Technology for Large Space Systems

A Bibliography
with Indexes

NASA SP-7046(21)
September 1989

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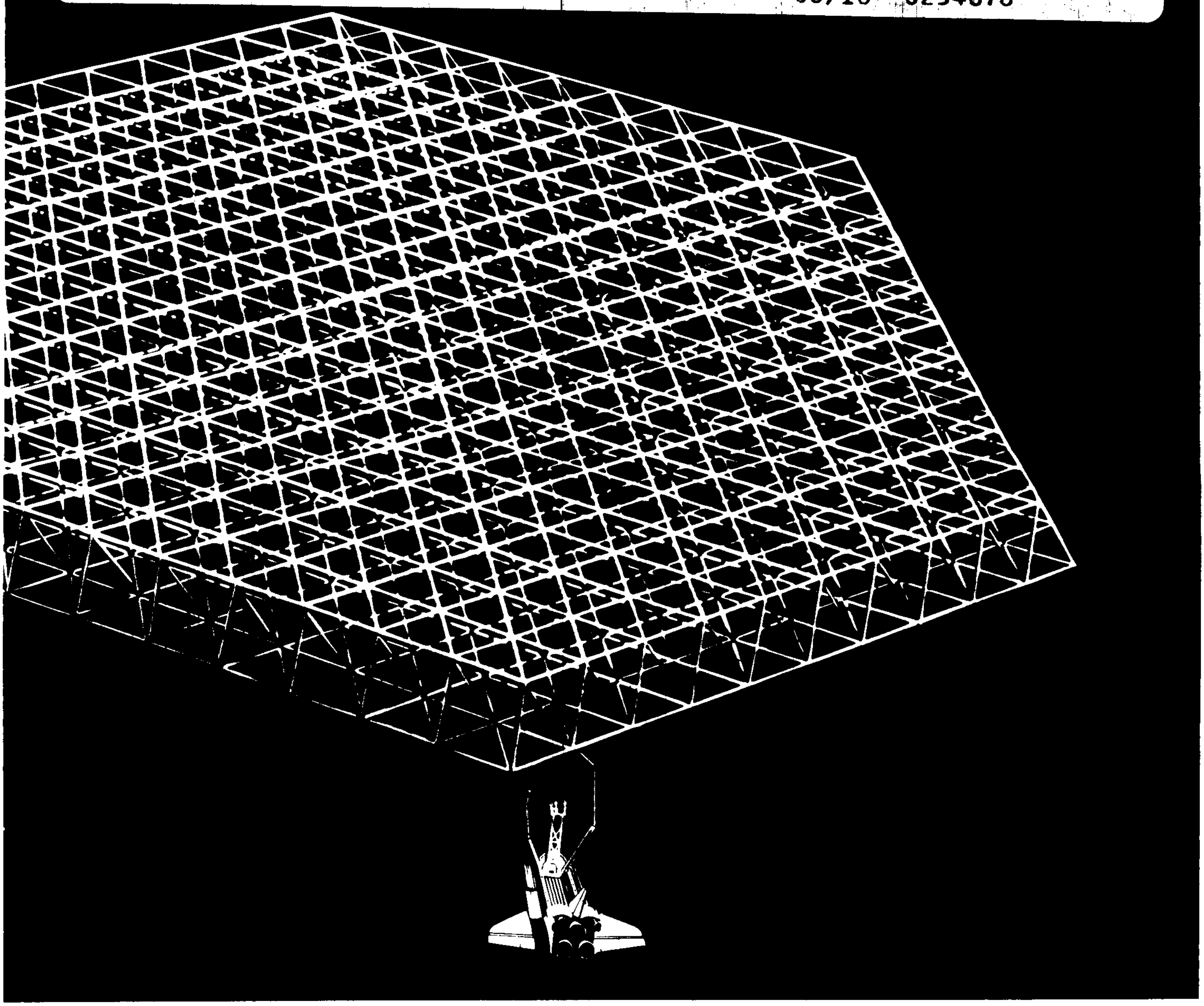

NASