RVD) system concept focusing on safe and automated RVD by unmanned Japanese vehicles is presented. Individual RVD steps and released key technologies for a low earth orbit mission are outlined. A planned in-orbit RVD demonstration using the Hope/SS experiment is addressed, including a list of relevant verification items. C.D.

A90-13371*# National Aeronautics and Space Administration, Washington, DC.
UNITED STATES ORBITAL TRANSFER VEHICLE PROGRAMS
CHARLES R. GUNN (NASA, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p.
(IAF PAPER 89-206) Copyright

Five U.S. orbital transfer vehicles carrying spacecraft to higher energy orbits than achievable by the Space Shuttle or various expandable launch vehicles are studied. These vehicles are the Payload Assist Module-Delta (PAM-D), an upgraded version designated PAM-DII, the Inertial Upper Stage (IUS), the U.S. Transfer Orbit Stage (TOS), and the Orbital Maneuvering Vehicle (OMV). Capabilities range from providing spacecraft with only a preprogrammed perigee velocity additions to man-in-the-loop remote controlled spacecraft rendezvous, docking, retrieval, and return to a space base. The PAM-D, PAM-DII, and IUS are mature vehicles currently available for mission support. Characteristics, flight records, and costs are defined. The TOS is being commercially developed while the OMV is government developed. The TOS and OMV capabilities, constraints, and costs are reviewed. C.E.

A90-13398#
ORBITAL SERVICING FROM AN EXPENDABLE LAUNCH VEHICLE
C. D. GRAVES and A. ROSEN (TRW, Inc., Federal Systems Div., Redondo Beach, CA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-242) Copyright

This paper presents a study of the feasibility and cost effectiveness of alternative ELV-based methods to service a single polar orbit satellite, e.g., NASA's Polar Orbiting Platform (POP). Servicing scenarios are defined, mission and system requirements are derived, candidate servicing vehicles are designed, and relative performances and life-cycle costs are estimated and compared. These results provide a comprehensive view of the POP servicing problem and of its alternative solutions; the performance and cost calculations allow the ranking of the servicing options, suggesting specific directions for further development. Author

A90-13399#
ASSESSMENT OF CREW OPERATIONS DURING INTERNAL SERVICING OF THE COLUMBUS FREE-FLYER BY HERMES
F. WINISDOERFFER, A. LAMOTHE, and J. C. BOURDEAUD'HUI (Aerospatiale, Les Mureaux, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 14 p.
(IAF PAPER 89-243) Copyright

The primary mission of the Hermes spaceplane will be the servicing of the Columbus free flyer (CFF). The mission will be based on the extensive use of the three crewmembers onboard Hermes to perform either the intra- and/or extravehicular activities. Preliminary results concerning the assessment of crew operations during internal servicing of the CFF are focused upon, and the dimensions of the various payloads of the basic reference cargo set are presented. The main constraints associated with their manipulation are also assessed independently of the configuration. S.A.V.

A90-13498#
OPTICAL SENSOR SYSTEMS FOR RENDEZ-VOUS AND DOCKING MANOEUVRES IN SPACE
G. SCHROER, J. CHEMNITZ, and H. WINKELMANN (MBB GmbH, Ottobrunn, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 9 p.
(IAF PAPER 89-385) Copyright

This paper presents two sensor systems, a CCD-camera, a proximity sensor and their dedicated processors for autonomous guidance and control of docking maneuvers in space. One of the spacecraft involved is called the chaser, which is equipped with the active sensor part, the optical transmitter, the receiver, and the preprocessor. The other one, the target vehicle, is equipped with retroreflectors arranged in a defined gemetrical pattern. This allows the chaser to dock even in case the target electrical power is cut off. The sensors cover an acquisition range of 0 to 100 m. The camera system is operating from 3 to 100 m, the proximity sensor from 0 to 10 m. The data received from the reflected

optical signals are preprocessed to meet the processor interface requirements. The processor output is the attitude and position vector of the target vehicle relative to the chaser coordinate system. These data are delivered to the Guidance, Navigation and Control (GNC) system for further processing to control the guidance and docking maneuver. Author

A90-13504*# Stanford Univ., CA.
CLOSED LOOP ORBIT TRIM USING GPS
B. W. PARKINSON (Stanford University, CA) and P. AXELRAD IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 14 p. refs
(Contract NAS8-36125)
(IAF PAPER 89-393) *Copyright*

This paper describes an onboard closed-loop navigation and control system capable of executing extremely precise orbit maneuvers. It uses information from the Global Positioning System (GPS) and an onboard controller to perform orbit adjustments. As a result, the system circumvents the need for extensive ground support. The particular application considered is an orbit injection system for NASA's Gravity Probe B (GP-B) spacecraft. Eccentricity adjustments of 0.0004 to 0.005, and inclination and node changes of 0.001 to 0.01 deg are demonstrated. The same technique can be adapted to other satellite missions. Author

A90-13726#
FINAL APPROACH DURING HERMES-MTFF RENDEZ-VOUS - DEFINITION OF OPTIMAL GUIDANCE AND CONTROL STRATEGIES
LAURE OLIVIER MARTIN and JEAN-PIERRE PROST (CNES; Ecole Nationale Superieure de l'Aeronautique et de l'Espace, Toulouse, France) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p.
(IAF PAPER ST-89-009) Copyright

An evaluation is made of guidance and control strategies for the final rendezvous approach of the ESA Hermes manned spacecraft to the Man-Tended Free Flier. Four strategies are considered, in which it is respectively found that: (1) the horizontal impulsive thrust does not satisfy previous constraints; (2) the vertical impulsive thrust has unsatisfactory control requirements; (3) the employment of constant vertical thrust furnishes good guidance and control; and (4) a high level of fuel consumption associated with a forced motion of the Hermes vehicle along the target's orbit may be justified by the resulting high level of rendezvous certainty. O.C.

A90-13730#
SIGHT - THE SIMULATED INTERACTIVE GRAPHICAL TRAJECTORY SYSTEM
DAN C. HUNT IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p. refs
(IAF PAPER ST-89-018) Copyright

SIGHT represents a multifunctional mission simulation and analysis system for the determination of orbital mechanics and spacecraft dynamics. SIGHT provides three dimensional real-time simulation of the orbital paths and rotations of multiple bodies. The system uses a numerical solution to the restricted three-body problem and introduces algorithms for navigation and guidance. The purpose of SIGHT is to create, model and analyze complex scenarios of thrusting and nonthrusting structures on high-speed image processing environments. The application of SIGHT will be discussed for the analysis of a low-thrust spacecraft currently being developed in conjunction with NASA Langley. Author

A90-13977#
ATTITUDE DETERMINATION WITH GPS
R. LUCAS, R. OKKES, and W. KRIEDTE (ESTEC, Noordwijk, Netherlands) IN: ION, Satellite Division's International Technical Meeting, Colorado Springs, CO, Sept. 19-23, 1988, Proceedings. Washington, DC, Institute of Navigation, 1989, p. 85-88. Research supported by ESA. refs

A numerical algorithm for determining the attitude of a space platform in LEO by means of interferometric measurements on GPS signals is developed analytically. The derivation of the algorithm is given in detail, and it is predicted that, for baselines of about 2 m, attitude accuracy of order 1 mrad or better can be obtained in real time, even in dynamic environments. T.K.

A90-13978#
GPS RELATIVE NAVIGATION FOR SPACE VEHICLES
R. W. OKKES and R. LUCAS (ESTEC, Noordwijk, Netherlands) IN: ION, Satellite Division's International Technical Meeting, Colorado Springs, CO, Sept. 19-23, 1988, Proceedings. Washington, DC, Institute of Navigation, 1989, p. 89-93.

The use of a satellite GPS to guide spacecraft in rendezvous operations is investigated analytically, considering the case of two spacecraft equipped with GPS receivers for absolute navigation. Consideration is given to (1) a method based on the use of each spacecraft's absolute state-vector data only and (2) a method involving the Kalman filtering of differenced pseudorange data and carrier phase or carrier-cycle count measurements (along with attitude, INS, and timing data). The characteristics of the GPS data and the implementation of the Kalman filter are described in detail, and the applicability of the present technique to rendezvous between the International Space Station and the Columbus MTFF or Hermes spacecraft is indicated. T.K.

A90-14002#
RELATIVE POSITIONING EXPERIMENTS FOR LOW DYNAMICS SPACE BASED APPLICATIONS
D. S. COCO, P. R. PASTOR, and D. J. KURTIN (Texas, University, Austin) IN: ION, Satellite Division's International Technical Meeting, Colorado Springs, CO, Sept. 19-23, 1988, Proceedings. Washington, DC, Institute of Navigation, 1989, p. 333-338.

A series of land-based relative positioning experiments has been performed to simulate low dynamic Space Station/orbiter maneuvers. The experiments used two TI 4100 receivers to measure the relative separation between two slow-moving vehicles. The GPS-derived ranges were compared to truth data obtained from a tellurometer microwave ranging system that provided centimeter level accuracies. The GPS data were processed through a differential Kalman filter in postprocessing using the phase smoothed pseudorange to generate relative positions for the two vehicles. The GPS vehicle-to-vehicle ranges show typical accuracies of 10 cm-5 m, depending on the vehicle dynamics and the quality of the data. Author

A90-16523
ORIENTATION OF LARGE ORBITAL STATIONS
V. A. SARYCHEV, M. IU. BELIAEV, V. V. SAZONOV, and T. N. TIAN (AN SSSR, Institut Prikladnoi Matematiki, Moscow, USSR) IN: Dynamics of controlled mechanical systems; Proceedings of the IUTAM/IFAC Symposium, Zurich, Switzerland, May 30-June 3, 1988. Berlin and New York, Springer-Verlag, 1989, p. 193-205. refs
Copyright

The single-axis gravitational orientation mode is considered for the Salyut 6 and 7 orbital stations. An integral statistical technique is described for determining the real rotational motion of the stations in this mode by the solar and magnetic sensor indications. The technique is illustrated by computations of residual microaccelerations aboard the station; their knowledge is important for an analysis of some technological experiments. Author

A90-17228
MATHEMATICAL MODELING OF ERRORS IN THE ACQUISITION OF TRAJECTORY DATA ON MOVING OBJECTS FROM SPACE PLATFORMS [MATEMATICHESKOE MODELIROVANIE OSHIBOK POLUCHENIIA TRAEKTORNOI INFORMATSII O DVIZHUSHCHIKHSIA OB'EKTAKH S KOSMICHESKIKH STANTSII]
S. A. LEONOV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 27, Sept.-Oct. 1989, p. 660-665. In Russian. refs
Copyright

A formal description of errors in the acquisition of trajectory data on moving objects from space platforms is presented.

Mathematical models are proposed for errors in the data acquisition due to the positioning of the acquisition instruments on a vibrating and deformable platform moving three-dimensionally. A classification of such errors is given. B.J.

A90-17231
SYNTHESIS OF CONTROL SIGNALS USING A PREDICTIVE MODEL IN A SPACECRAFT CONTROL SYSTEM WITH RELAY CONTROLLERS [SINTEZ UPRAVLIAIUSHCHIKH SIGNALOV S POMOSHCH'IU PROGNOZIRUIUSHCHEI MODELI V SISTEME UPRAVLENIIA KA S RELEINYMI ISPOLNITEL'NYMI ORGANAMI]
N. E. ZUBOV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 27, Sept.-Oct. 1989, p. 682-690. In Russian. refs
Copyright

The paper examines the synthesis of optimal control for a spacecraft represented as a nonlinear plant. A modified relay-control algorithm with a predictive model is proposed. This algorithm is applied to a problem of rendezvous control. B.J.

A90-19891#
BERTHING AND DOCKING MECHANISMS FOR FUTURE JAPANESE SPACE STRUCTURES
E. ENDO, H. MITSUMA (NASDA, Tsukuba Space Center, Japan), Y. TANIGUCHI, R. SAKATA (Kawasaki Heavy Industries, Ltd., Space Systems Dept., Kakamigahara, Japan), T. ITOKO (Kawasaki Heavy Industries, Ltd., Akashi, Japan) et al. AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs
(AIAA PAPER 90-0516) Copyright

The design of docking and berthing mechanisms for future Japanese space structures and the related computer simulation are discussed. The basic requirements for docking and a concept which has been developed to fulfill them are summarized. The design of the three major mechanisms and control devices, i.e., the probe, the structural latches, and umbilical connection device are examined along with the related control electronics. The proximity sensor and its specifications are examined and a block diagram is shown. The motion calculation model, interference calculation model, and reaction force calculation model involved in the simulation are described. C.D.

A90-19894*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FACTORS INFLUENCING MANUAL ABILITY TO RECOVER FROM AN ANOMALOUS THRUSTER INPUT DURING A SIMULATED DOCKING MANEUVER
ADAM R. BRODY (NASA, Ames Research Center; Sterling Software, Inc., Moffett Field, CA) and STEPHEN R. ELLIS (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. refs
(AIAA PAPER 90-0519) Copyright

An experiment was performed in the Space Station Proximity Operations Simulator. Five test subjects were instructed to perform twenty remote docking maneuvers of an orbital maneuvering vehicle (OMV) to the Space Station in which they were located. The OMV started from an initial range of 304.8 m on the Space Station's negative velocity vector. Time and fuel to return to a nominal trajectory, total mission duration, total fuel consumption, failure rate, and time histories of commanded burns were recorded for each trial. Analyses of the results added support to the hypothesis that slow approach velocities are not inherently safer than their more rapid counterparts. Naive subjects were capable of docking successfully at velocities faster than those prescribed by the '0.1 pct Rule' even when a simulated faulty thruster disturbed the nominal trajectory. Author

A90-20003*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CONTROL/STRUCTURE INTERACTION STUDY OF A SPACE STATION FREEDOM FIRST FLIGHT CONCEPT DURING REBOOST
TAE W. LIM (Lockheed Engineering and Sciences Co., Hampton, VA) and PAUL A. COOPER (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. refs
(AIAA PAPER 90-0747) Copyright

In the current design, the Space Station first-flight configuration will be assembled in a LEO and reboosted to a higher altitude such that the orbital decay due to atmospheric drag forces will lower the spacecraft to the proper altitude at the appropriate time to rendezvous with the next-assembly flight of the orbiter. The reboost maneuver will be performed by firing the on/off reaction control system jets to increase the forward velocity. This paper describes the design of a basic orbital reboost maneuver based on a burn-coast-burn scenario and a closed-loop attitude control system which will control the firing sequences of the jets to maintain the spacecraft attitude within required bounds. The design is then used to investigate the infuence of the elastic component response on the reboost jet firing logic. I.S.

A90-21526
GUIDANCE AND CONTROL 1989; PROCEEDINGS OF THE ANNUAL ROCKY MOUNTAIN GUIDANCE AND CONTROL CONFERENCE, KEYSTONE, CO, FEB. 4-8, 1989
ROBERT D. CULP, ED. (Colorado, University, Boulder) and ROBERT A. LEWIS, ED. (Ball Corp., Electro-Optics/Cryogenics Div., Boulder, CO) Conference sponsored by AAS. San Diego, CA, Univelt, Inc., 1989, 707 p. For individual items see A90-21527 to A90-21556.
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Papers are presented on advances in guidance, navigation, and control; guidance and control storyboard displays; attitude referenced pointing systems; guidance, navigation, and control for specialized missions; and recent experiences. Other topics of importance to support the application of guidance and control to the space community include concept design and performance test of a magnetically suspended single-gimbal control moment gyro; design, fabrication and test of a prototype double gimbal control moment gyroscope for the NASA Space Station; the Circumstellar Imaging Telescope Image Motion Compensation System providing ultra-precise control on the Space Station platform; pinpointing landing concepts for the Mars Rover Sample Return mission; and space missile guidance and control simulation and flight testing. C.E.

A90-21533
DISCRETE-TIME CONTROL OF A SPACECRAFT WITH RETARGETABLE FLEXIBLE ANTENNAS
LEONARD MEIROVITCH (Virginia Polytechnic Institute and State University, Blacksburg) and MARTIN E. B. FRANCE (USAF, Washington, DC) IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989, p. 119-143. refs
(AAS PAPER 89-007) Copyright

This paper is concerned with the control of a spacecraft consisting of a rigid platform and retargetable flexible antennas. The mission consists of a minimum-time maneuver of the antenna(s) to coincide with predetermined line(s) of sight, while stabilizing the platform in an inertial space and suppressing the elastic vibration of the antenna(s). The system is modeled by a set of linearized, time-varying equations of motion. A discrete-time approach permits consideration of the time-varying nature of the system in designing the digital control law. Several control techniques were investigateed and results from numerical examples involving a spacecraft with a single flexible antena are presented. Author

A90-21536* Colorado Univ., Boulder.
OPTIMIZED ORBITS FOR THE CONSTELLATION OF SPACE STATION POLAR PLATFORMS
ROBERT CHASE and MICHAEL MUNDT (Colorado, University, Boulder) IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989,

p. 185-203. refs
(Contract NAGW-1191)
(AAS PAPER 89-015) Copyright

The orbital configuration of the Eos polar-platform constellation is examined to determine if baseline orbital parameters are appropriately specified to meet the mission task of measuring global oceanic mesoscale variability. Using the Nyquist sampling theorem, spatial and temporal measurement requirements are first established for the constellation. Based upon these requirements, the optimum solution indicates that a total of five spacecraft equipped with nadir-pointing altimeters, or two multibeam-equipped platforms, would be required to meet the mesoscale mapping task. Additional analyses were performed on both one- and and two-platform configurations as well as the complete four-platform Eos constellation. The results of these calculations show that the preferred scenario would be to equip all four Eos polar platforms with multibeam altimeters. Author

A90-21548* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEMONSTRATING SYSTEM FOR SERVICING SATELLITES
LYLE M. JENKINS (NASA, Johnson Space Center, Houston, TX) IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989, p. 369-374.
(AAS PAPER 89-043) Copyright

NASA has initiated a program to demonstrate a Satellite Servicer System prototype in a series of flight tests with the Space Shuttle. When the commitment to an operational system has been demonstrated, it is anticipated that a variety of missions will develop that can productively use the servicing capability. Rendezvous and proximity operations contain key enabling technologies needed for an effective operational system. Guidance, navigation and control hardware and operational techniques must be integrated into the program. Supporting sensor technology may limit or enhance the capability of the system depending on its readiness. Requirements for docking the spacecraft in the system concept development and technology requirements are reviewed. Examples of the initial assessment of technology readiness and applications opportunities are discussed. The degree of autonomy is of particular interest. Author

A90-22269* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
OPTIMAL ORBIT TRANSFER SUITABLE FOR LARGE FLEXIBLE STRUCTURES
ALOK K. CHATTERJEE (JPL, Pasadena, CA) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 37, July-Sept. 1989, p. 261-280. refs
Copyright

The problem of continuous low-thrust planar orbit transfer of large flexible structures is formulated as an optimal control problem with terminal state constraints. The dynamics of the spacecraft motion are treated as a point-mass central force field problem; the thrust-acceleration magnitude is treated as an additional state variable; and the rate of change of thrust-acceleration is treated as a control variable. To ensure smooth transfer, essential for flexible structures, an additional quadratic term is appended to the time cost functional. This term penalizes any abrupt change in acceleration. Numerical results are presented for the special case of a planar transfer. Author

A90-22490
AVIONICS FOR MANNED SPACECRAFT
MYRON KAYTON (Kayton Engineering Co., Santa Monica, CA) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 25, Nov. 1989, p. 786-827. refs
Copyright

The author describes the avionic equipment for manned spacecraft, past, present, and future. He treats the four classic avionic systems-crew interface, flight control, navigation, and communication-and adds a fifth called subsystem management which refers to the monitoring and reconfiguration of equipment when faults occur. He starts by describing the functions of spacecraft avionics in general. He then discusses what he considers to have been the first manned spacecraft, the X-15. He continues with the early U.S. and Soviet spacecraft (including their space stations), the U.S. Shuttle, and the European Spacelab. He concludes with projections for the avionics in future manned spacecraft, such as the U.S. Space Station, a lunar base, and planetary explorers. I.E.

A90-23252*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EVALUATION OF THE '0.1 PERCENT RULE' FOR DOCKING MANEUVERS
ADAM R. BRODY (NASA, Ames Research Center, Moffett Field, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 7, 8. Previously cited in issue 09, p. 1300, Accession no. A89-25335. refs
Copyright

A90-25037#
DESIGNING THE EXPLORER PLATFORM TO FACILITATE EVA AND ROBOTIC SERVICING
THOMAS J. GRIFFIN and MARY E. BARNBY (CTA, Inc., Rockville, MD) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 14 p. refs
(AIAA PAPER 90-0611) Copyright

The Explorer Planform (EP) program provides an example of the successful integration of on-orbit servicing requirements. These requirements are based on three elements: a serviceable spacecraft design, appropriate space support equipment, and a flexible mission operations philosophy. This paper addresses how the EP fulfills these requirements for its planned payload changeout and maintenance missions. The Goddard Space Flight Center's Satellite Servicing Project's flight experience indicates that serviceable spacecraft design should be standardized and modular in form. The EP utilizes this concept by baselining the platform on the standard Multimission Modular Spacecraft. Author

A90-25655*# Ford Aerospace and Communications Corp., Palo Alto, CA.
SERVICING COMMUNICATION SATELLITES IN GEOSTATIONARY ORBIT
PAUL K. RUSSELL and KENT M. PRICE (Ford Aerospace Corp., Space Systems Div., Palo Alto, CA) IN: AIAA International Communication Satellite Systems Conference and Exhibit, 13th, Los Angeles, CA, Mar. 11-15, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 456-465.
(Contract NAS3-24253)
(AIAA PAPER 90-0830) Copyright

The econmic benefits of a LEO space station are quantified by identifying alternative operating scenarios utilizing the space station's transportation facilities and assembly and repair facilities. Particular consideration is given to the analysis of the impact of on-orbit assembly and servicing on a typical communications satellite is analyzed. The results of this study show that on-orbit servicing can increase the internal rate of return by as much as 30 percent. I.S.

A90-25985#
DECENTRALIZED FEEDBACK MANEUVER OF FLEXIBLE SPACECRAFT
LARRY SILVERBERG and LESTER A. FOSTER (North Carolina State University, Raleigh) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 258-264. refs
Copyright

This paper describes a novel approach to flexible spacecraft maneuver in which spacecraft motion relative to the motion of a shadow spacecraft is suppressed using a decentralized feedback control. The shadow spacecraft is a fictitious spacecraft that can be positioned, oriented, and allowed to undergo elastic deformations at the discretion of the designer. First, rest-to-spin

maneuvers are investigated, with different choices for the shadow coordinates. The angular velocities of the shadow coordinates are chosen as step functions, quadratic functions corresponding to minimum fuel maneuvers for rigid bodies, and quadratic functions with lag compensation in which the lag is associated with the spacecraft angular velocities relative to the shadow spacecraft angular velocities. The performance of the maneuvers is illustrated in the presence of multiple actuator failures. Next, both in-plane and out-of-plane rest-to-rest maneuvers are investigated. The associated shadow coordinates are chosen to correspond to those of minimum fuel maneuvers and minimum fuel maneuvers with lag compensation. Author

A90-28714
CAN SATELLITE SERVICING PAY?
STEPHANE CHENARD Interavia Space Markets (ISSN 0258-4212), vol. 6, Jan.-Feb. 1990, p. 29-35.
Copyright

The planning and development by NASA of new tools and vehicles which could soon bring satellite servicing into the commercial arena is reviewed. The smartest systems are designed for intervention in LEO, mostly in conjunction with Space Station Freedom. Studies now in progress leading to the definition of a Space Transfer Vehicle are presented. These include the Orbital Maneuvering Vehicle (OMV), the Short-Range Vehicle, and the Flight Telerobotic Servicer. Various Canadian, European, Soviet, and Japanese studies are also mentioned. By itself, the OMV has an altitude range of up to 2300 km and can make plane changes of up to 8 dgs. It is noted that scientific satellites are seldom replaced when they fail, nor are they normally insured. Even with a dedicated OMV and launch cost, the cost of servicing is much less than that of a new spacecraft. In any case, servicing is unlikely to become widespread before the end of the current generation of satellites. It is concluded that NASA is about to address the question whether things will change once robot servicers enter the geostationary world. R.E.P.

A90-29061
MANEUVERABILITY OF LARGE ORBITAL STATIONS [MANEVRENNOST' KRUPNYKH ORBITAL'NYKH STANTSII]
V. P. LEGOSTAEV and E. N. TOKAR' Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, Jan.-Feb. 1990, p. 3-10. In Russian. refs
Copyright

The maneuverability of orbital stations in the earth's gravity field is examined for different types of station orientation, i.e., constant orientation with respect to the inertial coordinate system and constant orientation with respect to the orbital coordinate system. A calculation is made of the total kinetic moment of gyro systems providing different degrees of angular maneuverability to the station. B.J.

A90-29066
STEADY-STATE MOTIONS OF AN ELASTIC MEMBRANE IN CIRCULAR ORBIT [O STATSIONARNYKH DVIZHENIIAKH UPRUGOI MEMBRANY NA KRUGOVOI ORBITE]
S. D. FURTA Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, Jan.-Feb. 1990, p. 47-55. In Russian. refs
Copyright

An analysis is made of the motion of an elastic membrane stretched onto a rigid closed contour in circular Keplerian motion in a central Newtonian force field. The existence of weak solutions of the equation of motion is demonstrated. Sufficient conditions for the existence of steady-state solutions are formulated, and their Liapunov stability is analyzed. The particular case of the bifurcation of a trivial steady-state motion is examined. B.J.

A90-29068
AN ALGORITHM FOR CALCULATING THE PARAMETERS OF MULTIPLE-CIRCUIT DISTANT-AIM MANEUVERS [ALGORITM RASCHETA PARAMETROV MNOGOVITKOVYKH MANEVROV DAL'NEGO NAVEDENIIA]
A. A. BARANOV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, Jan.-Feb. 1990, p. 69-76. In Russian.
Copyright

An analysis is made of four-impulse distant-aim maneuvers assuring a soft rendezvous of the active spacecraft with the target, which are moving in close nearly circular orbits. A numerical-analytical approach is used to construct an algorithm for determining the parameters of optimal maneuvers in a class of solutions for which the signs of all the transversal impulses coincide. A geometrical interpretation of the process of searching for the solution is given. B.J.

A90-29404#
DOCKING/SEPARATION TEST OF TWO-DIMENSIONAL TRUSS STRUCTURE WITH VARIABLE GEOMETRIES
YUJI MATSUZAKI, HIROSHI FURUYA (Nagoya University, Japan), FUMIHIRO KUWAO, and KENICHI TAKAHARA (Toshiba Corp., Kawasaki, Japan) IN: AIAA/ASME/ASCE/AHS/ASC Structures, *Structural Dynamics and Materials Conference, 31st, Long Beach, CA, Apr. 2-4, 1990, Technical Papers. Part 3. Washington, DC*, American Institute of Aeronautics and Astronautics, 1990, p. 1865-1870. Research sponsored by the Institute of Space and Astronautical Science. refs
(AIAA PAPER 90-0945) Copyright

This paper describes an experimental simulation of soft docking/separation of space structures, such as the Space Station and free-flyings where the low gravity condition will be utilized for a wide variety of tests and experiments. When the whole structure of a space vehicle having a large mass moves to dock to a target, it is usually difficult to avoid a dynamic impact which disturbs a stationary state of the target. A two-dimensional truss structure with variable geometries was constructed to apply an adaptive structural concept to a docking problem. The central idea of the soft docking is to deform the docking structure in such a way that the center of the structural mass has no motion to induce no inertia force of the structural mass. An experimental result shows that there was very slight difference between the acceleration of the target structure before and during the docking operation. Author

A90-29681
GUIDING SPACE STATION
IAN PARKER Space (ISSN 0267-954X), vol. 6, Mar.-Apr. 1990, p. 14-16.
Copyright

The involvement of Honeywell in developing the Space Station work package 2 is discussed, focusing on the data management, and the guidance, navigation, and control systems. The use of six-DOF devices for the controls and the possible inclusion of force reflective feedback are discussed. Consideration is given to the multiplex/demultiplex devices for the data management system, the attitude control subsystem, the inertial sensor assembly, the star tracker, and momentum storage devices. R.B.

N90-10125# Naval Postgraduate School, Monterey, CA.
MODELING, SIMULATION, AND ANALYSES OF ATTITUDE CONTROL FOR THE CREW/EQUIPMENT RETRIEVER (CER) PROPOSED FOR SPACE STATION M.S. Thesis
DANIEL L. HANSEN Mar. 1989 113 p
(AD-A208140) Avail: NTIS HC A06/MF A01 CSCL 22/3

The Crew/Equipment Retrieval System (CERS) is proposed for space station to provide the capability to rescue an EVA crewman or to retrieve equipment inadvertently detached from the station. Attitude control for the Crew/Equipment Retriever (CER) is modeled, simulated and analyzed with and without a target during autonomous attitude hold. Time-optimal and weighted-time-fuel optimal control laws are derived using Pontryagin's Minimum Principle. The CER baseline configuration is analyzed to accomplish some of the attitude control trade-off analyses planned for the CER preliminary design phase. Optimal thruster size and placement are evaluated for three-axis stabilization. Control stability when the moment of inertia tensor changes during target capture is evaluated for several worst-case

scenarios. Attitude control performance results are computed through computer simulation. Simulation of the CER baseline configuration shows it does not provide effective control during capture of a worst-case 850 pound target. A new CER configuration scheme is proposed, evaluated to the baseline configuration. Fuel optimal and end-of-mission performance for the new CER configuration is evaluated. Simulation of the CER proposed configuration is evaluated. Simulation of the CER proposed configuration shows it provides effective control during target capture for modified locations in the capture for modified locations in the capture net. GRA

N90-11798*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DOCKING SYSTEM FOR SPACECRAFT Patent Application
JON B. KAHN, inventor (to NASA) 30 Dec. 1988 21 p
(NASA-CASE-MSC-21327-1; NAS 1.71:MSC-21327-1; US-PATENT-APPL-SN-292121) Avail: NTIS HC A03/MF A01 CSCL 22/2

A mechanism is disclosed for the docking of a spacecraft to a space station where a connection for transfer of personnel and equipment is desired. The invention comprises an active docking structure on a spacecraft and a passive docking structure on the station. The passive structure includes a docking ring mounted on a tunnel structure fixed to the space station. The active structure includes a docking ring carried by an actuator-attenuator devices, each attached at one end to the ring and at its other end in the spacecraft payload bay. The devices respond to command signals for moving the docking ring between a stowed position in the spacecraft to a deployed position suitable for engagement with the docking ring. The devices comprise means responsive to signals of sensed loadings to absorb impact energy and retraction means for drawing the coupled spacecraft and station into final docked configuration and moving the tunnel structure to a berthed position in the spacecraft. Latches couple the spacecraft and space station upon contact of the docking rings and latches establish a structural tie between the spacecraft when retracted. NASA

N90-13413*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
FLIGHT MECHANICS/ESTIMATION THEORY SYMPOSIUM, 1989
THOMAS STENGLE, ed. Washington Oct. 1989 466 p Symposium held in Greenbelt, MD, 23-24 May 1989
(NASA-CP-3050; REPT-89B00261; NAS 1.55:3050) Avail: NTIS HC A20/MF A03 CSCL 22/1

Numerous topics in flight mechanics and estimation were discussed. Satellite attitude control, quaternion estimation, orbit and attitude determination, spacecraft maneuvers, spacecraft navigation, gyroscope calibration, spacecraft rendevous, and atmospheric drag model calculations for spacecraft lifetime prediction are among the topics covered.

N90-13419*# Auburn Univ., AL. Dept. of Aerospace Engineering.
SIMULATION OF SPACECRAFT ATTITUDE DYNAMICS USING TREETOPS AND MODEL-SPECIFIC COMPUTER CODES
JOHN E. COCHRAN, T. S. NO, and NORMAN G. FITZ-COY *In* NASA, Goddard Space Flight Center, Flight Mechanics/Estimation Theory Symposium, 1989 p 75-95 Oct. 1989
Avail: NTIS HC A20/MF A03 CSCL 22/2

The simulation of spacecraft attitude dynamics and control using the generic, multi-body code called TREETOPS and other codes written especially to simulate particular systems is discussed. Differences in the methods used to derive equations of motion--Kane's method for TREETOPS and the Lagrangian and Newton-Euler methods, respectively, for the other two codes--are considered. Simulation results from the TREETOPS code are compared with those from the other two codes for two example systems. One system is a chain of rigid bodies; the other consists of two rigid bodies attached to a flexible base body. Since the computer codes were developed independently, consistent results serve as a verification of the correctness of all the programs. Differences in the results are discussed. Results for the two-rigid-body, one-flexible-body system are useful also as information on multi-body, flexible, pointing payload dynamics. Author

N90-14243*# Old Dominion Univ., Norfolk, VA. Dept. of Electrical and Computer Engineering.
GUIDANCE AND CONTROL STRATEGIES FOR AEROSPACE VEHICLES Progress Report, 1 Jul. - 31 Dec. 1989
J. L. HIBEY, D. S. NAIDU, and C. D. CHARALAMBOUS Dec. 1989 100 p
(Contract NAG1-736)
(NASA-CR-186195; NAS 1.26:186195) Avail: NTIS HC A05/MF A01 CSCL 01/3

A neighboring optimal guidance scheme was devised for a nonlinear dynamic system with stochastic inputs and perfect measurements as applicable to fuel optimal control of an aeroassisted orbital transfer vehicle. For the deterministic nonlinear dynamic system describing the atmospheric maneuver, a nominal trajectory was determined. Then, a neighboring, optimal guidance scheme was obtained for open loop and closed loop control configurations. Taking modelling uncertainties into account, a linear, stochastic, neighboring optimal guidance scheme was devised. Finally, the optimal trajectory was approximated as the sum of the deterministic nominal trajectory and the stochastic neighboring optimal solution. Numerical results are presented for a typical vehicle. A fuel-optimal control problem in aeroassisted noncoplanar orbital transfer is also addressed. The equations of motion for the atmospheric maneuver are nonlinear and the optimal (nominal) trajectory and control are obtained. In order to follow the nominal trajectory under actual conditions, a neighboring optimum guidance scheme is designed using linear quadratic regulator theory for onboard real-time implementation. One of the state variables is used as the independent variable in reference to the time. The weighting matrices in the performance index are chosen by a combination of a heuristic method and an optimal modal approach. The necessary feedback control law is obtained in order to minimize the deviations from the nominal conditions. Author

N90-14266*# Michigan Univ., Ann Arbor. Aerospace System Design.
PROJECT ARGO: THE DESIGN AND ANALYSIS OF AN ALL-PROPULSIVE AND AN AEROASSISTED VERSION OF A MANNED SPACE TRANSPORTATION VEHICLE Final Report
Apr. 1989 212 p
(Contract NASW-4435)
(NASA-CR-186047; NAS 1.26:186047; AERO-483) Avail: NTIS HC A10/MF A02 CSCL 22/2

Project Argo is the design of a manned Space Transportation Vehicle (STV) that would transport payloads between LEO (altitude lying between 278 to 500 km above the Earth) and GEO (altitude is approximately 35,800 km above the Earth) and would be refueled and refurbished at the Space Station Freedom. Argo would be man's first space-based manned vehicle and would provide a crucial link to geosynchronous orbit where the vast majority of satellites are located. The vehicle could be built and launched shortly after the space station and give invaluable space experience while serving as a workhorse to deliver and repair satellites. Eventually, if a manned space station is established in GEO, then Argo could serve as the transport between the Space Station Freedom and a Geostation. If necessary, modifications could be made to allow the vehicle to reach the moon or possibly Mars. Project Argo is unique in that it consists of the design and comparison of two different concepts to accomplish the same mission. The first is an all-propulsive vehicle which uses chemical propulsion for all of its major maneuvers between LEO and GEO. The second is a vehicle that uses aeroassisted braking during its return from GEO to LEO by passing through the upper portions of the atmosphere. K.C.D.

N90-15982# European Space Agency, Paris (France).
RVD SCENARI AND INTERFACES BETWEEN HERMES AND SPACE STATION

J.-J. CAPART *In its* Crew Safety and Rescue in Space: An International Approach p 47-52 Aug. 1989
Copyright Avail: NTIS HC A04/MF A01; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 30 Dutch guilders

The European manned transportation system, Hermes, operational at the end of the century, is examined. The range of missions, for which Hermes is designed are presented. The adaptability of Hermes to visit diferent stations, and to various in-orbit interventions both external and internal (with the support of a manipulator arm and extravehicular suit) are illustrated. The possible scenarios for crew transport and rescue missions are discussed. An approach for improving the interoperability of manned systems, by international cooperation and standardization, is provided. ESA

N90-16778*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
COOPERATIVE CONTROL OF TWO ACTIVE SPACECRAFT DURING PROXIMITY OPERATIONS M.S. Thesis - MIT
ROBERT J. POLUTCHKO Aug. 1989 148 p
(Contract NAS9-18147)
(NASA-CR-185596; NAS 1.26:185596; CSDL-T-1037) Avail: NTIS HC A07/MF A01 CSCL 22/1

A cooperative autopilot is developed for the control of the relative attitude, relative position and absolute attitude of two maneuvering spacecraft during on orbit proximity operations. The autopilot consists of an open-loop trajectory solver which computes a nine dimensional linearized nominal state trajectory at the beginning of each maneuver and a phase space regulator which maintains the two spacecraft on the nominal trajectory during coast phases of the maneuver. A linear programming algorithm is used to perform jet selection. Simulation tests using a system of two space shuttle vehicles are performed to verify the performance of the cooperative controller and comparisons are made to a traditional passive target/active pursuit vehicle approach to proximity operations. The cooperative autopilot is shown to be able to control the two vehicle system when both the would be pursuit vehicle and the target vehicle are not completely controllable in six degrees of freedom. The cooperative controller is also shown to use as much as 37 percent less fuel and 57 percent fewer jet firings than a single pursuit vehicle during a simple docking approach maneuver. Author

N90-19295# Air War Coll., Maxwell AFB, AL.
ORBITAL SERVICING: ISSUE OR ANSWER
DOUGLAS P. HOTARD May 1989 58 p
(AD-A217284) Avail: NTIS HC A04/MF A01 CSCL 22/1

On-orbit satellite servicing as a forward-based logistic concept through an examination of its potential military benefits to endurance and survivability of space systems is reviewed. Reasons for opposition to implementation of the program within the military space environment are analyzed by focusing on the orbital refueling subfunction. The potential of orbital servicing to increase system capability and survivability while reducing system costs is assessed. GRA

N90-19420*# Kentucky Univ., Lexington. Dept. of Electrical Engineering.
YAW RATE CONTROL OF AN AIR BEARING VEHICLE
BRUCE L. WALCOTT *In* Alabama Univ., Research Reports: 1989 NASA/ASEE Summer Faculty Fellowship Program 46 p Dec. 1989
(Contract NGT-01-008-021)
Avail: NTIS HC A99/MF E06 CSCL 01/3

The results of a 6 week project which focused on the problem of controlling the yaw (rotational) rate the air bearing vehicle used on NASA's flat floor facility are summarized. Contained within is a listing of the equipment available for task completion and an evaluation of the suitability of this equipment. The identification (modeling) process of the air bearing vehicle is detailed as well as the subsequent closed-loop control strategy. The effectiveness of the solution is discussed and further recommendations are included. Author

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PROPULSION SYSTEMS/FLUID MANAGEMENT

Descriptions, analyses, and subsystem requirements of propellant/fluid management, and propulsion systems for attitude control, orbital maintenance and transfer maneuvers for the station and supporting vehicles.

A90-10509*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
KNOWLEDGE-BASED PROCESS CONTROL AND DIAGNOSTICS FOR ORBITAL CRYOGEN TRANSFER
ERIC A. RAYMOND (NASA, Ames Research Center; Sterling Software, Moffett Field, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 276-280. refs
(AIAA PAPER 89-3001)

AFDex is a rule based system designed to provide intelligent process control, diagnosis, and error recovery for a Shuttle based cryogenic experiment, SHOOT (Superfluid Helium On-Orbit Transfer). This paper describes the AFDex system in the context of traditional associative, model-based, and qualitative systems and discusses the implications of this first expert system in space. Author

A90-10561*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
INTERACTIVE REMOTE CONTROL FOR AN STS-BASED SUPERFLUID HELIUM TRANSFER DEMONSTRATION
JEFF C. SHAPIRO and FRANK A. ROBINSON (NASA, Ames Research Center; Sterling Software, Moffett Field, CA) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 696-704. refs
(AIAA PAPER 89-3074) Copyright

NASA's superfluid helium on-orbit transfer (SHOOT) experiment, which is a Shuttle-based demonstration of the technology required to service cryogenically cooled satellites in space, is described. The SHOOT Command and Monitoring System software, developed on Macintosh II, will provide a near-real-time highly interactive interface making it possible to control the experiment and to analyze and display its telemetry. User interface is discussed as well as conversion functions, and hardware. K.K.

A90-11019*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ELECTRIC PROPULSION FOR CONSTELLATION DEPLOYMENT AND SPACECRAFT MANEUVERING
W. D. DEININGER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and R. J. VONDRA (W. J. Schafer Associates, Arlington, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Sept.-Oct. 1989, p. 352-357. Research sponsored by SDIO. Previously cited in issue 20, p. 3356, Accession no. A88-48026. refs
Copyright

A90-11121*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AN ASSESSMENT OF LIQUID PROPULSION IN THE UNITED STATES
JOHN P. MCCARTY (NASA, Marshall Space Flight Center, Huntsville, AL) and J. M. MURPHY (Martin Marietta Technical Services Co., Huntsville, AL) AIAA, ASME, ASEE, and SAE, Joint Propulsion Conference, 25th, Monterey, CA, July 10-12, 1989, Paper. 22 p.

The paper examines the status of liquid propulsion capability and technology in the U.S. today versus where it needs to be to satisfy proposed near and long term goals. Attention is given to four areas of liquid propulsion: earth-to-orbit propulsion, orbital

transfer propulsion, on-orbit and planetary propulsion, and advanced propulsion. Recommendations on improving the state of liquid propulsion in the U.S. are presented. B.J.

A90-11255* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
SUPERFLUID HELIUM ORBITAL RESUPPLY - THE STATUS OF THE SHOOT FLIGHT EXPERIMENT AND PRELIMINARY USER REQUIREMENTS
MICHAEL J. DIPIRRO (NASA, Goddard Space Flight Center, Greenbelt, MD) and PETER KITTEL (NASA, Ames Research Center, Moffett Field, CA) IN: Cryogenic optical systems and instruments III; Proceedings of the Meeting, San Diego, CA, Aug. 17-19, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 44-51. refs
Copyright

The Superfluid Helium On-Orbit Transfer (SHOOT) flight experiment is designed to demonstrate the components and techniques necessary to resupply superfluid helium to satellites or Space Station based facilities. A top level description as well as the development status of the critical components to be used in SHOOT are discussed. Some of these components include the thermomechanical pump, the fluid acquisition system, the normal helium and superfluid helium phase separators, Venturi flow meter, cryogenic valves, burst disks, and astronaut-compatible EVA coupler and transfer line. The requirements for the control electronics and software are given. A preliminary description of the requirements that must be met by a satellite requiring superfluid helium servicing is given. In particular, minimum and optimum plumbing arrangements are shown, transfer line flow impedance and heat input impacts are assessed, instrumentation is described, and performance parameters are considered. Author

A90-11256* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ANALYSIS OF DEWAR AND TRANSFER LINE COOLDOWN IN SUPERFLUID HELIUM ON-ORBIT TRANSFER FLIGHT EXPERIMENT (SHOOT)
Y. S. NG (NASA, Ames Research Center, Moffett Field; Sterling Federal Systems, Inc., Palo Alto, CA) and J. H. LEE (NASA, Ames Research Center, Moffett Field, CA) IN: Cryogenic optical systems and instruments III; Proceedings of the Meeting, San Diego, CA, Aug. 17-19, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 52-59.
Copyright

The Superfluid Helium On-Orbit Transfer Flight Experiment (SHOOT) is designed to demonstrate the techniques and components required for orbital superfluid (He II) replenishment of observatories and satellites. One of the tasks planned in the experiment is to cool a warm cryogen tank and a warm transfer line to liquid helium temperature. A math model, based on single-phase vapor flow heat transfer, has been developed to predict the cooldown time, component temperature histories, and helium consumption rate, for various initial conditions of the components and for the thermomechanical pump heater powers of 2 W and 0.5 W. This paper discusses the model and the analytical results, which can be used for planning the experiment operations and determining the pump heater power required for the cooldown operation. Author

A90-13429#
THE RAE SPACE PROPULSION PROGRAMME
M. J. FIDDICK, R. D. GOULD, P. G. HERRINGTON, and S. P. FIELD (Royal Aerospace Establishment, Farnborough, England) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p. Research supported by the Ministry of Defence and Department of Trade and Industry.
(IAF PAPER 89-285) Copyright

The Royal Aerospace Establishment (RAE) is engaged in a program of work aiming at increasing the life, performance, reliability, and cost effectiveness of spacecraft propulsion systems. An overview of work on bipropellant thruster design, and research, development, and flight qualification is described, covering work on thrusters ranging in size between 2-20 kN. A summary of work on bipropellant chemistry covers flow decay, cleaning procedures, and propellant purification. Instrumentation techniques for the monitoring of firings and onboard control of spacecraft propulsion systems are discussed, along with some of the software codes used to design and monitor the performance of propulsion systems. Finally, the status of various thruster programs and supporting technology is summarized, including propellant filters, flow control valves, latch valves, propellant tank manufacture, and pyro valves. C.E.

A90-13433#
METHOD OF FUEL TANK DESIGN DEVELOPMENT FOR FUTURE LONG-TERM SPACE FLIGHTS
V. U. BEZUGLYI, N. E. BOITSUN, I. N. KOZLOV, and A. S. MAKAROVA (Dnepropetrovskii Gosudarstvennyi Universitet, Dnepropetrovsk, Ukrainian SSR) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-291) Copyright

Two typical experimental plants using mathematical models for prediction of liquid behavior at the final stage of propellant depletion out of spacecraft tanks have been developed. One of the plants is a design providing side overloads for a propellant tank model by moving in the horizontal plane and turning round a horizontal axis. The other plant makes it possible to investigate liquid drain out of the tank model while oscillating in two mutually perpendicular directions in the horizontal plane. Experimental investigation of hydrodynamic processes in propellant tank models at small filling has been carried out. Data on liquid free surface behavior have been obtained and used to study and check the mathematical models, to analyze empirical constants, and to determine the adequacy extent and applicability boundaries of the mathematical models. Analytical and experimental results are in good agreement. It is found that the application of the proposed mathematical models for designing propellant tanks makes it possible to reduce experiments to a great extent. C.E.

A90-13490#
ON THE SLOSHING DYNAMICS AND ATTITUDE STABILITY OF LIQUID-FILLED SPACECRAFT WITH COMPLEX STRUCTURES
ZHAOLIN WANG, BIN QUAN, and ZHONGPING DENG (Tsinghua University, Beijing, People's Republic of China) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p. refs
(IAF PAPER 89-374) Copyright

Sloshing of complex liquid-filled spacecraft and its influence on the control systems are discussed. The equations of a complex system filled with liquid are described. Liquid sloshing in the container with netted-hole spacers and the effects of viscous-elastic spacers baffling liquid sloshing are discussed. Author

A90-13516*# Alabama Univ., Huntsville.
EFFECT OF G-JITTERS ON THE STABILITY OF ROTATING BUBBLE UNDER MICROGRAVITY ENVIRONMENT
R. J. HUNG, Y. D. TSAO (Alabama, University, Huntsville), and F. W. LESLIE (NASA, Marshall Space Flight Center, Huntsville, AL) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(Contract NAG8-035; NAG8-129)
(IAF PAPER 89-409) Copyright

The instability of liquid and gas interface can be induced by the pressure of longitudinal and lateral accelerations, vehicle vibration, and rotational fields of spacecraft in a microgravity environment. Characteristics of slosh waves excited by the restoring force field of gravity jitters have been investigated. Results show that lower frequency gravity jitters excite slosh waves with higher ratio of maximum amplitude to wave length than that of the slosh waves generated by the higher frequency gravity jitters. Author

A90-16368*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE STATION FREEDOM RESISTOJET SYSTEM STUDY

ROBERT R. TACINA (NASA, Lewis Research Center, Cleveland, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 5, Nov.-Dec. 1989, p. 694-702. Previously cited in issue 20, p. 3175, Accession no. A87-45256. refs
Copyright

A90-16554
NEP FREIGHTER - A POINT DESIGN
PAUL G. PHILLIPS (Eagle Technical Services, Inc., Houston, TX) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 373-383.
(AAS PAPER 87-255) Copyright

Interplanetary vehicles using nuclear power and electric propulsion systems or nuclear electric propulsion (NEP) have been proposed for transporting cargo to Mars. A conceptual design and a mission scenario for a low-thrust nuclear electric propulsion freighter are discussed. The NEP freighter is conceived as a robust and flexible vehicle intended to carry large and diverse payloads through interplanetary space. The salient features of the freighter are detailed and the rationale behind the design is discussed. The NEP freighter is equipped with a 5 megawatt nuclear electric power source and a magnetoplasmadynamic thruster propulsion system. Existing technology or technology currently under development are utilized for the remaining design features of the NEP freighter. C.E.

A90-16555
HIGH PERFORMANCE NUCLEAR PROPULSION
RYAN K. HAALAND, G. ALLEN BEALE, and ANDREW S. MARTIN (USAF, Astronautics Laboratory, Edwards AFB, CA) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 387-395. refs
(AAS PAPER 87-256) Copyright

This discussion describes the Air Force Astronautics Laboratory's (AFAL) nuclear propulsion program which seeks to demonstrate a space nuclear propulsion capability for orbit transfer vehicles by the year 2001. The major factors and processes involved in the AFAL's selection of a nuclear propulsion system for development are summarized. The concepts under consideration, the NERVA derivative, particle bed, and cermet reactors, are presented. The discussion continues with a description of the performance growth potential of these reactor concepts and the potential impact on a round trip Mars mission. Author

A90-16556
LASER PROPULSION AND POSSIBLE MISSIONS TO MARS
JORDIN T. KARE (Lawrence Livermore National Laboratory, Livermore, CA) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 397-406. Research supported by SDIO. refs
(Contract W-7405-ENG-48)
(AAS PAPER 87-257) Copyright

Laser propulsion uses the energy of a large ground- or space-based laser to heat an inert propellant, producing high thrust at large specific impulse (500 - 2000 s) from a very simple thruster. Laser propulsion has until recently been considered largely for orbital transfer missions - including Mars missions - where high specific impulse and low thruster mass are critical; it remains a prime candidate for such missions. Recent developments, however, suggest that the major impact of laser propulsion will be in ground-to-orbit launching, where costs over an order of magnitude lower than those of proposed chemically-powered launch vehicles may be achievable within a decade. Author

A90-19884#
FLUID DYNAMICS AND THERMODYNAMICS OF A LOW GRAVITY LIQUID TANK FILLING METHOD
SAM M. DOMINICK and JAMES R. TEGART (Martin Marietta Corp., Denver, CO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p. Research supported by Martin Marietta Corp. refs
(AIAA PAPER 90-0509) Copyright

Resupply of liquid in the low-gravity environment is a requirement for many future space systems such as the Space Station Freedom. This paper shows how CFD models, in conjunction with existing test methods, can be applied to large orbital systems. Specifically, a method of tank filling in low gravity is examined where the fluid dynamics (FD) can be used to simplify greatly the resupply process. The FD of the liquid-vapor interface during the fill process and, in the case of cryogens, the thermodynamics associated with the FD are discussed. Experimental work done by NASA and others in drop tower facilities are reviewed along with new analytical correlations of these tests using a CFD code. C.D.

A90-19886#
ULLAGE EXCHANGE - AN ATTRACTIVE OPTION FOR ON-ORBIT CRYOGEN RESUPPLY
WILLIAM J. BAILEY and DOUGLAS H. BEEKMAN (Martin Marietta Corp., Denver, CO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. refs
(AIAA PAPER 90-0511) Copyright

This paper presents the ullage exchange method for transferring cryogenic liquids in a microgravity environment. This approach permits vented filling of a tank by connecting the supply and receiver tanks in a closed fluid circuit. The performance of an ullage exchange system is examined by performing several analytical simulations to investigate sensitivities to venting randomness, initial receiver tank temperature, initial supply tank volume, and the presence of gaseous helium in the receiver tank. The simulations demonstrate that an ullage exchange system can tolerate considerable variation in several parameters and still adequately transfer liquid. C.D.

A90-19946*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PROPULSIVE EFFECT OF SPACECRAFT PROPELLANT TANK RUPTURE FOLLOWING HYPERVELOCITY IMPACT BY A MICROMETEOROID
DARRELL L. JAN and KIM M. AARON (JPL, Pasadena, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p. refs
(AIAA PAPER 90-0614) Copyright

The impulse due to propellant tank micrometeroid damage is estimated for the Galileo spacecraft. The modes of tank failure considered are tank burst, or rupture, and puncture, which results in a hole through which propellant escapes. Other factors relevant to this calculation include spacecraft geometry, propellant volume and properties, and available heat sources. Tank burst was found to result in a spacecraft Delta V of less than 5 m/s, while the net impulse due to puncture is less than 10,000 Newton-seconds. Author

A90-19988*# Martin Marietta Space Systems, Inc., Denver, CO.
ON-ORBIT LOW GRAVITY CRYOGENIC SCIENTIFIC INVESTIGATIONS USING THE COLD-SAT SATELLITE
W. J. BAILEY (Martin Marietta Space Systems, Denver, CO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p.
(Contract NAS3-25063)
(AIAA PAPER 90-0718) Copyright

The Cryogenic On-Orbit Liquid Depot Storage, Acquisition and Transfer (COLD-SAT) Satellite is an experimental spacecraft designed to investigate the systems and technologies required for an efficient, effective, and reliable management of cryogenic fluids in reduced-gravity space environment. This paper defines the technology needs and the accompanying experimental three-month baseline mission of the COLD-SAT Satellite; describes the experiment subsystems, major features, and rationale for satisfying primary and secondary experimental requirements, using LH2 as the test fluid; and presents the conceptual design of the COLD-SAT spacecraft subsystems which support the on-orbit experiment. I.S.

A90-19989*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EVALUATION OF SUPERCRITICAL CRYOGEN STORAGE AND TRANSFER SYSTEMS FOR FUTURE NASA MISSIONS
HUGH ARIF, JOHN C. AYDELOTT, and DAVID J. CHATO (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. Previously announced in STAR as N90-10912. refs
(AIAA PAPER 90-0719) Copyright

Conceptual designs of Space Transportation Vehicles (STV), and their orbital servicing facilities, that utilize supercritical, single phase, cryogenic propellant were established and compared with conventional subcritical, two phases, STV concepts. The analytical study was motivated by the desire to avoid fluid management problems associated with the storage, acquisition and transfer of subcritical liquid oxygen and hydrogen propellants in the low gravity environment of space. Although feasible, the supercritical concepts suffer from STV weight penalties and propellant resupply system power requirements which make the concepts impractical.
Author

A90-21219*# Washington Univ., Saint Louis, MO.
PREDICTION OF SELF-PRESSURIZATION RATE OF CRYOGENIC PROPELLANT TANKAGE
JOHN I. HOCHSTEIN, HYUN-CHUL JI (Washington University, Saint Louis, MO), and JOHN C. AYDELOTT (NASA, Lewis Research Center, Cleveland, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, Jan.-Feb. 1990, p. 11-17. refs
(Contract NAG3-578)
Copyright

The SOLA-ECLIPSE code is being developed to enable prediction of the behavior of cryogenic propellants in spacecraft tankage. A brief description of the formulations used for modeling heat transfer and for determining the thermodynamic state is presented. Code performance is verified through comparison to experimental data for the self-pressurization of scale-model liquid hydrogen tanks. SOLA-ECLIPSE is used to examine the effect of initial subcooling of the liquid phase on the self-pressurization rate of an on-orbit full-scale liquid hydrogen tank typical for a chemical-propulsion orbit transfer vehicle. The computational predictions show that even small amounts of subcooling will significantly decrease the self-pressurization rate. Further, if the cooling is provided by a thermodynamic vent system, it is concluded that small levels of subcooling will maximize propellant conservation.
Author

A90-21220*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PERFORMANCE AND ENDURANCE TESTS OF A LABORATORY MODEL MULTIPROPELLANT RESISTOJET
W. EARL MORREN, MARGARET V. WHALEN, and JAMES S. SOVEY (NASA, Lewis Research Center, Cleveland, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, Jan.-Feb. 1990, p. 18-27. refs
Copyright

This paper presents the results of an effort to demonstrate the technological readiness of a long-life multipropellant resistojet for Space Station auxiliary propulsion. A laboratory model resistojet made from grain-stabilized platinum served as a test bed to evaluate the design characteristics, fabrication methods, and operating strategies for an engineering model multipropellant resistojet developed as part of the NASA Space Station propulsion system Advanced Development Program. The laboratory model thruster was characterized for performance on a variety of fluids expected to be available onboard a Space Station, then subjected to a 2000-h, 2400-thermal-cycle endurance test using carbon dioxide propellant. Maximum thruster temperatures were approximately 1400 C. Significant observations from the laboratory model thruster performance and endurance tests are discussed as they relate to the design of the engineering model thruster.
Author

A90-23259#
TERMINAL VELOCITY OF A LASER-DRIVEN LIGHT SAIL
COLIN R. MCINNES and JOHN C. BROWN (Glasgow, University, Scotland) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 48-52. refs
Copyright

It is shown that the maximum velocity attainable by a laser-driven light sail is constrained by the back pressure of the relativistically transformed microwave background radiation field with interstellar material having little effect. Using current sail concepts, terminal Lorentz factors much in excess of 100 are not possible, and therefore, limitations are imposed on the benefits of relativistic time dilation and the possible use of such sails for travel over long interstellar distances. This is a fundamental constraint imposed by nature on the ultimate performance of such sails.
Author

A90-26906*# Illinois Univ., Chicago.
NUMERICAL ANALYSIS OF BIPROPELLANT COMBUSTION IN ORBIT MANEUVERING VEHICLE THRUST CHAMBER
H. H. CHIU, T. L. JIANG (Illinois, University, Chicago), A. N. KREBSBACK, and K. W. GROSS (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 13 p. refs
(AIAA PAPER 90-0045)

The combustion and aerodynamic processes of liquid-liquid bipropellant; monomethylhydrazine and nitrogen tetroxide in the combustion chamber of a variable thrust engine (VTE) have been examined to assess the flow structure, combustion characteristics, and wall heat transfer under the simulated engine operations at two power levels. The Generalized Elliptic Multi-phase flow with Chemical reaction, Heat transfer and Interfacial Processes (GEM-CHIP) code and the Bipropellant Combustion (BICOMB) code, which is the GEMCHIP algorithm reformulated in the frame work of a body fitted coordinate system, have been used for the numerical study. Combustion flow structure with non-premixed type injection that simulates the impingement type injector is predicted and the results are compared with that of the premixed injector.
Author

A90-27418
LEAK DETECTION FOR SPACE STATION FREEDOM FLUID LINES
ROBERT H. HERTEL and RICHARD A. HEPPNER (Perkin-Elmer Corp., Applied Science Div., Pomona, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p.
(SAE PAPER 891448) Copyright

This paper describes a preliminary design concept developed for an ionization gauge to detect leaks in external fluid-carrying lines of Space Station Freedom. Special attention is given to the leak detection requirements of the gauge, the leak detection instrumentation, and the leak-detector operating modes. The pressure sensor proposed for leak sensing is a modified Bayard-Alpert ionization gauge. The design modifications introduced involve the filament, the gauge size, and gauge sensitivity. The redesigned gauge requires less than 5 W of power, weighs less than 4 lb, and was shown to meet the performance requirements.
I.S.

A90-27438
DEVELOPMENT OF TWO-PHASE FLUID LOOP SYSTEMS FOR FUTURE SPACE PLATFORMS
Y. ISHII, M. FURUKAWA, Y. MIYAZAKI (NASDA, Tsukuba, Japan), Y. KURIYAMA, K. FURUHAMA (Toshiba Corp., Tokyo, Japan) et al. SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 10 p. refs
(SAE PAPER 891470) Copyright

Since 1985 NASDA has made studies on advanced thermal management systems, especially on two-phase fluid loops, with a view to applying to temperature control and heat rejection of future space platforms of tens of kW class. The research on pump-driven two-phase fluid loop technology is in a new stage where the design and fabrication of a development model is completed. This paper describes the loop system design and gives details of components,

which are three kinds of cold plates (grooved double-pipe type, grooved multichannel type, tube and plate-heat-pipe type), two kinds of volumetric pumps (trochoid gear type, scroll type), and an accumulator of vapor pressure driven type. This paper, then, gives a brief description of an X-ray void meter which is measurements of void fractions and for graphical observations of various flow patterns in the cold plates. Author

A90-27560
A MODULAR APPROACH TO ON-ORBIT SERVICING
JOSEPH M. CARDIN (Moog, Inc., Space Products Div., East Aurora, NY) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 13 p.
(SAE PAPER 891604) Copyright

This paper describes a modular fluid interface to the spacecraft fluid systems, which uses a unique disconnect technology, called a rotary shut-off (RSO) disconnect. The flow control devices of the RSO, by axially engaging male and female RSO disconnect halves, enable a sequence to take place that opens a straight-through smooth-walled flow path. Separating the two halves allows the spherical valving elements to be driven shut and sealed. Data gathered to date indicate that the RSO disconnect is a significant improvement over current designs. I.S.

N90-10161*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LASER PROPULSION OPTION
DONALD H. HUMES *In its* Second Beamed Space-Power Workshop p 365-375 Jul. 1989
Avail: NTIS HC A19/MF A03 CSCL 20/5

The use of laser thrusters with exhaust powers in the 25 MW to 250 MW range can reduce the fuel that would be needed to transport the lunar outpost equipment to low-lunar orbit with a chemical OTV by 57000 Kg to 105000 Kg with no significant penalty in trip time. This would save one or two launches of the heavy-load launch vehicle. Nuclear-electric OTVs would take 40 to 120 times as long to get to the moon and would spend 100 to 1700 times as long in the Van Allen radiation belts as OTVs that have laser thrusters. Author

N90-10164*# Hampton Inst., VA. Dept. of Physics.
LASER THRUSTER
N. W. JALUFKA *In* NASA. Langley Research Center, Second Beamed Space-Power Workshop p 391-396 Jul. 1989
Avail: NTIS HC A19/MF A03 CSCL 20/5

Laser propulsion can reduce fuel by 57 t to 105 t over chemical propulsion for a 144 t Lunar base, with no significant increase in trip time. Laser propulsion reduces trip time by a factor of 40 to 120 over nuclear electric propulsion and time in radiation belts by a factor of 100 to 1700. Either solar or nuclear driven laser diode arrays could produce multimegawatt beams, typically 3,700 t for a 235 MW laser system. Laser diode arrays have high payoff due to short wavelength (850 nm) and high diode efficiency (70 percent). A dry laser OTV of 8790 kg and 60 percent efficiency can transport a 144 t lunar base. Laser propulsion could carry both personnel and cargo safely to the lunar base. Author

N90-10912*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EVALUATION OF SUPERCRITICAL CRYOGEN STORAGE AND TRANSFER SYSTEMS FOR FUTURE NASA MISSIONS
HUGH ARIF, JOHN C. AYDELOTT, and DAVID J. CHATO 1989 10 p Prepared for presentation at the 28th Aerospace Sciences Meeting, Reno, NV, 8-11 Jan. 1990; sponsored by AIAA
(NASA-TM-102394; E-5144; NAS 1.15:102394; AIAA-90-0719)
Avail: NTIS HC A02/MF A01 CSCL 22/2

Conceptual designs of Space Transportation Vehicles (STV), and their orbital servicing facilities, that utilize supercritical, single phase, cryogenic propellants were established and compared with conventional subcritical, two phase, STV concepts. The analytical study was motivated by the desire to avoid fluid management problems associated with the storage, acquisition and transfer of subcritical liquid oxygen and hydrogen propellants in the low gravity environment of space. Although feasible, the supercritical concepts suffer from STV weight penalties and propellant resupply system power requirements which make the concepts impractical. Author

N90-10983*# General Dynamics Corp., San Diego, CA. Space Systems Div.
EVOLUTIONARY SPACE STATION FLUIDS MANAGEMENT STRATEGIES Final Report
Aug. 1989 167 p
(Contract NAS3-25354)
(NASA-CR-185137; NAS 1.26:185137; GDSS-CRAD-89-002)
Avail: NTIS HC A08/MF A01 CSCL 22/2

Results are summarized for an 11-month study to define fluid storage and handling strategies and requirements for various specific mission case studies and their associated design impacts on the Space Station. There are a variety of fluid users which require a variety of fluids and use rates. Also, the cryogenic propellants required for NASA's STV, Planetary, and Code Z missions are enormous. The storage methods must accommodate fluids ranging from a high pressure gas or supercritical state fluid to a sub-cooled liquid (and superfluid helium). These requirements begin in the year 1994, reach a maximum of nearly 1800 metric tons in the year 2004, and trail off to the year 2018, as currently planned. It is conceivable that the cryogenic propellant needs for the STV and/or Lunar mission models will be met by LTCSF LH2/LO2 tanksets attached to the SS truss structure. Concepts and corresponding transfer and delivery operations have been presented for STV propellant provisioning from the SS. A growth orbit maneuvering vehicle (OMV) and associated servicing capability will be required to move tanksets from delivery launch vehicles to the SS or co-orbiting platforms. Also, appropriate changes to the software used for OMV operation are necessary to allow for the combined operation of the growth OMV. To support fluid management activities at the Space Station for the experimental payloads and propellant provisioning, there must be truss structure space allocated for fluid carriers and propellant tanksets, and substantial beam strengthening may be required. The Station must have two Mobile Remote Manipulator Systems (MRMS) and the growth OMV propellant handling operations for the STV at the SS. Propellant needs for the Planetary Initiatives and Code Z mission models will most likely be provided by co-orbiting propellant platform(s). Space Station impacts for Code Z mission fluid management activities will be minimal. Author

N90-11022# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (Germany, F.R.).
FLUID-STRUCTURE INTERACTION EFFECTS IN TANK STRUCTURES DUE TO SLOSHING AND HYDRODYNAMIC RAM: COUPLED LAGANGIAN-EULERIAN SIMULATIONS
W. W. JARZAB, R. CHWALINSKI, W. E. PFRANG, and G. TOKAR *In* ESA, Spacecraft Structures and Mechanical Testing p 263-268 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

Numerical simulation of hydrodynamic ram and of liquid sloshing with respect to large structural deformations is investigated. The effect of free surfaces is investigated using different partially filled tanks. The resultant structural loadings are discussed taking local loading, global loading, failure, and coupled response into consideration. The loading and unloading of structural members by shock waves, complex reflections, and cavitational effects are treated using coupled algorithms. ESA

N90-11023# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Space Communications and Propulsion Systems Div.
MODELING OF LIQUID SLOSHING EFFECTS IN MULTIBODY SYSTEMS
K. EBERT *In* ESA, Spacecraft Structures and Mechanical Testing p 269-275 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

Two modeling methods for the sloshing dynamics of liquids in partially filled tanks in a spinning spacecraft are presented. A

homogeneous vortex flow approximation and a boundary layer model are discussed. A modeling method which was used to implement liquid sloshing effects in a simulation program for multi body systems is discussed. Computer programs for the analysis of sloshing effects and an extended simulation program are applied to the Intelsat 6 spacecraft. ESA

N90-11024# *Ingenieurgesellschaft fuer Technische Software* G.m.b.H., Stuttgart (Germany, F.R.).
MODAL ANALYSIS OF FLUID-STRUCTURE SYSTEMS BY PARALLEL SUBSPACE ITERATION
H. WANDINGER *In* ESA, Spacecraft Structures and Mechanical Testing p 277-282 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

A method for the modal analysis of coupled fluid-structure systems is presented. For the fluid, a pressure formulation is adopted. The resulting unsymmetric eigenvalue problem is solved by special subspace iteration schemes using the original matrices of the uncoupled systems. Full advantage can thus be taken of a sparse population of these matrices. Singularities, i.e. rigid body modes of the solid structure and constant pressure modes of the fluid, are treated by means of decoupling transformations. This procedure enables the handling of singularity interaction effects as they occur e.g. in the case of floating structures. The method can be used to analyze coupled fluid-structure systems with compressible and incompressible fluids, including surface wave effects. Examples are given to illustrate the different classes of problems that can be solved as well as the applicability for the analysis of large problems. ESA

N90-11073# Dynamic Engineering N.V., Heverlee (Belgium).
NUMERICAL MODELS FOR EXTERIOR AND INTERIOR FLUID-STRUCTURE INTERACTION PROBLEMS
J. P. COYETTE *In* ESA, Spacecraft Structures and Mechanical Testing p 675-680 Jan. 1989
Copyright Avail: NTIS HC A99/MF E06

The development of efficient numerical tools for acoustics and elasto-acoustics is discussed. Both finite element (FE) and boundary element (BE) methods are considered with their specific advantages and limitations. Emphasis is placed on the presentation of frequency formulations selected for software implementation. Special attention is devoted to extraction of acoustic modes from a BE model. The main features of related software are summarized and trends for future developments are outlined. ESA

N90-12646*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.
NASA/USRA ADVANCED SPACE DESIGN PROGRAM: THE LASER POWERED INTERORBITAL VEHICLE
Jun. 1989 164 p Sponsored by USRA
(Contract NASW-4435)
(NASA-CR-186044; NAS 1.26:186044) Avail: NTIS HC A08/MF A01 CSCL 22/2

A preliminary design is presented for a low-thrust Laser Powered Interorbital Vehicle (LPIV) intended for cargo transportation between an earth space station and a lunar base. The LPIV receives its power from two iodide laser stations, one orbiting the earth and the other located on the surface of the moon. The selected mission utilizes a spiral trajectory, characteristic of a low-thrust spacecraft, requiring 8 days for a lunar rendezvous and an additional 9 days for return. The ship's configuration consists primarily of an optical train, two hydrogen plasma engines, a 37.1 m box beam truss, a payload module, and fuel tanks. The total mass of the vehicle fully loaded is 63300 kg. A single plasma, regeneratively cooled engine design is incorporated into the two 500 N engines. These are connected to the spacecraft by turntables which allow the vehicle to thrust tangentially to the flight path. Proper collection and transmission of the laser beam to the thrust chambers is provided through the optical train. This system consists of the 23 m diameter primary mirror, a convex parabolic secondary mirror, a beam splitter and two concave parabolic tertiary mirrors. The payload bay is capable of carrying 18000 kg of cargo. The module is located opposite the primary mirror on the main truss. Fuel tanks carrying a maximum of 35000 kg of liquid hydrogen are fastened to tracks which allow the tanks to be moved perpendicular to the main truss. This capability is required to prevent the center of mass from moving out of the thrust vector line. The laser beam is located and tracked by means of an acquisition, pointing and tracking system which can be locked onto the space-based laser station. Correct orientation of the spacecraft with the laser beam is maintained by control moment gyros and reaction control rockets. Additionally an aerobrake configuration was designed to provide the option of using the atmospheric drag in place of propulsion for a return trajectory. Author

N90-16957# Creare, Inc., Hanover, NH.
DESIGN MANUAL FOR MICROGRAVITY TWO-PHASE FLOW AND HEAT TRANSFER Final Report, Sep. 1988 - Jun. 1989
CHRISTOPHER J. CROWLEY and MICHAEL G. IZENSON Oct. 1989 143 p
(Contract F04611-88-C-0050)
(AD-A214937; TM-1309; AFAL-TR-89-027) Avail: NTIS HC A07/MF A01 CSCL 20/13

Two phase fluid flow and heat transfer methods for microgravity environments is documented. The applications of the work are thermal management, propulsion, and fluid storage and transfer systems for spacecraft. In the near future, these systems will include two phase, vapor-liquid flows. This Design Manual is intended for use by designers of these systems. Design methods are presented for predicting two phase flow regimes and pressure drops in pipe flows from earth gravity to microgravity conditions. Forced convection boiling heat transfer methods for pipes with uniform heat flux are included. Also included are methods for analyzing high vapor-shear condensation in pipes. The analysis methods are mechanistic; that is, based upon fundamental physical principles which should apply to heat transfer liquids with Pr approx = 1 and scale with pipe size and fluid properties. This Manual incorporates simplified methods (easy-to-use design charts), detailed descriptions of the analysis methods, comparisons with existing microgravity data, and recommended approaches to quantify the range of uncertainty in design calculations. GRA

N90-16967# Pacific Northwest Lab., Richland, WA.
AN ENGINEERING APPROACH TO TWO-PHASE FLOW MODELING IN REDUCED GRAVITY
JUDITH M. CUTA Jan. 1990 7 p Presented at the 7th Symposium on Space Nuclear Power Systems, Albuquerque, NM, 7-10 Jan. 1990
(Contract DE-AC06-76RL-01830)
(DE90-005539; PNL-SA-17510; CONF-900109-17) Avail: NTIS HC A02/MF A01

This paper presents a general approach for developing specific two-phase flow parameters that could be used in the analysis of fluid behavior in reduced gravity. We begin from a theoretical basis, determine the appropriate modifications required for reduced gravity, define a relevant data base for derivation of empirical terms, and look at the data needed for proper validation of the model. DOE

N90-17138*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MECHANIZED FLUID CONNECTOR AND ASSEMBLY TOOL SYSTEM Patent Application
RONALD C. ZENTNER, inventor (to NASA) and STEVEN A. SMITH, inventor (to NASA) (Boeing Aerospace Co., Seattle, WA.) 9 Nov. 1989 16 p
(NASA-CASE-MSC-21434-1; NAS 1.71:MSC-21434-1; US-PATENT-APPL-SN-433881) Avail: NTIS HC A03/MF A01 CSCL 13/9

A fluid connector system is disclosed which includes a modified plumbing union having a rotatable member for drawing said union into a fluid tight condition. A drive tool is electric motor actuated and includes a reduction gear train providing an output gear engaging an integral peripheral spur gear on the rotatable member. Coaxial alignment means are attached to both the connector assembly and the drive tool. A hand lever actuated latching system

includes a plurality of circumferentially spaced latching balls selectively wedged against the alignment means attached to the connector assembly or to secure the drive tool with its output gear in mesh with the integral peripheral spur gear. The drive motor is torque, speed, and direction controllable. NASA

N90-18482*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION TECHNOLOGY SUMMARY
R. IACABUCCI, S. EVANS, G. BRILEY, R. A. DELVENTHAL, and E. BRAUNSCHEIDEL (National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.) *In* Johns Hopkins Univ., The 1989 JANNAF Propulsion Meeting, Volume 1 p 457-470 May 1989
Avail: NTIS HC A25/MF A04 CSCL 22/2

The completion of the Space Station Propulsion Advanced Technology Programs established an in-depth data base for the baseline gaseous oxygen/gaseous hydrogen thruster, the waste gas resistojet, and the associated system operations. These efforts included testing of a full end-to-end system at National Aeronautics and Space Administration (NASA)-Marshall Space Flight Center (MSFC) in which oxygen and hydrogen were generated from water by electrolysis at 6.89 MPa (1,000 psia), stored and fired through the prototype thruster. Recent end-to-end system tests which generate the oxygen/hydrogen propellants by electrolysis of water at 20.67 MPa (3,000 psia) were completed on the Integrated Propulsion Test Article (IPTA) at NASA-Johnson Space Center (JSC). Resistojet testing has included 10,000 hours of life testing, plume characterization, and electromagnetic interference (EMI) testing. Extensive 25-lbf thruster testing was performed defining operating performance characteristics across the required mixture ratio and thrust level ranges. Life testing has accumulated 27 hours of operation on the prototype thruster. A total of seven injectors and five thrust chambers were fabricated to the same basic design. Five injectors and three thrust chambers designed to incorporate improved life, performance, and producibility characteristics are ready for testing. Five resistojets were fabricated and tested, with modifications made to improve producibility. The lessons learned in the area of producibility for both the O2/H2 thrusters and for the resistojet have resolved critical fabrication issues. The test results indicate that all major technology issues for long life and reliability for space station application were resolved. Author

N90-18486*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ZERO-GRAVITY VORTEX VENT AND PVT GAGING SYSTEM
M. G. DOWNEY and J. T. TREVATHAN *In* Johns Hopkins Univ., The 1989 JANNAF Propulsion Meeting, Volume 1 p 497-500 May 1989
Avail: NTIS HC A25/MF A04 CSCL 22/2

Space Station and satellite reservicing will require the ability to vent gas on orbit from liquid supply or storage tanks and to gage liquid quantity under microgravity conditions. In zero gravity, (zero-g) the vortex vent is capable of venting gas from a tank of liquid containing gas randomly distributed as bubbles. The concept uses a spinning impeller to create centrifugal force inside a vortex tube within a tank. This creates a gas pocket and forces the liquid through a venturi and back into the tank. Gas is then vented from the gas pocket through a liquid detector and then out through an exhaust port. If the liquid detector senses liquid in the vent line, the fluid is directed to the low-pressure port on the venturi and is returned to the tank. The advantages of this system is that it has no rotating seals and is compatible with most corrosive and cryogenic fluids. A prototype was designed and built at the NASA Johnson Space Center and flown on the KC-135 zero-g aircraft. During these test flights, where microgravity conditions are obtained for up to 30 sec, the prototype demonstrated that less than 0.10 percent of the volume of fluid vented was liquid when the tank was half full of liquid. The pressure volume temperature (PVT) gaging system is used in conjunction with the vortex vent to gage liquid quantity in zero or low gravity. The system consists of a gas compressor, accumulator, and temperature and pressure instrumentation. To measure the liquid in a tank a small amount of gas is vented from the tank to the compressor and compressed into the accumulator. Pressure and temperature in the tank and accumulator are measured before and after the gas transfer occurs. Knowing the total volume of the tank, the volume of the accumulator, the volume of the intermediate lines, and initial and final pressures and temperatures, the mass of the gas leaving the tank is equated to the mass of the gas entering the accumulator. The volume of liquid remaining in the tank is calculated using the ideal gas law. Author

N90-18487*# Martin Marietta Space Systems, Inc., Denver, CO.
ORBITAL FLUID RESUPPLY ASSESSMENT
RALPH N. EBERHARDT *In* Johns Hopkins Univ., The 1989 JANNAF Propulsion Meeting, Volume 1 p 501-511 May 1989
(Contract NAS9-17585; NAS9-17854)
Avail: NTIS HC A25/MF A04 CSCL 22/2

Orbital fluid resupply can significantly increase the cost-effectiveness and operational flexibility of spacecraft, satellites, and orbiting platforms and observatories. Reusable tankers are currently being designed for transporting fluids to space. A number of options exist for transporting the fluids and propellant to the space-based user systems. The fluids can be transported to space either in the Shuttle cargo bay or using expendable launch vehicles (ELVs). Resupply can thus be accomplished either from the Shuttle bay, or the tanker can be removed from the Shuttle bay or launched on an ELV and attached to a carrier such as the Orbital Maneuvering Vehicle (OMV) or Orbital Transfer Vehicle (OTV) for transport to the user to be serviced. A third option involves locating the tanker at the space station or an unmanned platform as a quasi-permanent servicing facility or depot which returns to the ground for recycling once its tanks are depleted. Current modular tanker designs for monopropellants, bipropellants, and water for space station propulsion are discussed. Superfluid helium tankers are addressed, including trade-offs in tanker sizes, shapes to fit the range of ELVs currently available, and boil-off losses associated with longer-term (greater than 6-month) space-basing. It is concluded that the mixed fleet approach to on-orbit consumables resupply offers significant advantages to the overall logistics requirements. Author

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COMMERCIALIZATION

Use of space stations for large scale commercial operations.

A90-13681#
MAN-INTO-ORBIT TRANSPORTATION COST - HISTORY AND OUTLOOK
DIETRICH E. KOELLE and WOLFGANG KLEINAU (MBB GmbH, Munich, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p.
(IAF PAPER 89-695) Copyright

The paper deals first with the assessment of the initial cost of launching astronauts with ballistic capsules like Mercury, Gemini, and Apollo (about $100 million per astronaut), via the Space Shuttle (some $16 million), in order to show the potential cost reduction in the future. Such a reduction to some $4 million per crew member could be realized by a dedicated launch vehicle for manned operations. The second area of analysis is the specific transportation cost per man-day in orbit. The Space Shuttle provides an 8-day capability for 8 persons for about $2 million per man-day. In connection with a manned space station and a launch frequency of 60 days, these costs could be reduced to some $350,000 per man-day. Author

A90-13683#
THE ECONOMIC IMPACTS ON SPACE OPERATIONS OF FUTURE LAUNCH SYSTEMS
RUSSELL JAMES HANNIGAN (British Aerospace /Space Systems/, Ltd., Stevenage, England) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 20 p. refs
(IAF PAPER 89-697) Copyright

The introduction of a future launch system (FLS), based on aerospace-plane-type concepts, is expected to have a profound effect on all space activities. The requirements for an FLS, allowing economic and routine access to space, are defined and discussed, and the impacts such a vehicle with these capabilities will have on present and future space operations are analyzed. It is shown that the average utilization cost of a transponder circuit, on the current generation of mass-optimized communications spacecraft, would be reduced by 15 - 20 percent and, if the design of such spacecraft were cost optimized to take fuller advantage of all the FLS capabilities, the transponder cost reduction would be 30 - 35 percent. Similarily, it is shown that using an FLS for logistics support of Space Station Freedom can lead to annual savings of 1.5 billion AU, where 1 AU = $1.18. Author

A90-13686#
FEASIBILITY OF SPACE TOURISM - 'COST STUDY FOR SPACE TOUR'
SHINJI MATSUMOTO, YOSHIHIKO AMINO, TOHRU MITSUHASHI, KENJI TAKAGI, and HIDEKI KANAYAMA (Shimizu Corp., Tokyo, Japan) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. refs
(IAF PAPER 89-700) Copyright

Development of space tourism will bring space closer to the average person while expanding the space industry. A space station hotel that meets various conditions for space tourism in the second development stage is presented. The proposed hotel was used as a model in cost simulation, indicating that transportation cost reduction by approximately 4.3 percent is the key for space tourism to be a successful business. The feasibility of space tourism is studied with emphasis placed on the transportation costs of construction materials into space. C.E.

A90-13687#
SPACE COMMERCIALIZATION - THE CASE OF THE COMMERCIALLY DEVELOPED SPACE FACILITY
RICHARD M. OBERMANN, JOANN C. CLAYTON, ROBERT H. KORKEGI (National Research Council, Washington, DC), and JOSEPH F. SHEA (Raytheon Co., Lexington, MA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p. refs
(IAF PAPER 89-703) Copyright

The commercialization of space activities has been an increasing focus of a number of nations' space programs over the last decade. In the U.S., the National Research Council has been asked to conduct an independent study of the orbiting facility named the Commercially Developed Space Facility (CDSF). In addition to studying the scientific and commercial benefit to the nation of a commercially developed space facility prior to Space Station operations, the issue of the technical characteristics of the CDSF for optimal use is addressed. The paper summarizes the findings, recommendations, and aftermath of the committee report on the study of the CDSF. C.E.

A90-13689*# *National Aeronautics and Space Administration*, Washington, DC.
COMMERCIAL DEVELOPMENT OF SPACE - A NATIONAL COMMITMENT
JAMES T. ROSE and BARBARA A. STONE (NASA, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-706) Copyright

The United States is currently in a unique position. It has all the assets required to lead the world in commercial space development. It has the transportation: the Shuttle and a family of expendable launch vehicles. Space Station Freedom is forthcoming. It has the extrepreneurial spirit, coupled with a strong university system and lending institutions with financial capacity necessary for entrepreneurial activities. But, there are a number of actions that the government should take to improve the climate and prospects for greater commercial development of space. This paper outlines some of the steps that NASA is taking to incentivize the private sector to apply its resources and talents to commercial space endeavors. Author

A90-13692#
THE GLOBAL OUTPOST PROGRAM - COMMERCIAL SERVICES IN LOW EARTH ORBIT
WILLFRED J. MELLORS, THOMAS C. TAYLOR, and JAMES E. WILSON (Global Outpost, Inc., Alexandria, VA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 11 p. refs
(IAF PAPER 89-711) Copyright

In full cooperation with NASA, Global Outpost Inc., proposes to inject the Space Shuttle External Tank (ET) into low earth orbit with comparatively simple changes to current Shuttle operational procedures and with very small sacrifice of performance. The Global Outpost program offers the capability of providing commercial customers with a range of orbital services such as extended duration testing, prototype subsystem demonstration, basic and applied experimental projects, and mechanical as well as chemical process operations with power and communications available to all of these activities. The use of the ET in orbit is one of a series of possible measures which can lead to the more efficient use of resources and hence accelerate the exploration and utilization of space. C.E.

A90-17731#
THE LOW EARTH ORBIT ENVIRONMENT FOR RESEARCH IN SPACE
P. KLEBER (DLR, Cologne, Federal Republic of Germany) IN: Annual Space: Technology, Commerce and Communications Conference, 2nd, Houston, TX, Nov. 1-4, 1988, Proceedings. Boston, MA, T. F. Associates, Inc., 1988, 15 p.

The industrial applications of research conducted in LEO are examined. The characterstics of the LEO environment are discussed, including microgravity and the improved containerless vacuum. The commercial advantages of conducting research in microgravity are considered. R.B.

A90-18547
FOR SALE - COMMERCIAL SPACE
JOHN J. EGAN (Egan Group, Washington, DC) Ad Astra (ISSN 1041-102X), vol. 1, Dec. 1989, p. 8-11, 13-15.
Copyright

The current status of commercial space activity is evaluated. Consideration is given to the factors which have influenced the development of commercial space activities. Trends in the communications satellite industry, the launch vehicle industry, remote sensing, and production in microgravity are discussed. The development of a commercial space infrastructure is examined and centers for the commercial development of space are listed. R.B.

A90-18549
SPACE COMMERCE, SOVIET STYLE
JAN GOLDMAN Ad Astra (ISSN 1041-102X), vol. 1, Dec. 1989, p. 24, 25, 27, 28, 30.
Copyright

Soviet commercial space activities are examined. The Glavkosmos agency, which handles commercial launch services and sells and leases Soviet satellites, is described. The commercial applications of crystalline substances grown on the Mir space station are noted. Also, the production of remote sensing imagery and the use of space technology in communications, weather forecasting, and geological surveys are discussed. Consideration is given to economic problems associated with the Buran shuttle program. R.B.

A90-19944#
IN-SPACE TEST AND EVALUATION FACILITY (STEF)
RONALD E. GIUNTINI and KAREN M. SEISER (Wyle Laboratories, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 6 p.
(AIAA PAPER 90-0610) Copyright

The concept of an in-space test facility meeting the requirements of users in the development of commercial activities in space is presented. The determination of user requirements for a space test and evaluation facility (STEF) is a continuous process, and specific requirements are necessary to determine the STEF candidate configurations that will eventually lead to the one that is selected. In lieu of such requirements, generic experiments and tests (E/T) characteristics and discriminators are focused upon. The discriminators enable the identification of mission-compatible groupings, where each grouping could be satisfied by a specific type of STEF configuration. A comparative analysis of the basic element capabilities and the E/T mission requirements provide the ingredients for formulation of STEF concepts. Various trades and analyses are identified in order to assist in selecting the optimum STEF configuration. S.A.V.

A90-21730#
FACILITIES FOR CELL-BIOLOGY RESEARCH IN WEIGHTLESSNESS [FACILITEITEN VOOR CELBIOLOGISCH ONDERZOEK IN GEWICHTSLOOSHEID]
R. H. HUIJSER (Fokker Space and Systems, Amsterdam, Netherlands) Ruimtevaart, vol. 38, Oct. 1989, p. 45-55. In Dutch.

The history, current status, and future prospects of space cell-biology experimentation are reviewed, with an emphasis on Dutch contributions. Topics examined include the instrumentation required for space cell-biology facilities, the relationship between facility requirements and scientific goals, the Cells In Space (CIS) module for ESA sounding-rocket experiments, the successful flight of CIS-1 in April 1988, the Biorack flown on the first FRG Spacelab mission D-1 (November-December 1985), the smaller Biobox payload being developed for flights on the Soviet Biocosmos satellites, and the Columbus Biolab. Drawings, diagrams, and photographs of the CIS-1 launch and capsule recovery are provided. T.K.

A90-21731#
BIOLOGICAL PROCESSING IN SPACE [BIOPROCESSING IN DE RUIMTE]
F. ECKHARD (Comprimo, Netherlands) Ruimtevaart, vol. 38, Oct. 1989, p. 56-61. In Dutch.

The current status of research on space biological processing technology is reviewed, with a focus on the Dutch contributions to ESA programs and plans for the International Space Station. The advantages of the microgravity environment for protein crystallization, cell fusion, and electrophoresis are discussed, and the practical application of biofiltration to the waste-recycling process on manned space missions is described. T.K.

A90-22695#
INVENTIONS AND PATENTS IN SPACE
HERMANN ERSFELD (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) Hermann Oberth Gesellschaft, Raumfahrtkongress, 38th, Salzburg, Austria, June 22-25, 1989, Paper. 21 p.
(MBB-UO-0057/89)

Unresolved issues in the space utilization of inventions and patents are considered. Issues related to the territorial application of patent law are examined, including the risks of patent infringments arising from utilization of the Space Station and Columbus. Issues related to exemptions from the territorial application of patent law are discussed, including the question of whether spacecraft and related equipment are entitled to the same treatment as ships and aircraft while temporarily visiting or in transit across foreign territory. Issues related to the secrecy of inventions are addressed, including the question of whether a Space Station user-inventor has a choice of jurisdictions in which to apply for a patent. C.D.

A90-22697#
AMICA - A PROJECT FOR INDUSTRIALIZING THE ORBITAL INFRASTRUCTURE WITH TRANSATLANTIC COOPERATION [AMICA - EIN VORHABEN ZUR INDUSTRIALISIERUNG EINER ORBITALEN INFRASTRUKTUR IN TRANSATLANTISCHER KOOPERATION]
K. FUCHS (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) DGLR, Jahrestagung, Hamburg, Federal Republic of Germany, Oct. 2-4, 1989, Paper. 7 p. In German.
(MBB-UO-0058/89)

The AMICA project, which will enable European space industry to commercialize free-flying platforms, is discussed using the Eureca platform as an example. The industrialization of the Eureca platform is summarized, showing the structure of the Eureca industry team. The industrialization organization of AMICA is described, and the apportionment of payload data for the AMICA and Eureca platforms is addressed. C.D.

A90-23646
THE 'OTHER NASAS' - WHERE HAVE THEY GONE?
LORI KEESEY Ad Astra (ISSN 1041-102X), vol. 2, Jan. 1990, p. 14-19.
Copyright

The roles of NASA and the Departments of Commerce and Transportation in space commercialization activities are reviewed, focusing on the relationships between the agencies and the role of the various agencies in determining U.S. space policy. Issues related to governmental vs private development of space activities and issues concerning NASA's program of providing commercial launch services are examined. The Industrial Space Facility, which the Department of Commerce supported as an alternative to the Space Station, is discussed. R.B.

A90-23691* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE MANUFACTURING IN AN AUTOMATED CRYSTAL GROWTH FACILITY
ALBERTA W. QUINN, MELODY C. HERRMANN, and PAMELA J. NELSON (NASA, Marshall Space Flight Center, Huntsville, AL) Society of Manufacturing Engineers, World Conference on Robotics Research: The next five years and beyond, Gaithersburg, MD, May 7-11, 1989. 15 p.
(SME PAPER MS89-278) Copyright

An account is given of a Space Station Freedom-based robotic laboratory system for crystal growth experiments; the robot must interface with both the experimental apparatus and such human input as may be required for control and display. The goal of the system is the simultaneous growth of several hundred protein crystals in microgravity. The robot possesses six degrees-of-freedom, allowing it to efficiently manipulate the cultured crystals as well as their respective growth cells; the crystals produced are expected to be of sufficiently high quality for complete structural determination on the basis of XRD. O.C.

A90-24768
APPLYING SCIENCE IN SPACE TO PRACTICAL NEEDS
GUION S. BLUFORD, JR. (USAF, Washington, DC) IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 117-124.
Copyright

The benefits of spinoff technology from the space program are examined. Consideration is given to the benefits of satellite technology such as global communications, navigational systems, and agricultural production. The industrialization of space is discussed, including biomedical and pharmaceutical processing and the production of microspheres for instrument calibration. The possible benefits of the Space Station are noted. R.B.

A90-24770
CONDUCTING BUSINESS AND SCIENTIFIC EXPERIMENTS IN SPACE
JOHN J. EGAN (Egan Group, Washington, DC) IN: Space: National programs and international cooperation. Boulder, CO, Westview Press, 1989, p. 135-142.
Copyright
Problems associated with commercial space operations are reviewed. Consideration is given to commercial launchers, the commercial use of the microgravity environment, and the question of refurbishing or replacing satellites. International competition in the commercial use of microgravity processing is examined. Also, the role of the government in commercial space activities is discussed. R.B.

A90-24776
SPACE MANUFACTURING 7 - SPACE RESOURCES TO IMPROVE LIFE ON EARTH; PROCEEDINGS OF THE NINTH PRINCETON/AIAA/SSI CONFERENCE, PRINCETON, NJ, MAY 10-13, 1989
GREGG MARYNIAK, ED. (Space Studies Institute, Princeton, NJ) and BARBARA FAUGHNAN, ED. Conference sponsored by AIAA and Space Studies Institute. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, 377 p. For individual items see A90-24777 to A90-24823.
Copyright
Papers on space manufacturing are presented covering topics such as a commercial space platform, the possible use of Space Shuttle External Tanks as space habitats, mapping nonterrestrial resources, lunar oxygen production, products from lunar anorthite, lunar silicon production, and the volatile resource of carbonaceous chondrites. Other topics include lunar resources for energy systems, lunar teleoperations investigations, lunar production of solar cells, solar power satellites, truss construction in space, recycling organic materials, bioregenerative habitats, ecological life support systems, and international and economic considerations in space ventures such as the Space Station and a lunar base. Additional topics include space transportation systems, space debris, lunar transporter concepts, a lunar propellant supply system, solar power for a lunar base, structural and site considerations for a lunar base, the use of artificial gravity in long-duration spaceflight, the physiological parameters of artificial gravity, anesthesia in space, space immunology, selection of atmospheric pressure for a lunar base, the use of precast concrete reinforced with GFRP, and alternative funding for a Mars expedition. R.B.

A90-24777#
THE OUTPOST CONCEPT, A COMMERCIAL SPACE PLATFORM OPPORTUNITY
THOMAS C. TAYLOR and WILLIAM A. GOOD (Global Outpost, Inc., Alexandria, VA) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 27-36. refs
Copyright
The possibility of using Space Shuttle External Tanks for a commercial orbiting platform is examined. This Outpost concept is proposed as a minimum cost, man visited facility for low cost commercial ventures in space. The objectives for developing the platform and the possible market for space facilities are discussed. The characteristics of the External Tanks are outlined and the results of previous studies concerning orbiting External Tanks are reviewed. R.B.

A90-24798*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION FREEDOM COMMERCIAL INFRASTRUCTURE
KEVIN BARQUINERO (NASA, Office of Space Station, Washington, DC) and JEFF CASSIDY (Egan Group, Washington, DC) IN: Space manufacturing 7 - Space resources to improve life on earth; Proceedings of the Ninth Princeton/AIAA/SSI Conference, Princeton, NJ, May 10-13, 1989. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 197-203.
Copyright
NASA policy concerning the commercial infrastructure of the Space Station is examined. Plans for receiving and evaluating unsolicited proposals to provide commercial infrastructure are outlined. The guidelines for development of the commercial infrastructure and examples of opportunities for industry are listed. Also, a program for industry feedback concerning the commercial infrastructure policy is discussed. R.B.

A90-30279
SPACE INDUSTRY (2ND REVISED AND ENLARGED EDITION) [KOSMICHESKAIA INDUSTRIIA /2ND REVISED AND ENLARGED EDITION/]
VSEVOLOD S. AVDUEVSKII and GEORGII R. USPENSKII Moscow, Izdatel'stvo Mashinostroenie, 1989, 568 p. In Russian. refs
Copyright
Problems related to the design, development, and operation of scientific and economy-oriented space systems are reviewed. In particular, attention is given to space engineering, construction and operation of space systems, processing of materials in space, and space systems designed for the study of natural resources, environmental monitoring, and meteorological studies. The discussion also covers the design of space-based communication systems, geodesical and navigation space systems, and space systems for astrophysical and space studies. V.L.

A90-30747
SPACE ENTERPRISE - BEYOND NASA
DAVID P. GUMP New York, Praeger, 1990, 227 p.
Copyright
Economic and policy issues related to the possible exploitation of space by U.S. commercial interests are examined critically. Chapters are devoted to the reasons for and implications of the loss of the Space Shuttle Challenger, the birth of the commercial space industry, rockets and spaceplanes planned for the 1990s, and the potential of low-cost space transport based on laser propulsion. Consideration is given to space production of pharmaceuticals and semiconductors, the advantages of orbital R&D programs for ground applications, terrestrial remote sensing from space, the commercial availability of the NASA Space Station, some proposed commercial stations, and the moon-Mars-LEO trade routes of the future. T.K.

N90-14151*# National Aeronautics and Space Administration, Washington, DC.
CENTERS FOR THE COMMERCIAL DEVELOPMENT OF SPACE
SUSAN E. WALKER, ed. 1989 22 p Original contains color illustrations
(NASA-PAM-525) Avail: NTIS HC A03/MF A01 CSCL 05/1
In 1985, NASA initiated an innovative effort called Centers for the Commercial Development of Space (CCDS). The CCDS program was designed to increase private-sector interest and investment in space-related activities, while encouraging U.S. economic leadership and stimulating advances in promising areas of research and development. Research conducted in the Centers handling the following areas is summarized: materials processing; life sciences; remote sensing; automation and robotics; space propulsion; space structures and materials; and space power. B.G.

N90-16785# Arianespace, Evry (France).
THE INTERNATIONAL SPACE TRANSPORTATION MARKET: A EUROPEAN PERSPECTIVE
KLAUS ISERLAND *In* ESA, Progress in Space Transportation p 15-20 Aug. 1989
Copyright Avail: NTIS HC A22/MF A03
The future of space transportation is examined in four areas: the launching of satellites and space probes, the launch of payloads for microgravity and technological experiments, the transport into

low orbit of space structures, modules etc. used in building space stations, and later, space factories, and regular transport of men and materials to and from these stations and repair and maintenance missions. These four areas are analyzed in terms of their market aspects from a European viewpoint. Conclusions are made regarding the future structure of space transportation.
ESA

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EXPERIMENTS

Design and description of experiments to be performed or managed from the space station.

A90-10612#
EXPERIMENT SCHEDULING FOR THE INDUSTRIAL SPACE FACILITY
CLIFFORD R. KURTZMAN (Space Industries, Inc., Webster, TX) IN: AIAA Computers in Aerospace Conference, 7th, Monterey, CA, Oct. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1088-1094.
(AIAA PAPER 89-3138) Copyright

The ability to provide flexible manifesting and scheduling is critical to the operation of the Industrial Space Facility (ISF). The ISF is a man-tended free-flying space platform which will be launched in the early 1990s, and will serve as a bridge to the Space Station era. Efficient and cost effective operation of the ISF can be facilitated through the use of multivariable optimization techniques. A software tool, called the Prototype ISF Experiment Scheduler, was developed to implement a learning heuristic algorithm and to show that efficient use can be made of available ISF resources, given the requirements of a realistic set of payloads. Author

A90-11494* Massachusetts Inst. of Tech., Cambridge.
INFLUENCE OF NON STEADY GRAVITY ON NATURAL CONVECTION DURING MICRO-GRAVITY SOLIDIFICATION OF SEMICONDUCTORS. I - TIME SCALE ANALYSIS. II - IMPLICATIONS FOR CRYSTAL GROWTH EXPERIMENTS
P. R. GRIFFIN and S. MOTAKEF (MIT, Cambridge, MA) Applied Microgravity Technology (ISSN 0931-9530), vol. 2, Oct. 1989, p. 121-132. refs
(Contract NSG-7645)
Copyright

Consideration is given to the influence of temporal variations in the magnitude of gravity on natural convection during unidirectional solidification of semiconductors. It is shown that the response time to step changes in g at low Rayleigh numbers is controlled by the momentum diffusive time scale. At higher Rayleigh numbers, the response time to increases in g is reduced because of inertial effects. The degree of perturbation of flow fields by transients in the gravitational acceleration on the Space Shuttle and the Space Station is determined. The analysis is used to derive the requirements for crystal growth experiments conducted on low duration low-g vehicles. Also, the effectiveness of sounding rockets and KC-135 aircraft for microgravity experiments is examined. R.B.

A90-13246#
RECOVERY OF SMALL PAYLOADS BY MEANS OF SIMPLE RE-ENTRY CAPSULES FROM ORBITAL SYSTEMS
C. DORN, I. ENGELN, and K. SOMMER (OHB System GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-006) Copyright

Two possibilities exist for the return of experiments or samples from orbit to earth: (1) to return jointly with a retrievable (ground based) payload carrier or (2) to utilize dedicated reentry capsules available onboard a space-based orbital system like Columbus. The proposed Taurus retrieval system is characterized by the advantage of frequent return opportunities for small payloads (m less than 20 kg) during a space station mission. This paper presents the Taurus retrieval concept, as elaborated by the OHB-system in a feasibility study for the DLR, and describes the main system elements, i.e., the Payload Capsule, the Ejection Device and the Support Units. The potential impact of the retrieval system on the orbital system and the payload is discussed, in order to demonstrate the necessary system compatibility. Author

A90-13252#
RAUMKURIER - A MISSION OPPORTUNITY FOR RETRIEVABLE EXPERIMENTS
M. EYB and R. HENKEL (Dornier, GmbH, Friedrichshafen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-014) Copyright

Raumkurier is a low cost flight opportunity with re-entry capability for autonomous experiments. It is designed to carry payloads for experiments in several fields of space research and technology and is important for the preparation of the Columbus Utilization. The capsule can be launched with Ariane and other existing and proposed transportation systems. Raumkurier allows independent and quick access to space and is of high interest to a potential commercial market. System and subsystem design will account for a low cost program, first flight late 1992 and a mission duration of 7 to 30 days typically. Author

A90-13316#
SPACE PROJECT 'SHIPKA' IMPLEMENTATION OF THE SCIENTIFIC-TECHNICAL PROGRAMME AND SOME RESULTS OF THE INVESTIGATIONS ON BOARD THE 'MIR' STATION
B. BONEV (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia za Kosmicheski Izsledvaniia, Sofia, Bulgaria), A. SOLOV'EV, V. SAVINICH, and A. ALEKSANDROV IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-108)

Some scientific experiments in space carried out on board the Mir station in June 1988 under the Soviet-Bulgarian Shipka space project are briefly reviewed. The experimental work comprises the following basic areas: space physics, remote sensing of the earth, space biology and medicine, and space materials science. The discussion covers results of observations with the Rozhen astrophysical payload, results of an evaluation of the work performance of a cosmonaut, and results of microgravity experiments on aluminum-tungsten alloys. V.L.

A90-13319#
UTILIZATION AND OPERATIONS ABOARD THE MIR SPACE STATION FOR A PROTEIN CRYSTAL GROWTH EXPERIMENT
V. NIJHAWAN and A. P. ARROTT (Payload Systems, Inc., Cambridge, MA) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 4 p.
(IAF PAPER 89-113) Copyright

A multiple-spaceflight agreement has been concluded with the Soviet Union to perform commercially sponsored protein crystal growth research and production aboard the Mir Space Station. Using expertise and experience in manned spaceflight experiments, a comprehensive commercial spaceflight program has been established to produce protein crystals for the pharmaceutical, chemical, and biotechnology industries. In association with the Protein Laboratory at the MIT Department of Chemistry, a research and development plan has been undertaken to verify and demonstrate the value of long-duration spaceflight as a means of obtaining larger and more regular protein crystals. Author

A90-13320#
OPTIMISING OF THE SCIENTIFIC-TECHNICAL COMPLEX ON BOARD OF THE ORBITAL STATION 'MIR' AND SPECIFIC PECULIARITIES OF WORK DURING THE SECOND BULGARIAN-SOVIET SPACEFLIGHT

ALEKSAND'R ALEKSANDROV IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 3 p.
(IAF PAPER 89-114)

The scientific equipment and experiments on the Mir orbital station are discussed, focusing on the research conducted during the second Bulgarian-Soviet spaceflight in June, 1988. The methodology used to optimize the efficiency of the scientific and technical systems on the station is outlined. The equipment used for remote sensing, psychophysiological, space physics, astrophyscial, and photographic studies is considered. R.B.

A90-13329#
MICROWAVE REMOTE SENSING FROM SPACE - THE SELENIA SPAZIO APPROACH
F. S. RUBERTONE and R. SOMMA (Selenia Spazio S.p.A., Rome, Italy) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-131)

The development of microwave remote sensing instruments is discussed. The instruments include the radar altimeter for the ESA/ERS-1 program, the X-band SAR, and the Advanced Microwave Imaging Radiometer (AMIR) for possible inclusion on the Columbus Polar Platform. The system configuration and performance of the radar altimeter are examined and functional descriptions of the X-band SAR and the AMIR are given. R.B.

A90-13517#
MICROGRAVITY UTILIZATION SELECTION OF THE MELT CRYSTAL GROWTH TECHNOLOGY IN SPACE
RISHENG XI, KANG WANG, and YI KANG (Ministry of Aeronautics and Astronautics, Lanzhou Institute of Physics, People's Republic of China) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p. refs
(IAF PAPER 89-410) Copyright

The acquisition of a standard for selecting microgravity utilization for materials processing in space is addressed. The technical difficulties involved in growing melts on the ground are reviewed, and the conditions for the elimination of gravity-driven buoyancy convection and stability of the surface tension-driven Marangoni convection flow are comprehensively analyzed. The advantages of using the zone melting method under microgravity conditions are discussed. C.D.

A90-13519#
TELESCIENCE - AN OPPORTUNITY OFFERED TO FLUID SCIENCE EXPERIMENTATION ON DIFFERENT MICROGRAVITY PLATFORMS
R. MONTI (Napoli, Universita, Naples, Italy) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 20 p.
(IAF PAPER 89-414) Copyright

The opportunities offered by telescience for experiments in short-duration platforms (that could not otherwise be performed) in medium duration missions (to take maximum advantage of the microgravity time) and in permanent orbiting facilities (to optimize the scientific return) are addressed. The fluid science (FS) requirements for telescience activities and the implementation of these requirements are discussed. Operational aspects of telescience in FS are reviewed. Specific reference is made to the Texus sounding-rocket mission, which elucidates the typical problems encountered in the implementation of telescience in FS. C.D.

A90-13529#
FUTURE EXPERIMENTS AND IMPROVED SERVICE SYSTEM FOR AUTOMATED MAUS PAYLOADS
G. H. OTTO, H.-W. GRONERT (DLR, Cologne, Federal Republic of Germany), and J. DOEPKENS (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p. Research supported by BMFT. refs
(IAF PAPER 89-427) Copyright

The German MAUS project was developed as a standard system offering a range of services for performing material science experiments under microgravity conditions within NASA's Get-Away-Special (GAS) program. MAUS payloads are housed in GAS containers and consist of the experiment mounting structure, the batteries, the standard electronic data controls, the housekeeping systems, and the individual experiment hardware. MAUS payloads can either be flown in the Get-away-Special or with specific carrier structures. Ten MAUS experiments have been performed and seven payloads are currently in preparation for future Space Shuttle missions. The top four experiments in preparation for the upcoming flight opportunities are from the area of material science and aim at improving understanding of special microgravity phenomena and providing valuable material data. The experiments include critical Marangoni convection, oscillatory Marangoni convection, gas bubbles in glass melts, and pool boiling in liquids. C.E.

A90-13530#
INTEGRATION OF A MICROGRAVITY ISOLATION MOUNT (MGIM) WITHIN A COLUMBUS SINGLE RACK
R. G. OWEN, D. I. JONES, A. R. OWENS (University of Wales, Bangor), and A. A. ROBINSON (ESTEC, Noordwijk, Netherlands) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(Contract ESTEC-7637/88)
(IAF PAPER 89-428) Copyright

An investigation of the predicted vibration environment aboard the two Columbus Laboratories suggests that the microgravity levels demanded by some payloads can only be satisfied by isolating the payload by means of an active isolation mount. A Feasibility Study has shown that the required microgravity level can be most easily achieved by adopting a non-contact strategy, whereby the payload floats inside its rack, its position being controlled by magnetic actuators. This paper describes the main elements and sub-systems of a Microgravity Isolation Mount (MGIM) based on this non-contact strategy and designed to be accommodated inside a Columbus single rack. Author

A90-13531#
CONTAINERLESS PROCESSING OF METALS IN SPACE
B. FEUERBACHER and D. M. HERLACH (DLR, Institut fuer Raumsimulation, Cologne, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 8 p. refs
(IAF PAPER 89-429) Copyright

Within the German space research program, a facility designated TEMPUS has been developed to accomplish containerless processing of metals in space. In the TEMPUS facility, the functions of heating and positioning are largely independent, even though both operate through RF electromagnetic forces. This is achieved by a two-coil system, with a quadrupole field for positioning and a dipole field for heating. The frequencies of two independent RF generators are optimized towards their functions, resulting in 100 kHz for positioning and 400 kHz for heating. Heating temperature of about 20 percent have been measured with this coil system. A number of experiments have been proposed which relate to undercooling, including the study of homogeneous or heterogeneous nucleation processes and possible hypercooling effects. Fast temperature data can be evaluated in terms of growth velocities as a function of undercooling. Fundamental thermodynamic properties relating to the metastable system of an undercooled melt become accessible to experimental investigation. C.E.

A90-13532#
ADVANCED FACILITIES FOR CRYSTAL GROWTH
H. LENSKI (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p. Research supported by DLR.
(IAF PAPER 89-430)

A new generation of European advanced facilities for crystal growth is described, including the following furnaces: the advanced gradient heating facility; the paraboloid ellipsoid mirror furnace;

and the zone melting facility. All facilities are characterized by a general design philosophy: minimum use of common infrastructure or Spacelab subsystems. The main design features of these facilities as well as performance test results are presented, outlining the present technical status, recent development trends, and future advanced facility concepts. A modular design concept for crystal growth furnaces onboard the Space Station is discussed in particular. C.E.

A90-13534*# National Aeronautics and Space Administration, Washington, DC.
MICROGRAVITY RESEARCH IN THE ERA OF SPACE STATION FREEDOM
MARK C. LEE (NASA, Microgravity Science and Applications Div., Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-432) Copyright

NASA has developed numerous microgravity research-related missions planned for the period of 1991 to 1994, leading to Space Station Freedom (SSF). Space Transportation System (STS) flights are designed with the philosophy that STS, Spacelab, and SSF will constitute an integrated system allowing an evolutionary approach to microgravity research in low earth orbit. Ground experiments, tested and refined on short-duration STS flights, will be developed and deployed on SSF where long-duration operation is required. In addition, this sequence will ensure maximum scientific return, encourage growth of the research community, and increase the chances of identifying new techniques and processes to be used in the SSF time frame. The paper discusses the rationale, justification, and approach taken by NASA to fully exploit this environment. C.E.

A90-13555*# National Aeronautics and Space Administration, Washington, DC.
ASTROMAG - PARTICLE ASTROPHYSICS MAGNET FACILITY FOR SPACE STATION FREEDOM
W. VERNON JONES (NASA, Space Physics Div., Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-466) Copyright

The Astromag (for astrophysics magnet) superconducting magnet facility to be flown aboard the Space Station in the late 1990s is described together with its scientific objectives. The Astromag facility is basically a magnetic spectrometer capable of determining the momentum per unit charge and the sign of the charge of fully ionized cosmic rays. The Astromag's science goals include investigating the origin and the evolution of matter in the Galaxy by direct sampling of Galactic material, examining cosmological models by searching for antimatter and an evidence of dark matter, and studying the origin of extremely energetic particles and their effects on the dynamics and evolution of the Galaxy. The Astromag's instrumentation will include an array of particle detectors (the WIZard instrument), a large spectrometer (LISA), and a stack of passive high-resolution track detectors in the Astromag's magnetic field (the SCIN/MAGIC instrument). I.S.

A90-15057
BIOLOGICAL EFFECTS OF GALACTIC RADIATION HZE PARTICLES IN EXPERIMENTS ON THE ORBITAL STATION SALYUT 7
A. T. MILLER and L. V. NEVZGODINA (Institut Mediko-Biologicheskikh Problem, Moscow, USSR) (COSPAR, IAU, International Union of Physiological Sciences, and International Academy of Astronautics, Plenary Meeting and Workshops XVII and XVIII on Life Sciences and Space Research XXIII(5) - Gravitational Biology, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 11, 1989, p. 47-51. refs
Copyright

Consideration is given to the extent of radiation damage to lettuce (Lactuca sativa) seeds flown on the orbital station Salyut 7 for 66 to 457 days. It is found that a single HZE particle hitting a seed has little effect on subsequent plant growth. Various morphological anomalies in primordial leaves and roots show a correlation with the location of the HZE particle track. Light and electron microscopy show the presence of channels in dry and soaked seeds. It is suggested that these channels are related to the LET of the incident particle. The implications of the study for space flight radiation hazards are noted. R.B.

A90-15407
THE XLA - A LARGE SPACEBORNE X-RAY DETECTOR ARRAY AND ITS RELATION TO ADVANCES IN GENERAL RELATIVITY
H. GURSKY, K. WOOD (U.S. Navy, E. O. Hulburt Center for Space Research, Washington, DC), W. M. FAIRBANK, and P. MICHELSON (Stanford University, CA) (COSPAR and IAU, Plenary Meeting, 27th, Symposium on Relativistic Gravitation, 15th, Espoo, Finland, July 18-29, 1988) Advances in Space Research (ISSN 0273-1177), vol. 9, no. 9, 1989, p. 51-59. refs
Copyright

The most important areas pertaining to general relativity which will be studied using the XLA are discussed. Technical issues involving the XLA are outlined. Packaging options for the XLA are shown and discussed. C.D.

A90-19640#
CANADIAN APPARATUS AND CAPABILITIES FOR MATERIALS SCIENCES IN SPACE
M. Z. SAGHIR (Canadian Space Agency, Ottawa, Canada) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p.
(AIAA PAPER 90-0025) Copyright

The types of furnaces available in Canada for materials science projects in space are presented. The experimental facilities are designed for use in different space carriers such as the Space Shuttle, sounding rockets, and the Space Station. The individual hardware described in detail include: (1) the configurable hardware for multidisciplinary projects in space (CHAMPS), (2) the float zone furnace, (3) the large diameter gradient freeze furnace, (4) the directional solidification furnace, (5) the isothermal heat pipe furnace, (6) the Queen's University experiments using the Space Transportation System (QUESTS), and (7) the protein crystallization facility. S.A.V.

A90-19999*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NONINTRUSIVE INERTIAL VIBRATION ISOLATION TECHNOLOGY FOR MICROGRAVITY SPACE EXPERIMENTS
CARLOS M. GRODSINSKY and GERALD V. BROWN (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. Previously announced in STAR as N90-11901. refs
(AIAA PAPER 90-0741) Copyright

The dynamic acceleration environment observed on Space Shuttle flights to date and predicted for the Space Station has complicated the analysis of prior microgravity experiments and prompted concern for the viability of proposed space experiments requiring long-term, microgravity environments. Isolation systems capable of providing significant improvements to this environment exist, but at present have not been demonstrated in flight configurations. A summary of the theoretical evaluation for two one degree-of-freedom (DOF) active magnetic isolators and their predicted response to both direct and base excitations is presented. These isolators can be used independently or in concert to isolate acceleration-sensitive microgravity space experiments, dependent on the isolation capability required for specific experimenter needs. Author

A90-21732#
SCIENTIFIC RESEARCH WITH COLUMBUS - THE SPACE STATION AS OBSERVATION PLATFORM [WETENSCHAPPELIJK ONDERZOEK MET COLUMBUS - HET RUIMTESTATION ALS WAARNEMINGSPLATFORM]

H. OLTHOF (ESTEC, Noordwijk, Netherlands) Ruimtevaart, vol. 38, Oct. 1989, p. 62-64. In Dutch.

The potential use of the Columbus Attached Laboratory for astropysical observations is discussed. It is pointed out that a scientific airlock similar to that on Spacelab could house instruments for UV imaging, plasma diagnostics, solar monitoring, X-ray observations, testing new detector systems, and measurements with calibration sources. Also described are two instruments packaged as Space Station attached payloads: (1) a high-resolution solar interferometer and (2) a small telescope for a sky survey in the submillimeter lines of water. T.K.

A90-22279
COLUMBUS POLAR PLATFORM UTILISATIONS AND OPERATIONS
C. P. LEE (British Aerospace, PLC, Space and Communications Div., Bristol, England) IN: Spacecraft ground operations and data handling; Proceedings of the Conference, London, England, Feb. 23, 1988. London, Royal Aeronautical Society, 1988, p. 3.1-3.15.
Copyright

ESA's prospective Columbus Polar Platform contribution to the International Space Station program possesses a well-defined community of earth remote sensing data users. The multidisciplinary payload undergoing definition will exploit the full range of synergisms available from a variety of active and passive sensors. Highly reconfigurable satellite hardware will facilitate satellite servicing to extend payload and increase service life. Cost-effectiveness is expected to derive from the large-scale sharing of operating costs among the members of its large, international user community. O.C.

A90-23263*# Iowa Univ., Iowa City.
SPACELAB 2 PLASMA DIAGNOSTICS PACKAGE
W. S. KURTH and L. A. FRANK (Iowa, University, Iowa City) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 70-75. refs
(Contract NAS8-32807; NAG3-449)
Copyright

The Plasma Diagnostics Package is a small, deployable satellite designed to study the interaction of the Space Shuttle Orbiter with the ionospheric environment as well as to be used in joint experiments with the plasma depletion and the vehicle charging and potential investigations during the Spacelab 2 mission. This paper provides a brief description of the small spacecraft, its instrumentation and operation, and the scientific objectives of the investigations. A brief summary of the scientific results obtained thus far is also presented. Author

A90-23293
THE ANTICIPATED ROLE OF THE LARGE FORMAT CAMERA IN FUTURE EARTH OBSERVATION STRATEGIES
MATTHEW HERIC and CARROLL LUCAS (Autometric, Inc., Alexandria, VA) Geocarto International (ISSN 1010-6049), vol. 4, Dec. 1989, p. 23-26. refs
Copyright

The operational status of the Large Format Camera (LFC) is evaluated and possibilities for future applications of the LFC are discussed. The results for Space Shuttle flights using the LFC are reviewed and the advantages of using LFC imagery are outlined. Consideration is given to the possible inclusion of the LFC as part of the earth observation sensor bed on the Space Station. R.B.

A90-23743
INTERFACING EXPERIMENTS TO THE COLUMBUS TELESCIENCE TEST BED
N. WOOTTON (Logica Space and Defence Systems, Ltd., London, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Feb. 1990, p. 73-82. refs
Copyright

A telescience test bed installed at ESTEC for use in evaluating the operational procedures of Columbus payloads is described. The test bed requirements and components are outlined. Two experiments to evaluate the telescience concept are reviewed: a human physiology experiment involving the telemonitoring of a crew member's ECG and blood pressure while performing work on an ergometer cycle, and a botany experiment telemonitoring plant growth under controlled gravity, lighting, and watering conditions. The process of determining the hardware and user interface requirements for these experiments and the procedures for mapping onto the test bed are discussed. R.B.

A90-23744
MICROGRAVITY EXPERIMENT DESIGN
S. BUSWELL (Logica, S.A. Brussels, Belgium) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Feb. 1990, p. 83-88. refs
Copyright

The development of the ESA Anthrorack for human physiology experiments on Spacelab is discussed. Anthrorack is designed to support experiments in the fields of cardiovascular and pulmonary function and adaptation, metabolic processes, hormonal function, and sensorimotor function. The Anthrorack hardware, experiments, and users are listed. The plans for using Anthrorack on a Spacelab mission are outlined. The development of a specialized Experiment Description Language (EDL), for describing Anthrorack experiments, is examined in detail, including the basic characteristics and possible future applications of EDL. R.B.

A90-27491* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DESIGN CONCEPTS FOR THE CENTRIFUGE FACILITY LIFE SCIENCES GLOVEBOX
SIDNEY C. SUN, MICHAEL J. HORKACHUCK, and KELLIE A. MCKEOWN (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 14 p.
(SAE PAPER 891527) Copyright

The Life Sciences Glovebox will provide the bioisolated environment to support on-orbit operations involving non-human live specimens and samples for human life sceinces experiments. It will be part of the Centrifuge Facility, in which animal and plant specimens are housed in bioisolated Habitat modules and transported to the Glovebox as part of the experiment protocols supported by the crew. At the Glovebox, up to two crew members and two habitat modules must be accommodated to provide flexibility and support optimal operations. This paper will present several innovative design concepts that attempt to satisfy the basic Glovebox requirements. These concepts were evaluated for ergonomics and ease of operations using computer modeling and full-scale mockups. The more promising ideas were presented to scientists and astronauts for their evaluation. Their comments, and the results from other evaluations are presented. Based on the evaluations, the authors recommend designs and features that will help optimize crew performance and facilitate science accommodations, and specify problem areas that require further study. Author

A90-27675#
TECHNOLOGY OF MAINTAINING MICROGRAVITY ENVIRONMENT IN SPACECRAFTS
KATSUHIDE KITAMURA, KENJI SAKANO, KOJI TANIDA, and KOUICHI SHOUJI Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 29, Sept. 1989, p. 343-348. In Japanese, with abstract in English. refs

Results on experiments related to the maintenance of the microgravity environment in a spacecraft are presented. Requirements for maintaining the microgravity environment are described together with four sources of microgravity. A gravity gradient model is presented along with an atmospheric drag model and a guidance navigation and control model. Attention is also given to structural vibration and its countermeasures. The microgravity requirement values at each level of the spacecraft are discussed. I.S.

A90-27743
FROM RUSSIA WITH HOPE
JEFF MANBER (Space Foundation, Washington, DC) Ad Astra (ISSN 1041-102X), vol. 2, Feb. 1990, p. 23-25, 27.
Copyright

Consideration is given to the first commercial U.S. experiment to fly on the Soviet space station Mir. The protein crystal experiment is briefly discussed and the various stages of planning and conducting the mission are described in detail. R.B.

A90-30131
CONCEPTUAL DESIGN OF RAIN RADARS IN THE TROPICAL RAINFALL MEASURING MISSION AND ON THE JAPANESE EXPERIMENT MODULE AT THE MANNED SPACE STATION PROGRAM
KEN'ICHI OKAMOTO, JUN AWAKA, TOSHIO IHARA, KENJI NAKAMURA, TOSHIAKI KOZU (Ministry of Posts and Telecommunications, Communications Research Laboratory, Koganei, Japan) et al. IN: Conference on Satellite Meteorology and Oceanography, 4th, San Diego, CA, May 16-19, 1989, Preprints. Boston, MA, American Meteorological Society, 1989, p. 18-21.
Copyright

The designs for the rain radars on the Tropical Rainfall Measuring Mission (TRMM) and the JEM on the Space Station are briefly described. The main system parameters of the radars are listed and the radars' baseline configurations are illustrated. The mission requirements for the TRMM radar and precipitation model are outlined and a candidate active array radar at 13.8 GHz is discussed. Also, the relationship of the JEM rain radar experiment to the other instruments and experiments on the JEM is considered. R.B.

N90-10808*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ASTROMETRIC TELESCOPE FACILITY. PRELIMINARY SYSTEMS DEFINITION STUDY. VOLUME 3: COST ESTIMATE
CHARLIE SOBECK, ed. Jul. 1987 10 p
(NASA-TM-89429-VOL-3; A-87239; NAS 1.15:89429-VOL-3)
Avail: NTIS HC A02/MF A01 CSCL 03/1

The results of the Astrometric Telescope Facility (ATF) Preliminary System Definition Study conducted in the period between March and September 1986 are described. The main body of the report consists primarily of the charts presented at the study final review which was held at NASA Ames Research Center on July 30 and 31, 1986. The charts have been revised to reflect the results of that review. Explanations for the charts are provided on the adjoining pages where required. Note that charts which have been changed or added since the review are dated 10/1/86; unchanged charts carry the review date 7/30/86. In addition, a narrative summary is presented of the study results and two appendices. The first appendix is a copy of the ATF Characteristics and Requirements Document generated as part of the study. The second appendix shows the inputs to the Space Station Mission Requirements Data Base submitted in May 1986. The report is issued in three volumes. Volume 1 contains an executive summary of the ATF mission, strawman design, and study results. Volume 2 contains the detailed study information. Volume 3 has the ATF cost estimate, and will have limited distribution. Author

N90-11901*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NONINTRUSIVE INERTIAL VIBRATION ISOLATION TECHNOLOGY FOR MICROGRAVITY SPACE EXPERIMENTS
CARLOS M. GRODSINSKY and GERALD V. BROWN 1989 10 p Proposed for presentation at the 28th Aerospace Sciences Meeting, Reno, NV, 8-11 Jan. 1990; sponsored by AIAA
(NASA-TM-102386; E-5127; NAS 1.15:102386; AIAA-90-0741)
Avail: NTIS HC A02/MF A01 CSCL 22/1

The dynamic acceleration environment observed on Space Shuttle flights to date and predicted for the Space Station has complicated the analysis of prior microgravity experiments and prompted concern for the viability of proposed space experiments requiring long-term, microgravity environments. Isolation systems capable of providing significant improvements to this environment exist, but at present have not been demonstrated in flight configurations. A summary of the theoretical evaluation for two one degree-of-freedom (DOF) active magnetic isolators and their predicted response to both direct and base excitations is presented. These isolators can be used independently or in concert to isolate acceleration-sensitive microgravity space experiments, dependent on the isolation capability required for specific experimenter needs. Author

N90-12768*# Alabama Univ., Huntsville. Center for Microgravity and Materials Research.
VIBRATION ISOLATION TECHNOLOGY: SENSITIVITY OF SELECTED CLASSES OF SPACE EXPERIMENTS TO RESIDUAL ACCELERATIONS Annual Report No. 1, 1 Jul. 1988 - 30 Jun. 1989
J. IWAN D. ALEXANDER, Y. Q. ZHANG, and ADEBIMPE *ADEBIYI 1989* 67 p
(Contract NAG8-724)
(NASA-CR-185443; NAS 1.26:185443) Avail: NTIS HC A04/MF A01 CSCL 22/1

Progress performed on each task is described. Order of magnitude analyses related to liquid zone sensitivity and thermo-capillary flow sensitivity are covered. Progress with numerical models of the sensitivity of isothermal liquid zones is described. Progress towards a numerical model of coupled buoyancy-driven and thermo-capillary convection experiments is also described. Interaction with NASA personnel is covered. Results to date are summarized and they are discussed in terms of the predicted space station acceleration environment. Work planned for the second year is also discussed. B.G.

N90-12769# European Space Agency, Paris (France).
BIOLOGY IN MICROGRAVITY: A GUIDE FOR EXPERIMENTERS
L. G. BRIARTY (Nottingham Univ., England) and B. KALDEICH, ed. May 1989 128 p Original contains color illustrations
(ESA-TM-02; ISSN-1013-7076; ETN-89-95387) Copyright Avail: NTIS HC A07/MF A01

The techniques that were developed for studying the effects of spaceflight (principally microgravity) on living systems are discussed. The effects of weightlessness on plant and animal cells are given particular attention. The areas of whole animal physiology, space medicine and human physiology are not covered. The goal of the paper is to serve as a handbook for biologists embarking on studies in the field, and to provide data on some of the particular problems that may be encountered. The specialized hardware used in spaceborne biology experiments is described in detail. ESA

N90-13679*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FACILITIES FOR MICROGRAVITY COMBUSTION RESEARCH
KURT R. SACKSTEDER 1988 20 p Presented at the 39th Annual Astronautical Congress of the International Astronautical Federation, Bangalore, India, 8-15 Oct. 1988
(NASA-TM-102014; E-4726; NAS 1.15:102014; IAF-88-355)
Avail: NTIS HC A03/MF A01 CSCL 21/2

Combustion science and applications have benefited in unforeseen ways from experimental research performed in the low-gravity environment. The capability to control for the first time the influence of gravitational buoyancy has provided some insight into soot formation in droplet combustion, the nature of flammability limits in premixed gases, and the relationship between normal-gravity and low-gravity material flammability that may influence how materials are best selected for routine use in habitable spacecraft. The opportunity to learn about these complex phenomena is derived from the control of the ambient body-force field and, perhaps as importantly, the simplified boundary conditions that can be established in well designed low-gravity combustion experiments. A description of the test facilities and typical experimental apparatus are provided; and conceptual plans for a

Space Station Freedom capability, the Modular Combustion Facility, are described. Author

N90-13952*# Lockheed Missiles and Space Co., Sunnyvale, CA. Bioastronautics Div.
HUMAN FACTORS ISSUES IN PERFORMING LIFE SCIENCE EXPERIMENTS IN A 0-G ENVIRONMENT
WAYNE GONZALEZ *In* NASA, Ames Research Center, Cells in Space p 161-165 Aug. 1989
Avail: NTIS HC A14/MF A02 CSCL 06/3

An overview of the environmental conditions within the Spacelab and the planned Space Station Freedom is presented. How this environment causes specific Human Factors problems and the nature of design solutions are described. The impact of these problems and solutions on the performance of life science activities onboard Spacelab (SL) and Space Station Freedom (SSF) is discussed. The first area highlighted is contamination. The permanence of SSF in contrast to the two-week mission of SL has significant impacts on crew and specimen protection requirements and, thus, resource utilization. These requirements, in turn impose restrictions on working volumes, scheduling, training, and scope of experimental procedures. A second area is microgravity. This means that all specimens, materials, and apparatus must be restrained and carefully controlled. Because so much of the scientific activity must occur within restricted enclosures (gloveboxes), the provisions for restraint and control are made more complex. The third topic is crewmember biomechanics and the problems of movement and task performance in microgravity. In addition to the need to stabilize the body for the performance of tasks, performance of very sensitive tasks such as dissection is difficult. The issue of space sickness and adaption is considered in this context. Author

N90-14274*# Universities Space Research Association, Huntsville, AL.
SPACE STATION ATTACHED PAYLOAD PROGRAM SUPPORT
Final Report, 4 Oct. 1988 - 30 Sep. 1989
MAURICE G. ESTES, JR. and BARDLE D. BROWN 27 Oct. 1989 11 p
(Contract NAS8-37583)
(NASA-CR-183838; NAS 1.26:183838; REPT-4) Avail: NTIS HC A03/MF A01 CSCL 22/2

The USRA is providing management and technical support for the peer review of the Space Station Freedom Attached Payload proposals. USRA is arranging for consultants to evaluate proposals, arranging meeting facilities for the reviewers to meet in Huntsville, Alabama and management of the actual review meetings. Assistance in developing an Experiment Requirements Data Base and Engineering/Technical Assessment support for the MSFC Technical Evaluation Team is also being provided. The results of the project will be coordinated into a consistent set of reviews and reports by USRA. The strengths and weaknesses analysis provided by the peer panel reviewers will by used NASA personnel in the selection of experiments for implementation on the Space Station Freedom. Author

N90-15331# California Univ., Berkeley. Lawrence Berkeley Lab. Engineering Div.
RETRACTABLE GAS COOLED LEADS FOR ASTROMAG
W. L. POPE and M. A. GREEN Jul. 1989 8 p Presented at the International Cryogenic Materials Conference, Los Angeles, CA, 24-28 Jul. 1989
(Contract DE-AC03-76SF-00098)
(DE90-002679; LBL-27746; CONF-890701-19) Avail: NTIS HC A02/MF A01

This paper discusses retractable gas cooled leads for the ASTROMAG experiment superconducting solenoid which will operate on the space station. The ASTROMAG magnet will be cooled by superfluid helium pumped from a storage tank by a fountain effect pump. Since it is desirable to keep the helium consumption low, retractable gas cooled leads are proposed for the ASTROMAG magnet. These leads, which will be in the cryostat vacuum space, will connect directly with the helium flow circuitry which cools the magnet. The leads will operate in a flow circuit separated from the shields. DOE

N90-16087*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CONCEPTUAL DESIGN FOR THE SPACE STATION FREEDOM MODULAR COMBUSTION FACILITY
17 May 1989 63 p Presented at the MCF Assessment Workshop, Cleveland, OH, 17-18 May 1989; sponsored by NASA, Washington
(NASA-TM-102037; E-4786; NAS 1.15:102037) Avail: NTIS HC A04/MF A01 CSCL 22/1

A definition study and conceptual design for a combustion science facility that will be located in the Space Station Freedom's baseline U.S. Laboratory module is being performed. This modular, user-friendly facility, called the Modular Combustion Facility, will be available for use by industry, academic, and government research communities in the mid-1990's. The Facility will support research experiments dealing with the study of combustion and its byproducts. Because of the lack of gravity-induced convection, research into the mechanisms of combustion in the absence of gravity will help to provide a better understanding of the fundamentals of the combustion process. The background, current status, and future activities of the effort are covered. Author

N90-17897*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MICROGRAVITY NONCONTACT TEMPERATURE REQUIREMENTS AT NASA LEWIS RESEARCH CENTER
G. SANTORO *In* JPL, Proceedings of the Second Noncontact Temperature Measurement Workshop p 19-32 1 Jun. 1989
Avail: NTIS HC A16/MF A03 CSCL 22/1

NASA Lewis Research Center is currently supporting 66 microgravity science and applications projects. The 66 projects are separated into 23 flight projects and 43 ground-based projects. The part of the NASA Lewis program dealing with flight experiments is divided into six areas: Combustion Science, Materials Science, Fluid Physics, Instrumentation/Equipment, Advanced Technology Development, and Space Station Multi-User Facility studies. The part of the NASA Lewis program dealing with ground-based experiments is coincidentally also divided into six areas: Electronic Materials, Combustion Science, Fluid Dynamics and Transport Phenomena, Metals and Alloys, Glasses and Ceramics, and Physics and Chemistry Experiments. Several purposes exist for ground-based experimenting. Preliminary information is necessary before a decision can be made for flight status, the short low gravity durations available in ground facilities are adequate for a particular study, or extensive ground-based research must be conducted to define and support the microgravity science endeavors contemplated for space. Not all of the 66 microgravity science and application projects at NASA Lewis have temperature requirements, but most do. Since space allocation does not permit a review of all the pertinent projects, a decision was made to restrict the coverage to the science flight projects, flight projects minus the advanced technology development, and multiuser facility efforts. Very little is lost by this decision as the types of temperature requirements for science flight projects can be considered representative of those for the ground-based projects. The noncontact temperature needs at NASA Lewis, as represented by the science flight projects are discussed by describing briefly the experiments themselves, by displaying an illustration of each experimental setup, and by specifying their temperature requisites. Author

N90-17898*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
NON-CONTACT TEMPERATURE MEASUREMENT REQUIREMENTS
D. B. HIGGINS and W. K. WITHEROW *In* JPL, Proceedings of the Second Noncontact Temperature Measurement Workshop p 33-38 1 Jun. 1989
Avail: NTIS HC A16/MF A03 CSCL 22/1

The Marshall Space Flight Center is involved with levitation experiments for Spacelab, Space Station, and drop tube/tower operations. These experiments have temperature measurement requirements, that of course must be non-contact in nature. The experiment modules involved are the Acoustic Levitator Furnace (ALF), and the Modular Electromagnetic Levitator (MEL). User requirements of the ALF and drop tube are presented. The center also has temperature measurement needs that are not microgravity experiment oriented, but rather are related to the propulsion system for the STS. This requirement will also be discussed. Author

N90-18242# Washington Univ., Seattle. Dept. of Physics.
ELEMENTARY PARTICLE PHYSICS: EXPERIMENTAL
JERE J. LORD, T. H. BURNETT, and R. JEFFREY WILKES 22 Sep. 1989 38 p
(Contract DE-AS06-88ER-40423)
(DE90-005973; DOE/ER-40423/13) Avail: NTIS HC A03/MF A01

A research program was performed in high energy experimental particle physics. Studies of high energy hadronic interactions and leptoproduction processes continue using several experimental techniques. Progress was made on the study of multiparticle production processes in nuclei. Ultra-high energy cosmic ray nucleus-nucleus interactions were investigated by the Japanese American Cosmic Emulsion Experiment (JACEE) using balloon-borne emulsion chamber detectors. In the area of particle astrophysics, studies of cosmic ray nuclear interactions made possible the use of the world's most accurate determination of the comparison of the cosmic rays above 10(exp 13)eV. It is the only detector that can observe interaction vertices and identify particles at energies up to 10 to 15 eV. The observations are getting close to placing limits on the acceleration mechanisms postulated for pulsars in which the spin and magnetic moment axes are at different angles. In June, 1989 approval was given by NASA for our participation in the Space Station program. The SCINATT experiment will make use of emulsion chamber detectors, similar to the planned JACEE hybrid balloon flight detectors. These detector will permit precise determination of secondary particle charges, momenta and rapidities, and the accumulation of data will be at least a factor of 10 to 100 greater than in balloon experiments. Emulsion chamber techniques are also employed in an experiment using accelerator heavy ion beams at CERN and Brookhaven National Laboratory to investigate particle production processes in central collisions of nuclei in the energy range 15 to 200A GeV. The study of hadroproduction in lepton interactions is continuing with approval of another 8 months run for deep inelastic muon scattering experiment E665 at Fermilab. DOE

N90-18607# Pacific Northwest Lab., Richland, WA.
CONDENSATION FLUID DYNAMICS AND HEAT TRANSFER ON ROTATING SPHERICAL SURFACES IN A MICROGRAVITATIONAL FIELD
KEITH A. PAULEY, ANDREW C. KLEIN (Oregon State Univ., Corvallis.), and BRENT J. WEBB Jan. 1990 4 p Presented at the 7th Symposium on Space Nuclear Power Systems, Albuquerque, NM, 7-11 Jan. 1990
(Contract DE-AC06-76RL-01830)
(DE90-005540; PNL-SA-17331; CONF-900109-18) Avail: NTIS HC A01/MF A01

A heat injection system is an integral part of any space mission. The successful operation of the spacecraft and other secondary equipment is related to the effectiveness and survivability of the thermal management system. The heat rejection system should have a small launch volume and weight in relation to the entire mission payload. This has not previously been the case. An advanced thermal management system was developed for space power applications which is both effective and light weight. The Bubble Membrane Radiator (BMR) is a space-based heat rejection system which uses direct radiation to space and operating fluid condensation as the primary heat transfer mechanisms. This heat exchanger rotates about a central axis in order to induce a small artificial gravity. The working fluid enters the radiator via feed lines incorporated in the axis of rotation and is then sprayed. DOE

N90-18744*# Texas A&M Univ., College Station. Dept. of Mechanical Engineering.
PAYLOAD VIBRATION ISOLATION IN A MICROGRAVITY ENVIRONMENT Final Report, 1 Jun. 1988 - 31 Dec. 1989
RICHARD M. ALEXANDER 15 Jan. 1990 67 p
(Contract NAS9-17972)
(NASA-CR-186191; NAS 1.26:186191) Avail: NTIS HC A04/MF A01 CSCL 20/11

Many in-space research experiments require the microgravity environment attainable near the center of mass of the Space Station. Disturbances to the structure surrounding an experiment may lead to vibration levels that will degrade the microgravity environment and undermine the experiment's validity. In-flight disturbances will include vibration transmission from nearby equipment and excitation from crew activity. Isolation of these vibration-sensitive experiments is required. Analytical and experimental work accomplished to develop a payload (experiment) isolation system for use in space is described. The isolation scheme allows the payload to float freely within a prescribed boundary while being kept centered with forces generated by small jets of air. The vibration criterion was a maximum payload acceleration of 10 micro-g's (9.81x10(exp -5)m/s(exp 2), independent of frequency. An experimental setup, composed of a cart supported by air bearings on a flat granite slab, was designed and constructed to simulate the microgravity environment in the horizontal plane. Experimental results demonstrate that the air jet control system can effectively manage payload oscillatory response. An analytical model was developed and verified by comparing predicted and measured payload response. The mathematical model, which includes payload dynamics, control logic, and air jet forces, is used to investigate payload response to disturbances likely to be present in the Space Station. Author

N90-19834# Washington Univ., Seattle. Dept. of Physics.
EXPERIMENTAL AND THEORETICAL HIGH ENERGY PHYSICS
DAVID BOULWARE 1988 59 p
(Contract DE-AS06-88ER-40423)
(DE90-005974; DOE/ER-40423/26) Avail: NTIS HC A04/MF A01

We are carrying out a research program in high energy experimental particle physics. Studies of high energy hadronic interactions and leptoproduction processes continue using several experimental techniques. Progress has been made on the study of multiparticle production processes in nuclei. Ultra-high energy cosmic ray nucleus-nucleus interactions have been investigated by the Japanese American Cosmic Emulsion Experiment (JACEE) using balloon-borne emulsion chamber detectors. In the area of particle astrophysics, our studies of cosmic ray nuclear interactions have enabled us to make the world's most accurate determination of the composition of the cosmic rays above 10(13) eV. We have the only detector that can observe interaction vertices and identify particles at energies up to 10 to 15 eV. Our observations are getting close to placing limits on the acceleration mechanisms postulated for pulsars in which the spin and magnetic moment axes are at different angles. In June, 1989 approval was given by NASA for our participation in the Space Station program. The SCINATT experiment will make use of emulsion chamber detectors, similar to the planned JACEE hybrid balloon flight detectors. These detectors will permit precise determination of secondary particle charges, momenta and rapidities, and the accumulation of data will be at least a factor of 10 to 100 greater than in balloon experiments. DOE

N90-19954*# Maryland Univ., College Park. Dept. of Physics and Astronomy.
EARTH-ORBITING RESONANT-MASS GRAVITATIONAL WAVE DETECTORS
HO JUNG PAIK *In* NASA, Relativistic Gravitational Experiments in Space p 89-92 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 03/2

Earth-based gravitational wave detectors suffer from the need to support the large antenna masses against the earth's gravity without transmitting a significant amount of seismic noise. Passive vibration isolation is difficult to achieve below 1 Hz on the earth. Vibration-free space environment thus gives an opportunity to extend the frequency window of gravitational wave detection to ultralow frequencies. The weightless condition of a space laboratory also enables construction of a highly symmetric multimode antenna which is capable of resolving the direction of the source and the polarization of the incoming wave without resorting to multiantenna coincidence. Two types of earth-orbiting resonant-mass gravitational wave detectors are considered. One is a skyhook *gravitational wave detector, proposed by Braginsky and Thorne* (1985). The other is a spherical detector, proposed by Forward (1971) and analyzed by Wagoner and Paik (1976). Author

N90-19963*# Stanford Univ., CA. Dept. of Physics.
THE STANFORD EQUIVALENCE PRINCIPLE PROGRAM
PAUL W. WORDEN, JR., C. W. FRANCIS EVERITT, and M. BYE *In* NASA, Relativistic Gravitational Experiments in Space p 137-140 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 03/2

The Stanford Equivalence Principle Program (Worden, Jr. 1983) is intended to test the uniqueness of free fall to the ultimate possible accuracy. The program is being conducted in two phases: first, a ground-based version of the experiment, which should have a sensitivity to differences in rate of fall of one part in 10(exp 12); followed by an orbital experiment with a sensitivity of one part in 10(exp 17) or better. The ground-based experiment, although a sensitive equivalence principle test in its own right, is being used for technology development for the orbital experiment. A secondary goal of the experiment is a search for exotic forces. The instrument is very well suited for this search, which would be conducted mostly with the ground-based apparatus. The short range predicted for these forces means that forces originating in the Earth would not be detectable in orbit. But detection of Yukawa-type exotic forces from a nearby large satellite (such as Space Station) is feasible, and gives a very sensitive and controllable test for little more effort than the orbiting equivalence principle test itself. Author

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PLATFORMS & TETHERS

Descriptions and requirements of independent experimental platforms or missions using tethers aboard space stations.

A90-10293#
CUIS - THE COLUMBUS UTILISATION INFORMATION SYSTEM
G. ALVISI, M. DOUZAL (ESA, European Space Research Institute, Frascati, Italy), G. PETERS, and PH. WILLEKENS (ESA, Promotion and Utilisation Dept., Paris, France) ESA Bulletin (ISSN 0376-4265), no. 59, Aug. 1989, p. 35-38.
Copyright

The launch of Columbus and the Space Station Freedom in the early 1990s brings with it the possibility of 30 years of utilization and the opportunity for innumerable flights and experiments. There will be the possibility of exchanging experiments every three months in the Columbus Attached Laboratory, and every six months in the Columbus Free-Flying Laboratory. This operational scenario will provide European users with the facility to conduct a large number of experiments producing a great deal of information. Author

A90-13249#
PERSPECTIVE FEATURES OF THE TETHERED SYSTEMS FOR SPACE APPLICATIONS
CARLO BUONGIORNO (Agenzia Spaziale Italiana, Rome, Italy) and ERNESTO VALLERANI (Aeritalia S.p.A., Turin, Italy) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 14 p. refs
(IAF PAPER 89-011) Copyright

Some of the possible new applications of tethered systems are reviewed with emphasis on the International Space Station scenario. Applications of the tethered systems as supporting tools in the field of reentry technology are also addressed. Brief reviews of several experiments designed to validate the enabling technologies required by the new applications are presented. The experiments discussed include the Tether Inspection and Repair Experiment, the Tether Initiated Space Recovery System, and the *Shuttle Tethered Aerothermodynamic Research Facility.* V.L.

A90-13251#
ELECTRODYNAMICS OF TETHERED SATELLITE SYSTEMS - TWO CONCEPTS
N. A. SAVICH (AN SSSR, Institut Radiotekhniki i Elektroniki, Moscow, USSR) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 5 p. refs
(IAF PAPER 89-013) Copyright

Two approaches to the problem of the electrodynamics of active tethered satellite systems are discussed: first, from the point of view of closed current circuits, and second, from the point of view of charges pumping over from one region of space to another. A qualitative analysis of such systems functioning in the earth ionosphere taking into account the magnetic field influence shows that the concept of charge separation is more advantageous due to the possibility of considering the events, occurring in the tethered satellite system itself and in the earth ionosphere separately. It allows to outline the paths of a quantitative decision of the problem current and potentials distributions in the system collector-tether-emitter. Author

A90-13286*# National Aeronautics and Space Administration, Washington, DC.
ATMOSPHERIC DEPLOYMENT OF TETHERED SYSTEMS - THE PROPOSED TSS-2 FLIGHT DEMONSTRATION
L. M. COUCH, L. A. HARRIS, R. GUALDONI, and J. L. ANDERSON (NASA, Office of Aeronautics and Space Technology, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 10 p. refs
(IAF PAPER 89-062) Copyright

Areas of strong user interest in the atmospheric deployment of tethered systems are addressed. They include hypersonic and aerothermodynamics research to support next-generation aerospace vehicle design, lower thermosphere scientific research supporting global change monitoring and earth systems investigations, and payload recovery/trash disposal from Space Station Freedom. The proposed tethered flight demonstration TSS-2 is described. C.D.

A90-13492#
OFFSET CONTROL OF TETHERED SATELLITE SYSTEMS - ANALYSIS AND EXPERIMENTAL VERIFICATION
V. J. MODI, P. K. LAKSHMANAN (British Columbia, University, Vancouver, Canada), and A. K. MISRA (McGill University, Montreal, Canada) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 12 p. refs
(Contract NSERC-5-80029)
(IAF PAPER 89-376) Copyright

Using a ground based experimental facility, the paper demonstrates validity of the mathematical model aimed at studying offset control of an orbiting platform supported tethered satellite system. The mathematical model for the system is discussed first and some representative control data presented. This is followed by a description of the ground based experimental simulation involving controller, actuator and sensors used in the test program. Results confirm effectiveness of the offset control strategy during both the stationkeeping and retrieval phases. Author

A90-13502#
THREE-DIMENSIONAL DYNAMICS AND CONTROL OF TETHER-CONNECTED THREE-BODY SYSTEMS
A. K. MISRA (McGill University, Montreal, Canada) and V. MODI (British Columbia, University, Vancouver, Canada) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 17 p. refs
(IAF PAPER 89-390) Copyright

A formulation for the three-dimensional dynamics of tethered three-body system is presented, using a double-pendulum model. Control laws for both in-plane and out of plane motions are considered. The equations derived are valid for large motion, variable length, and arbitrary orbit, but the tethers are assumed to be massless and straight. It is found that the two out-of-plane librational frequencies are always related to the two in-plane librational frequencies. Typical transient response of three-body tethered systems is also presented. C.E.

A90-14740#
EFFECT OF TETHER FLEXIBILITY ON THE TETHERED SHUTTLE SUBSATELLITE STABILITY AND CONTROL
LIANGDONG LIU and PETER M. BAINUM (Howard University, Washington, DC) (Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987, p. 93-103) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Nov.-Dec. 1989, p. 866-873. Previously cited in issue 18, p. 2771, Accession no. A89-43339. refs
Copyright

A90-17821*# Auburn Univ., AL.
ELECTRODYNAMICS OF THE GETAWAY TETHER EXPERIMENT
MICHAEL GREENE, MICHAEL BAGINSKI (Auburn University, AL), and DOUGLAS WHEELOCK (SCI Systems, Inc., Huntsville, AL) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Nov.-Dec. 1989, p. 452-459. refs
(Contract NAG8-618)
Copyright

An electrodynamic circuit model of the interaction of a pair of small tethered satellites and the ionosphere is developed and analyzed. The system under study, the Getaway Tether Experiment (GATE), is composed of two small satellites and 1 km of insulated conducting tether. The nonlinear model has elements representing the emission, collection, and resistive flow of charge through an electrically conductive tether, plasma contactors, and the ionosphere. The circuit model is incorporated into a dynamic orbital simulation to predict mission performance. Simulation results show the feasibility to bilaterally transfer energy between stored electrical energy and orbital momentum. A transient model is also developed using the circuit model and a string of N lumped-parameter modules, each consisting of resistance, capacitance, and induced potential for the tether. Transients are shown via simulation to occur over millisecond intervals. Author

A90-19565*# Stanford Univ., CA.
TETHER DAMPING IN SPACE
XIAOHUA HE and J. DAVID POWELL (Stanford University, CA) (Space tethers for science in the space station era; Proceedings of the Second International Conference, Venice, Italy, Oct. 4-8, 1987, p. 153-162) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Jan.-Feb. 1990, p. 104-112. Previously cited in issue 18, p. 2772, Accession no. A89-43346. refs
(Contract NCC2-389; NCA2-54)
Copyright

A90-19897#
TETHERED AEROTHERMODYNAMIC RESEARCH NEEDS
F. C. HURLBUT (California, University, Berkeley) and J. L. POTTER (Vanderbilt University, Nashville, TN) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. refs
(AIAA PAPER 90-0533) Copyright

The tethered satellite is increasingly recognized as a vehicle of significant promise for new aerothermodynamic study. In this paper, the new information needs essential to progress in understanding the aerothermodynamics of flow in regimes which are both hypersonic and rarefied are identified and discussed. Measurement requirements implied by research needs are discussed in the context of a tethered research satellite which has the approximate mass and sophistication of the proposed Tethered Satellite System 2. C.D.

A90-19970#
DYNAMICS OF A TETHERED SATELLITE SUBJECTED TO AERODYNAMIC FORCES
GUIDO DE MATTEIS and LUCIANO M. DE SOCIO (Roma I, Universita, Rome, Italy) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. Research supported by MPI. refs
(AIAA PAPER 90-0656) Copyright

The equations of motion of a subsatellite and its tether are dealt with in order to show the influence of the aerodynamic forces on the equilibrium of the system and on its time history following a perturbation. It is shown that those forces can play a nonnegligible role in determining the stability of the equilibrium and the evolution with the time of the system itself in situations of relevant practical interest. Author

A90-19971#
ACTIVE CONTROL OF ORBITING TETHERED ANTENNAS/REFLECTORS FOR OUT-OF-PLANE MOTION
LIANGDONG LIU and PETER M. BAINUM (Howard University, Washington, DC) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. refs
(Contract F49620-89-C-0002)
(AIAA PAPER 90-0657) Copyright

The active control for out-of-plane motion of the orbiting tethered antenna system is assumed to be provided by using point actuators. Both single-axis control (about the roll axis) and two-axis control (about the roll and yaw axes) are considered. For single-axis control, a long transient time constant results for the rigid motion based on an LQR-designed optimal control law. The tme constant could be significantly reduced with pole placement techniques, but large overshoots (especially for yaw motion) could be experienced. The tether flexible vibrations (which are induced by initial tether vibrations) could be effectively suppressed by including the state feedback of the vibrational modes into the control law. For two-axis active control, the transient responses for the rigid motion could be significantly improved (both with respect to time constants and overshoots), while the time responses for the tether vibrational suppression are almost the same as those for single-axis control. Author

A90-20007#
THREE-DIMENSIONAL DYNAMICS AND CONTROL OF TETHER-CONNECTED N-BODY SYSTEMS
A. K. MISRA (McGill University, Montreal, Canada) and V. J. MODI (British Columbia, University, Vancouver, Canada) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p. refs
(AIAA PAPER 90-0751) Copyright

Using a multiple-pendulum model, a formulation for the three-dimensional dynamics of tether-connected N-body systems is carried out and control laws are developed for both in-plane and out-of-plane motions of these systems. It is shown that the equations of motion are valid for large motion, variable length, and arbitrary orbit. It is also shown that the two out-of-plane librational frequencies are always related to the two in-plane librational frequencies. A typical transient response of three-body tethered systems is shown. I.S.

A90-23146
TETHER WORKSHOP, COLOGNE, FEDERAL REPUBLIC OF GERMANY, FEB. 10, 1988, REPORT
Cologne, Federal Republic of Germany, Deutsche Forschungs- und

Versuchsanstalt fuer Luft- und Raumfahrt, 1988, 257 p. For individual items see A90-23147 to A90-23149.

Papers are presented from a workshop on tethers, covering topics such as the basics of tether technology, the use of tethered satellites, the physics of the electromagnetic tether, the status of tether studies in Germany, and plans for future activities in tether research. Other topics include the mechanical applications of tethers and orbit transfer, electron distribution measurements on a tethered satellite, the use of an electrodynamic tether, tether applications for remote sensing and telecommunications, and aerodynamic experiments on tethered satellites. Also, papers are presented on use of the TSS neutral mass spectrometer to study lower thermospheric vertical transport processes, electric propulsion and tethers, the system and control engineering aspects of tethered systems, proximity motion of free and tethered bodies associated with orbital stations, tether applications and Eureca, the use of tethers on Columbus, and tether activities in the ESA. R.B.

A90-23147#
TETHERS IN SPACE
M. DOBROWOLNY (CNR, Istituto di Fisica dello Spazio Interplanetario, Frascati, Italy) IN: Tether Workshop, Cologne, Federal Republic of Germany, Feb. 10, 1988, Report. Cologne, Federal Republic of Germany, Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, 1988, p. 1-31.

Research and development in the field of space tethers is reviewed. The scientific and technical applications of tether technology are outlined, including transporting a payload in a transfer orbit and controlling the gravity environment. The basic concepts of electrodynamic tethers are discussed and the results of the Tethered Satellite System, TSS-1, mission are examined. Also, consideration is given to the possible future applications of tether technology. R.B.

A90-23148#
TETHERED SATELLITES IN THE LOW ATMOSPHERE - GEOMAGNETIC FIELD, GRAVITY FIELD AND . . MORE
F. MARIANI (Roma II, Universita, Rome, Italy) IN: Tether Workshop, Cologne, Federal Republic of Germany, Feb. 10, 1988, Report. Cologne, Federal Republic of Germany, Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, 1988, p. 33-69, 71-84. refs

An overview of the use of tethered satellites at low altitudes is given, focusing on the geomagnetic and gravity fields. The characteristics and applications of low-altitude tethered satellites are outlined. The geomagnetic and gravity field structures are described focusing on the way in which tethered satellites could be used as platforms for making systematic surveys of geomagnetic and gravity anomalies. Consideration is given to instruments for gravity gradiometry and for making magnetic measurements. R.B.

A90-23149#
THE ENERGETIC ELECTRON DISTRIBUTION OF THE IONOSPHERIC PLASMA AND ITS REACTION TO ACTIVE EXPERIMENTATION ON A TETHERED SPACECRAFT SYSTEM
K. WILHELM (Max-Planck-Institut fuer Aeronomie, Katlenburg-Lindau, Federal Republic of Germany), C. B. COSMOVICI (CNR, Istituto per il Plasma nello Spazio, Frascati, Italy), A. EGIDI (L'Aquila, Universita, Italy), M. P. GOUGH (Sussex, University, Brighton, England), W. RIEDLER (Oesterreichische Akademie der Wissenschaften, Institut fuer Weltraumforschung, Graz, Austria) et al. IN: Tether Workshop, Cologne, Federal Republic of Germany, Feb. 10, 1988, Report. Cologne, Federal Republic of Germany, Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, 1988, p. 85-111. refs

A suprathermal electron analyzer proposed for use on a tethered satellite during a Space Shuttle mission is described. The spectrometer would measure electrons in the 0.1-12.5 keV energy range in a wide field-of-view using electrostatic devices for energy and direction determinations. It is suggested that the proposed electron spectrometer experiment may be used to study the particle aspects of wave-particle interactions induced by the Space Shuttle/tethered satellite system. The instrumentation for the proposed mission is described and the mission scenario is outlined. R.B.

A90-23260*# George Washington Univ., Hampton, VA.
SYSTEMS ANALYSIS OF A LOW-ACCELERATION RESEARCH FACILITY
GARY L. MARTIN (George Washington University, Hampton, VA), MELVIN J. FEREBEE, JR., and ROBERT L. WRIGHT (NASA, Langley Research Center, Hampton, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 53-60. Previously cited in issue 17, p. 2786, Accession no. A88-42909. refs
Copyright

A90-25999#
LIBRATION DAMPING OF A TETHERED SATELLITE BY YO-YO CONTROL WITH ANGLE MEASUREMENT
W. R. DAVIS and A. K. BANERJEE (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 370-374. refs
Copyright

The libration damping of a tether system operating in a gravity-gradient mode has been simulated and demonstrated to be effective. Simultaneous roll, pitch, and length perturbations of the order of 10 percent are either damped or fully eliminated within six to seven orbit periods; the actual length of time largely depends on the initial roll perturbation, and requires about one orbit-period for a 20-percent reduction, using nominal, or less than 10 percent, length variations. O.C.

A90-26001#
COMMENT ON 'SOME APPROXIMATIONS FOR THE DYNAMICS OF SPACECRAFT TETHERS'
A. K. MISRA (McGill University, Montreal, Canada) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Mar.-Apr. 1990, p. 380; Author's Reply, p. 380, 381. refs
Copyright

A90-26781*# British Columbia Univ., Vancouver.
DYNAMICS AND CONTROL OF TETHERED SPACECRAFT - A BRIEF OVERVIEW
V. J. MODI (British Columbia, University, Vancouver, Canada), P. K. LAKSHMANAN (NASA, Marshall Space Flight Center, Huntsville, AL; British Columbia, University, Vancouver, Canada), and A. K. MISRA (McGill University, Montreal, Canada) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 42-57. refs
(AIAA PAPER 90-1195) Copyright

Work related to the dynamics of tether connected orbiting systems and their control during deployment, operational, and retrieval phases is briefly reviewed. In particular, attention is given to the modeling of tether dynamics and control, end bodies tethered at point masses, deployment dynamics and tension control, and thruster and offset control. Directions of future efforts aimed at gaining a better understanding of the performance of tethered systems are outlined. V.L.

A90-26782#
AN OPTIMAL GUIDANCE APPROACH TO RETRIEVAL OF A TETHERED SUB-SATELLITE
DARRYLL J. PINES, ERIC J. FLEURISSON, and A. H. VON FLOTOW (MIT, Cambridge, MA) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 58-65. refs
(AIAA PAPER 90-1196) Copyright

This paper presents a feed-forward control scheme for finding optimal retrieval trajectories of a Tethered Satellite System potentially consisting of the Space Shuttle Orbiter and the tethered

sub-satellite. The optimal retrieval trajectories are computed by determining the length rate time history which minimizes a combination of pitch angle, pitch rate and final retrieval time at docking. The optimal solution of this cost function results in a bang-bang acceleration control law with acceleration limits imposed by physical constraints. By specifying a parameterized form of the retrieval length-rate profile, the open loop guidance problem is simplified. For simple parameterizations the tether-reel-in controller can be commanded to follow constant velocity and constant acceleration profiles. Examples exploiting these parameterizations show good performance. Since the retrieval is open-loop unstable, the trajectory (and thus the cost) is very sensitive to perturbations in the control and in initial conditions. Thus this feed-forward scheme would need to be implemented with stabilizing feedback. Author

A90-26783#
FEEDBACK CONTROL OF TETHERED SATELLITES USING LIAPUNOV STABILITY THEORY
S. R. VADALI (Texas A & M University, College Station) and E.-S. KIM IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 66-73. Research supported by the Texas Advanced Research and Technology Program. refs
(AIAA PAPER 90-1197) Copyright

This paper treats the three-dimensional aspects of tethered satellite deployment and retrieval. Feedback control laws with guaranteed closed loop stabilizability are obtained using the second method of Liapunov. Tether mass and aerodynamic effects are not included in the design of the control laws. First, a coordinate transformation is presented that partially uncouples the in-plane and out-of-plane dynamics. A combination of tension control as well as out-of-plane thrusting is shown to be adequate for a speedy retrieval. Next, a unified control design method based on an integral of motion (for the coupled system) is pesented. It is shown that the controller designed by the latter method is superior to that of the former primarily from the out-of-plane thrust usage point of view. A detailed analysis of stability of the closed loop system is presented and existence of limit cycles is ruled out if out-of-plane thrusting is used in conjunction with tension control. Finally a tether rate control law is also developed using the integral of motion mentioned above. The control laws developed in the paper can also be used for stationkeeping. Author

A90-26784#
INSIGHTS AND APPROXIMATIONS IN DYNAMIC ANALYSIS OF SPACECRAFT TETHERS
ANDREAS H. VON FLOTOW and NORMAN M. WERELEY (MIT, Cambridge, MA) IN: AIAA Dynamics Specialists Conference, Long Beach, CA, Apr. 5, 6, 1990, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 74-87. Research sponsored by USAF. refs
(AIAA PAPER 90-1198) Copyright

This paper presents a critical discussion of selected physical effects in the dynamics of spacecraft tethers. Nonlinear extensional stress-strain behavior of the tether is identified as an important effect. Spectral separation is invoked to decouple the motion into a slow libration akin to that of a rigid body upon which fast oscillations involving tether deformation and end body attitude motions are superimposed. The effect of a slight quasi-equilibrium tether curvature on this fast motion is illuminated via a linearized analysis. Eigenmotion, frequency response, and wave propagation behavior are investigated in the course of this linearized analysis. The paper closes with a discussion of the effects of slow tether deployment and retrieval and with an investigation into the possibility for a thruster-driven dynamic instability. Author

A90-26964*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
STUDIES OF THE LOWER THERMOSPHERE USING A TETHERED SATELLITE
MARSHA R. TORR (NASA, Marshall Space Flight Center, Huntsville, AL), D. G. TORR (Alabama, University, Huntsville), and T. GORDON (Science and Engineering Associates, Inc., Denver, CO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 22 p. refs
(AIAA PAPER 90-0532) Copyright

Investigation of a proposed facility and review of the Atmosphere Explorer C (AE-C) satellite experience is presented. In order to properly take advantage of plans to operate in the lower thermosphere, it is necessary to have some foreknowledge of the natural environment in this region, how vehicles interact with the natural environment, and how instruments must be designed and built to operate in this environment. Some of the fundamental questions to be addressed by such a mission are reviewed as well as the AE-C satellite experience. R.E.P.

A90-29698*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DOWNWARD-DEPLOYED TETHERED PLATFORMS FOR HIGH-ENTHALPY AEROTHERMODYNAMIC RESEARCH
GEORGE M. WOOD, PAUL M. SIEMERS (NASA, Langley Research Center, Hampton, VA), R. KENNETH SQUIRES, HENRY WOLF (Analytical Mechanics Associates, Hampton, VA), GIOVANNI M. CARLOMAGNO (Napoli, Universita, Naples, Italy) et al. Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Mar.-Apr. 1990, p. 216-221. Previously cited in issue 17, p. 958, Accession no. A88-22514. refs
Copyright

N90-13423*# McDonnell-Douglas Astronautics Co., Houston, TX. Engineering Services Div.
SHUTTLE RELATIVE NAVIGATION OF A TETHERED SATELLITE MISSION WITH CURRENT ON BOARD SOFTWARE
KEVIN A. LEE *In* NASA, Goddard Space Flight Center, Flight Mechanics/Estimation Theory Symposium, 1989 p 149-168 Oct. 1989
Avail: NTIS HC A20/MF A03 CSCL 22/1

A Shuttle mission planned in 1991 will test the feasibility of tethers in space. This mission, a joint effort between Italy and the United States, will connect a satellite (built by the Italians) to the Shuttle with a 20 km long tether. This mission poses unique navigation problems. The flight software on the Shuttle was never designed to account for the low level acceleration that is generated by the gravity gradient. IMUs on the Shuttle was never designed to account for the low level acceleration that is generated by the gravity gradient. Inertial Maneuvering Units on the shuttle will sense the acceleration of the tether but it turns out that incorporating the continuous accelerometer noise also generates large error growth. Relative navigation is another important issue since the majority of the mission will be conducted while the satellite is out of the visual range of the crew. Some kind of feedback on the motion of the satellite will be desirable. Feedback of the satellite motion can be generated by using the rendezvous radar. To process the radar measurements, the flight software uses a 13 state Kalman Filter, but unfortunately with the filter currently tuned as it is, valid measurements tend to be ignored. This is due to the constraint of the tether on the satellite, which is an unmodeled force. Analysis shows that with proper tuning, relative navigation is possible. Author

N90-13425*# McDonnell-Douglas Astronautics Co., Houston, TX. Guidance and Control Mechanics.
SHUTTLE TETHERED OPERATIONS: THE EFFECT ON ORBITAL TRAJECTORY AND INERTIAL NAVIGATION
MARK N. LARDAS *In* NASA, Goddard Space Flight Center, Flight Mechanics/Estimation Theory Symposium, 1989 p 181-199 Oct. 1989
Avail: NTIS HC A20/MF A03 CSCL 22/1

The first full scale test of a large tethered satellite system is planned. The Orbiter will be linked to a 500 kg payload by a 20 km tether, an action with a profound effect on the trajectory of the Orbiter. For the first time in the history of the Shuttle program, the vehicle will conduct prolonged operations with the center of

mass of the orbiting system a significant distance from the center of mass of the Space Shuttle Orbiter, a violation of the fundamental assumption made in both the Orbiter ground-based and onboard navigation software. Inertial navigation of tethered operations with the Shuttle is further complicated by the presence of non-conservative forces in the system: Reaction Control System (RCS) translational effects, atmospheric drag, and electro-magnetic dynamics. These can couple with the conservative tether dynamics effects, and degrade the navigation software performance. The primary effects are examined on the Orbiter's trajectory, coupling by conservative forces during tethered operations, and the impact of both on the ability to meet inertial navigation constraints. The impact of electrodynamics, different RCS control modes, commanded attitudes, and attitude deadbands are presented. Operational guidelines which optimize successful mission navigation, and necessary navigation constraints are discussed.
Author

N90-14265*# University of Central Florida, Orlando.
THE SPACE STATION TETHERED ELEVATOR SYSTEM
LOREN A. ANDERSON 15 May 1989 346 p
(Contract NASW-4435)
(NASA-CR-186051; NAS 1.26:186051) Avail: NTIS HC A15/MF A02 CSCL 22/2

The optimized conceptual engineering design of a space station tethered elevator is presented. The elevator is an unmanned mobile structure which operates on a ten kilometer tether spanning the distance between the Space Station and a tethered platform. Elevator capabilities include providing access to residual gravity levels, remote servicing, and transportation to any point along a tether. The potential uses, parameters, and evolution of the spacecraft design are discussed. Engineering development of the tethered elevator is the result of work conducted in the following areas: structural configurations; robotics, drive mechanisms; and power generation and transmission systems. The structural configuration of the elevator is presented. The structure supports, houses, and protects all systems on board the elevator. The implementation of robotics on board the elevator is discussed. Elevator robotics allow for the deployment, retrieval, and manipulation of tethered objects. Robotic manipulators also aid in hooking the elevator on a tether. Critical to the operation of the tethered elevator is the design of its drive mechanisms, which are discussed. Two drivers, located internal to the elevator, propel the vehicle along a tether. These modular components consist of endless toothed belts, shunt-wound motors, regenerative power braking, and computer controlled linear actuators. The designs of self-sufficient power generation and transmission systems are reviewed. Thorough research indicates all components of the elevator will operate under power provided by fuel cells. The fuel cell systems will power the vehicle at seven kilowatts continuously and twelve kilowatts maximally. A set of secondary fuel cells provides redundancy in the unlikely event of a primary system failure. Power storage exists in the form of Nickel-Hydrogen batteries capable of powering the elevator under maximum loads.
Author

N90-15988# Consiglio Nazionale delle Ricerche, Frascati (Italy). Ist. di Fisica dello Spazio Interplanetario.
RETE EXPERIMENT ACTIVITY AT THE TSS-1 POCC
U. GUIDONI May 1989 36 p
(IFSI-89-12; ETN-90-96174) Avail: NTIS HC A03/MF A01

The Tethered Satellite System (TSS) project, with the Payload Operation Control Center (POCC) support requirements for Research Electrical Tethered Effect (RETE) real time activity during the TSS-1 mission is reported. Data access, reduction and display requirements are covered for the RETE Electrical Ground Support Equipment (EGSE), and information on the ground support of the experiment is addressed. The RETE activity requires full accessibility of its own data. This implies the request to have RETE telemetry streeped from the incoming telemetry stream and routed to the experiment's EGSE. A set of monitors, where the main aspects of the mission are summarized in real time, are needed, for the scientific return of the mission. ESA

N90-15990# Technische Univ., Berlin (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.
A MODULAR HABITATION UNIT ADAPTED FOR SERVICE IN LOW EARTH AND GEOSTATIONARY EARTH ORBITS [SYSTEMENTWURF EINER MODULAREN WOHNANLAGE MIT VARIABLER SCHWERKRAFT FUER ERDUMLAUFBAHNEN UNTER BESONDERER BERUECKSICHTIGUNG BETRIEBLICHER ERFORDERNISSE]
JENS LASSMANN 20 Sep. 1988 93 p In GERMAN; ENGLISH summary
(ILR-MITT-217; ETN-90-95355) Avail: NTIS HC A05/MF A01

A possible concept for an extraterrestrial habitation unit is presented. It would provide an Earthlike environment and is designed to operate in orbit heights varying from 400 km (low earth orbit) to 36,000 km (geostationary earth orbit). Operational design aspects are described. Cost evaluations are presented.
ESA

N90-16849# Royal Aerospace Establishment, Farnborough (England). Space Dept.
ENVIRONMENTAL CONSTRAINTS FOR POLAR PLATFORM DESIGN
A. J. SIMS, P. R. TRUSCOTT, G. L. WRENN, and C. S. DYER Mar. 1989 28 p Presented at the 38th International Astronautical Federation Congress, Brighton, England, Oct. 1987
(RAE-TR-89014; BR111596; AD-A215300; ETN-90-96139)
Copyright Avail: NTIS HC A03/MF A01

Factors relevant to the polar platform are reviewed. Environment models and radiation transport codes are employed to assess primary and secondary particle fluxes, dose rates and energy loss spectra. Monitors which can improve the database, are described. The size increase of future polar platforms compared with current spacecraft shows the need for further investigation and modeling of the deleterious influences of charging and plasma wake phenomena. A need for further modeling of the environment and its effects in conjunction with environment measurements and both in-orbit and ground based characterization of key technologies is demonstrated.
ESA

N90-19249*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EARTH SCIENCE GEOSTATIONARY PLATFORM TECHNOLOGY
ROBERT L. WRIGHT, ed. and THOMAS G. CAMPBELL, ed. Washington Jul. 1989 386 p Workshop held in Hampton, VA, 21-22 Sep. 1988
(NASA-CP-3040; L-16612; NAS 1.55:3040) Avail: NTIS HC A17/MF A03 CSCL 22/2

The objective of the workshop was to address problems in science and in four technology areas (large space antenna technology, microwave sensor technology, electromagnetics-phased array adaptive systems technology, and optical metrology technology) related to Earth Science Geostationary Platform missions.

N90-19250*# National Oceanic and Atmospheric Administration, Washington, DC. Office of Systems Development.
OPERATIONAL REQUIREMENTS AND THE GEOSTATIONARY PLATFORM
JAMES K. SPARKMAN, JR. *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 29-33 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 22/2

For 22 years (from ATS-1 to GOES-H) a single technology has dominated imaging from geosynchronous altitudes. In 1990, with the scheduled launch of GOES-I, a major change will occur which will in turn open the way for the Geostationary Platform. The need for improved observations of severe storms has led NOAA to a decision to replace spinning geostationary spacecraft with a three-axis-stabilized type (non-spinning) vehicle already common among communications spacecraft and demonstrated by INSAT. Also, the current spin-scan imager with sounder channels

will be replaced by separate instruments capable of independent aiming. The advantages and challenges of the changes are discussed. Author

N90-19252*# Lockheed Missiles and Space Co., Sunnyvale, CA.
GEOSTATIONARY EARTH SCIENCE PLATFORM CONCEPTS
M. M. HERARDIAN *In* NASA, Langley Research Center, Earth Science Geostationary Platform Technology p 55-62 Jul. 1989
Avail: NTIS HC A17/MF A03 CSCL 22/2

The new concepts are presented for the Geostationary Earth Science Platform. Bus and payload arrangements, with instrument locations on the payload module and basic payload dimensions, are depicted and compared for each concept. The Titan 4 SRMU (with solid rocket motor upgrage) launch vehicle is described and compared to the standard Titan 4. The upgraded Titan 4 is capable of launching a 13,500 lb payload to GEO. The launch configuration showing each concept packaged within the 16 ft diameter payload envelope is presented. This presentation is represented by viewgraph only. Author

N90-19393*# South Carolina Univ., Columbia. Dept. of Mechanical Engineering.
KALMAN ESTIMATION FOR SEDS MEASUREMENTS
CONNIE K. CARRINGTON *In* Alabama Univ., Research Reports: 1989 NASA/ASEE Summer Faculty Fellowship Program 20 p Dec. 1989
(Contract NGT-01-008-021)
Avail: NTIS HC A99/MF E06 CSCL 22/2

The first on-orbit experiment of the Small Expendable Deployer System (SEDS) for tethered satellites will collect telemetry data for tethered length, rate of deployment, and tether tension. The post-flight analysis will use this data to reconstruct the deployment history and determine payload position and tether shape. Two Kalman estimator algorithms were written, and output using simulated measurement data was compared. Both estimators exhibited the same estimated state histories, indicating that numerical instability in the traditional algorithm was not the cause of filter divergence. Estimation of acceleration biases was added, which reduced the error but did not correct the divergence. An add-a-bead estimator that adds lumped masses as the tether is deployed was written, which provides a state model that matches the BEADSIM simulation providing the true measurements and states. This twenty-one bead estimator produced state histories similar to those of the two-bead estimator, indicating that the filter divergence was not caused by a reduced-order model. The noise models used to date are relatively simple and may be the source of estimator divergence. The investigation of colored noise models, cross-correlated measurement and process covariances, and noise-adaptive filter techniques is recommended. Author

N90-19423*# Alabama Univ., Tuscaloosa. Dept. of Engineering Mechanics.
A VECTORIZED ALGORITHM FOR 3D DYNAMICS OF A TETHERED SATELLITE
HOWARD B. WILSON *In* Alabama Univ., Research Reports: 1989 NASA/ASEE Summer Faculty Fellowship Program 30 p Dec. 1989
(Contract NGT-01-008-021)
Avail: NTIS HC A99/MF E06 CSCL 22/2

Equations of motion characterizing the three dimensional motion of a tethered satellite during the retrieval phase are studied. The mathematical model involves an arbitrary number of point masses connected by weightless cords. Motion occurs in a gravity gradient field. The formulation presented accounts for general functions describing support point motion, rate of tether retrieval, and arbitrary forces applied to the point masses. The matrix oriented program language MATLAB is used to produce an efficient vectorized formulation for computing natural frequencies and mode shapes for small oscillations about the static equilibrium configuration; and for integrating the nonlinear differential equations governing large amplitude motions. An example of time response pertaining to the skip rope effect is investigated. Author

21

TRANSPORTATION NODE

Use of the space station as a node for the launching, assembly or support of lunar or other exploratory missions.

A90-13571*# National Aeronautics and Space Administration, Washington, DC.
A SMALLER SCALE MANNED MARS EVOLUTIONARY PROGRAM
IVAN BEKEY (NASA, Office of Exploration, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 7 p.
(IAF PAPER 89-494) Copyright

This paper describes a concept for a manned Mars mission in which the parameters and trajectories are chosen to minimize the initial mass in earth orbit. The concept permits ready evolution from an initial modes step to full Mars surface operations. It uses a new heavy lift launch vehicle concept, the Shuttle Z. C.D.

A90-13572*# National Aeronautics and Space Administration, Washington, DC.
BUILDING A PATHWAY TO THE PLANETS - EXPANDING THE FRONTIERS OF HUMAN EXPLORATION
DOUGLAS A. O'HANDLEY (NASA, Washington, DC) IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989. 6 p.
(IAF PAPER 89-495) Copyright

The basic mission options, transportation, robotic precursors, technology, and human factors involved in the advance into interplanetary exploration and establishment of bases on the moon, planets, and planetary satellites are discussed. Case studies that have been undertaken for four candidate missions are briefly addressed. The role of international cooperation and the selection criteria pertaining to such missions are addressed. C.D.

A90-16526* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE CASE FOR MARS III: STRATEGIES FOR EXPLORATION - TECHNICAL
CAROL R. STOKER, ED. (NASA, Ames Research Center, Moffett Field, CA) San Diego, CA, Univelt, Inc. (Science and Technology Series. Volume 75), 1989, 645 p. For individual items see A90-16527 to A90-16570.
Copyright

Papers on issues related to Mars exploration are presented, covering topics such as the social implications of manned missions to Mars, mission strategies, mission designs, the economics of a Mars mission, Space Station support for a Mars mission, a Diagnostic and Environmental Monitoring System, and a zero-g CELSS/recreation facility for an earth/Mars crew shuttle. Other topics include biomedical concerns and fitness in spaceflight, spaceflight environment habitability, the Mars Rover/Sample Return Mission, a rooitic Mars surface sampler, a Mars Orbiter, and scientific goals of Mars exploration. Additional topics include Space Station evolution, mission options, modeling advanced space systems, computer support for Mars missions, launch system options, advanced propulsion techniques, the utilization of resources on Mars, the development of a Martian base, and options for mobility on Mars. R.B.

A90-16547* National Aeronautics and Space Administration, Washington, DC.
MARS MISSION EFFECTS ON SPACE STATION EVOLUTION
BARBARA S. ASKINS and STEPHEN G. COOK (NASA, Washington, DC) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 285-292.
(AAS PAPER 87-248) Copyright

The permanently manned Space Station scheduled to be operational in low earth by the mid 1990's, will provide

accommodations for science, applications, technology, and commercial users, and will develop enabling capabilities for future missions. A major aspect of the baseline Space Station design is that provisions for evolution to greater capabilities are included in the systems and subsystems designs. User requirements are the basis for conceptual evolution modes or infrastructure to support the paths. Four such modes are discussed in support of a Human to Mars mission, along with some of the near term actions protecting the future of supporting Mars missions on the Space Station. The evolution modes include crew and payload transfer, storage, checkout, assembly, maintenance, repair, and fueling. C.E.

A90-16548
MARS MISSION AND PROGRAM ANALYSIS
EDWARD E. MONTGOMERY and JAMES C. PEARSON, JR. (Spectra Research Systems, Inc., Huntsville, AL) IN: The case for Mars III: Strategies for exploration - Technical. San Diego, CA, Univelt, Inc., 1989, p. 293-309. refs
(AAS PAPER 87-249) Copyright

The total initial mass required in the Space station orbit is estimated for several different operational scenarios culminating in the retrieval of Mars Space Vehicle stages to the space station for refurbishment and reuse. Interplanetary and planetary velocity change requirements are calculated for a 2003 high thrust conjuction class direct stopover mission to Mars and subsequently employed in mass fraction equations to estimate mass of the Mars vehicle and OTVs. The implications on ETO vehicle payload capacity and launch rate are also presented parametrically. Evaluations include the effects of aerobraking, propellant boiloff, and recovery trajectory. Author

A90-16651* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE CASE FOR MARS III: STRATEGIES FOR EXPLORATION - GENERAL INTEREST AND OVERVIEW
CAROL R. STOKER, ED. (NASA, Ames Research Center, Moffett Field, CA) San Diego, CA, Univelt, Inc. (Science and Technology Series. Volume 74), 1989, 743 p. For individual items see A90-16652 to A90-16690.
Copyright

Papers on the possibilities for manned Mars missions are presented, covering topics such as space policy, space education and Mars exploration, economic issues, international cooperation, life support, biomedical factors, human factors, the Mars Rover Sample Return Mission, and possible unmanned precursor missions to Mars. Other topics include the scientific objectives for human exploration of Mars, mission strategies, possible transportation systems for manned Mars flight, advanced propulsion techniques, and the utilization of Mars resources. Additional subjects include the construction and maintenance of a Martian base, possible systems for mobility on the Martian surface, space power systems, and the use of the Space Station for a Mars mission. R.B.

A90-16671* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
EARTH ORBITAL PREPARATION FOR MARS EXPEDITIONS
ROBERT L. STAEHLE (JPL, Pasadena; World Space Foundation, South Pasadena, CA) IN: The case for Mars III: Strategies for exploration - General interest and overview. San Diego, CA, Univelt, Inc., 1989, p. 373-396. refs
(AAS PAPER 87-205) Copyright

Consideration is given to the facilities in earth orbit that would be required to prepare for a manned mission to Mars. It is suggested that the facilities required for the development of technology for a Mars mission include the Space Station, a variable gravity research station, and an assembly dock, in addition to ground facilities. The types of research that would be conducted at each of these facilities are examined. R.B.

A90-16674* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
HEAVY LIFT VEHICLES FOR TRANSPORTATION TO A LOW EARTH ORBIT SPACE STATION FOR ASSEMBLY OF A HUMAN TO MARS MISSION
FRANK E. SWALLEY (NASA, Marshall Space Flight Center, Huntsville, AL) IN: The case for Mars III: Strategies for exploration - General interest and overview. San Diego, CA, Univelt, Inc., 1989, p. 421-431. refs
(AAS PAPER 87-208) Copyright

Heavy lift vehicle configurations are proposed which will meet the requirements for transporting the elements of a Human to Mars Mission to a low earth orbit Space Station for assembly. Both near term derivative type vehiles as well as advanced technology vehicles are considered. The capability of these vehicles to accommodate the precursor missions are also examined. The implications on launch vehicle payload accommodation design and orbital operations are discussed. Author

A90-16687
MARS GLOBAL EXPLORATION VEHICLE
J. MARK MCCANN, MARK J. SNAUFER, and ROBERT J. SVENSON IN: The case for Mars III: Strategies for exploration - General interest and overview. San Diego, CA, Univelt, Inc., 1989, p. 647-663. refs
(AAS PAPER 87-222) Copyright

Any establishment of a permanent base on Mars will require a transportation system to facilitate the logistical support of the base and the scientific exploration of the planet. The design of such a system of transportation wil require innovative approaches to powering the vehicles and providing life support. Power, life support, and vehicle components are analyzed and a possible vehicle configuration proposed. Emphasis is placed on design criteria and physical data needed to fulfill the global requirements of such a system. Author

A90-16688* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
POWER CONSIDERATIONS FOR AN EARLY MANNED MARS MISSION UTILIZING THE SPACE STATION
MARTIN E. VALGORA (NASA, Lewis Research Center, Cleveland, OH) IN: The case for Mars III: Strategies for exploration - General interest and overview. San Diego, CA, Univelt, Inc., 1989, p. 667-679.
(AAS PAPER 87-223) Copyright

Power requirements and candidate electrical power sources were examined for the supporting space infrastructure for an early (2004) manned Mars mission. This two-year mission (60-day stay time) assumed a single six crew piloted vehicle with a Mars lander for four of the crew. The transportation vehicle was assumed to be a hydrogen/oxygen propulsion design with or without large aerobrakes and assembled and checked out on the LEO Space Station. The long transit time necessitated artificial gravity of the crew by rotating the crew compartments. This rotation complicates power source selection. Candidate power sources were examined for the Lander, Mars Orbiter, supporting Space Station, co-orbiting Propellant Storage Depot, and, alternatively, a co-orbiting Propellant Generation (water electrolysis) Depot. Candidates considered were photovoltaics with regenerative fuel cells or batteries, solar dynamics, isotope dynamics, and nuclear power. Author

A90-20002*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DYNAMIC CHARACTERISTICS OF A SPACE STATION FREEDOM MARS EVOLUTION REFERENCE CONFIGURATION
J. KIRK AYERS, TAE W. LIM (Lockheed Engineering and Sciences Co., Hampton, VA), and PAUL A. COOPER (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p.
(AIAA PAPER 90-0746) Copyright

One concept for a manned mission to Mars uses as a transportation mode an evolutionary version of Space Station Freedom (SSF), termed the Mars Evolution Reference Configuration

(MERC). The MERC is configured by adding to SSF dual keels, an upper and lower boom, additional laboratory and habitation modules, increased power, and an assembly platform. A finite-element model of the MERC was formulated to investigate the expected low frequency modes, and its variations with the addition of large payload. A basic reboost procedure using near-continuous firing of reaction control system jets is described with the closed-loop attitude control system. The elastic dynamic behavior at critical points during a reboost of the MERC, both with and without the Mars piloted vehicle installed, is examined. I.S.

A90-21727*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE ROLE OF THE SPACE STATION IN THE FURTHER EXPLORATION OF SPACE [DE ROL VAN HET RUIMTESTATION BIJ DE VERDERE EXPLORATIE VAN HET HEELAL]
S. L. BONTING (NASA, Ames Research Center, Moffett Field, CA) Ruimtevaart, vol. 38, Oct. 1989, p. 13-23. In Dutch.

Plans for space-science experiments on the International Space Station (ISS) are reviewed, with a focus on biological and medical research with implications for manned missions to the moon and planets (in a scenario culminating in the establishment of a space colony by about the year 2018). Both applied biomedical research (determining the limits of human endurance in space and developing CELSS technology to extend them) and basic research (on the physiological response of plants and animals to the space environment) are discussed, and particular attention is given to the design and deployment schedule for the ISS biomedical hardware modules (Life Sciences Module, Centrifuge Module, and Variable-Gravity Research Facility). Also included are diagrams; drawings; photographs; and tables listing the individual experiments, their objectives, and the hardware required. T.K.

A90-23923
ESTABLISHING A LUNAR OUTPOST. I
Aerospace Engineering (ISSN 0736-2536), vol. 10, Feb. 1990, p. 27-30.
Copyright

The possibility of establishing a lunar base to learn to live, work, and explore on another planetary surface is being studied. Topological and cartographic data along with sample collections must be studied to assure the proper location and design of the outpost. All of the spacecraft, propellant, cargo, and personnel for the moon will be launched from earth to an orbiting transportation node (TN). Three possible TN configurations have been designed taking into account both internal and external factors. The transportation system elements such as the orbital transfer vehicle (OTV), aerobrake, and landing craft will be assembled at the transportation node in low earth orbit. After loading, the OTV leaves the transportation node and travels to the moon. Once in lunar orbit, the OTV and landing craft separate. On the OTV's return trip, it skims through the earth's atmosphere and begins a rendezvous sequence which eventually returns it to the transportation node. Concepts for safe transportation and site selection which are necessary prior to establishing a lunar outpost are presented. R.E.P.

A90-25182
PRODUCTION POSSIBILITY FRONTIERS FOR A CIS-LUNAR TRANSPORTATION SYSTEM
KENT L. MILLER (International Management Institute, Geneva, Switzerland) Acta Astronautica (ISSN 0094-5765), vol. 19, Dec. 1989, p. 969-972.
Copyright

A cis-lunar transportation system (CLTS) can be designed to provide combinations of two services: lunar export import. The set of all such combinations is called the production possibility frontier (PPF), which in turn is a familiar concept from micro-economics. The CLTS envisioned operates flights between space stations in low earth orbit (LEO) and low lunar orbit (LLO), and flights between LLO and lunar base (LB). A system of 28 equations is presented which models the interactions between structure, payload and propellants in the CLTS. The traffic ratio of LB-LLO-LB flights to LEO-LLO-LEO flights is determined to be a key parameter for achieving high lunar export/import ratios. It is also shown that the CLTS can achieve a significant net mass gain in LEO, thus creating the possibility of lunar exports generating revenues for the colony by competing on price in LEO with terrestrial exports. Author

A90-27401* National Aeronautics and Space Administration, Washington, DC.
HUMAN PATHWAY TO THE SOLAR SYSTEM IN THE 21ST CENTURY
DOUGLAS A. O'HANDLEY (NASA, Office of Exploration, Washington, DC) SAE, Intersociety Conference on Environmental Systems, 19th, San Diego, CA, July 24-26, 1989. 8 p.
(SAE PAPER 891430) Copyright

Some proposed space exploration missions are examined. Consideration is given to requirements for human expeditions to Phobos and Mars and for establishing a lunar observatory and a permanent, self-sufficient facility on Mars. Earth-to-orbit transportation, propellant management, extraterrestrial construction and operations, life support technology, space transfer systems, and automation and robotics are examined in terms of proposed missions. I.F.

N90-15029*# Colorado Univ., Boulder.
CIS-LUNAR SPACE INFRASTRUCTURE LUNAR TECHNOLOGIES: EXECUTIVE SUMMARY Final Report
W. FALLER, A. HOEHN, S. JOHNSON, P. MOOS, and N. WILTBERGER 1989 135 p
(Contract NASW-4435)
(NASA-CR-186220; NAS 1.26:186220) Avail: NTIS HC A07/MF A01 CSCL 13/2

Technologies necessary for the creation of a cis-Lunar infrastructure, namely: (1) automation and robotics; (2) life support systems; (3) fluid management; (4) propulsion; and (5) rotating technologies, are explored. The technological focal point is on the development of automated and robotic systems for the implementation of a Lunar Oasis produced by Automation and Robotics (LOAR). Under direction from the NASA Office of Exploration, automation and robotics were extensively utilized as an initiating stage in the return to the Moon. A pair of autonomous rovers, modular in design and built from interchangeable and specialized components, is proposed. Utilizing a buddy system, these rovers will be able to support each other and to enhance their individual capabilities. One rover primarily explores and maps while the second rover tests the feasibility of various materials-processing techniques. The automated missions emphasize availability and potential uses of Lunar resources, and the deployment and operations of the LOAR program. An experimental bio-volume is put into place as the precursor to a Lunar environmentally controlled life support system. The bio-volume will determine the reproduction, growth and production characteristics of various life forms housed on the Lunar surface. Physicochemical regenerative technologies and stored resources will be used to buffer biological disturbances of the bio-volume environment. The in situ Lunar resources will be both tested and used within this bio-volume. Second phase development on the Lunar surface calls for manned operations. Repairs and re-configuration of the initial framework will ensue. An autonomously-initiated manned Lunar oasis can become an essential component of the United States space program. Author

N90-18350*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TECHNOLOGY DEVELOPMENT, DEMONSTRATION, AND ORBITAL SUPPORT REQUIREMENTS FOR MANNED LUNAR AND MARS MISSIONS
CHARLES P. LLEWELLYN (Analytical Mechanics Associates, Inc., Hampton, VA.) and KAREN D. BRENDER Feb. 1990 13 p Proposed for presentation at the Space 90 Conference,

Albuquerque, NM, 23-26 Apr. 1990
(NASA-TM-101666; NAS 1.15:101666) Avail: NTIS HC A03/MF A01 CSCL 03/2

An overview of the critical technology needs and the Space Station Freedom (SSF) focused support requirements for the Office of Exploration's (OEXP) manned lunar and Mars missions is presented. Major emphasis is directed at the technology needs associated with the low earth orbit (LEO) transportation node assembly and vehicle processing functions required by the lunar and Mars mission flight elements. The key technology areas identified as crucial to support the LEO node function include in-space assembly and construction, in-space vehicle processing and refurbishment, space storable cryogenics, and autonomous rendezvous and docking. Author

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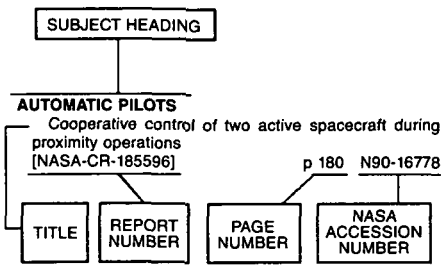

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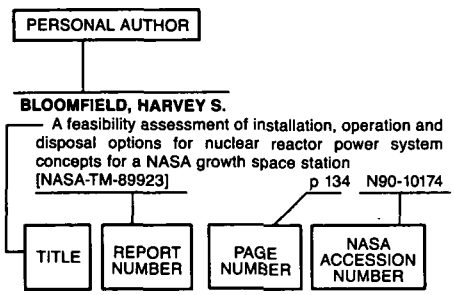

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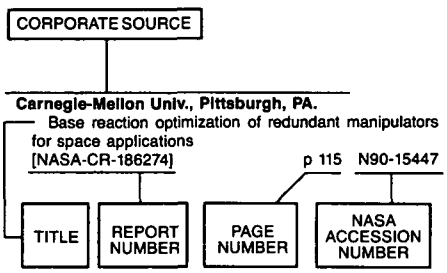

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LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA / *A Bibliography (Supplement 01)*

NOVEMBER 1990

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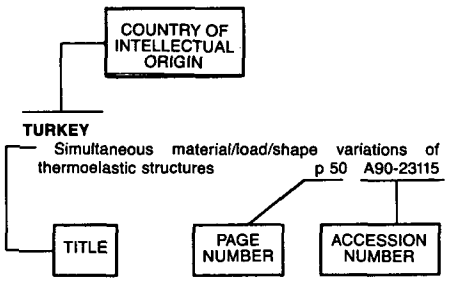

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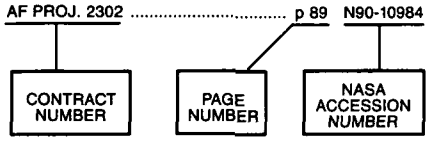

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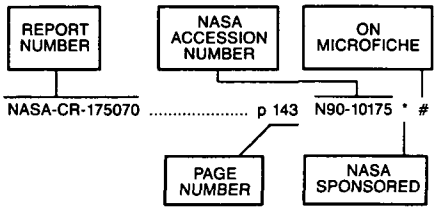

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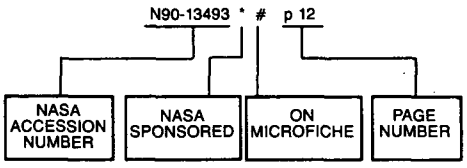

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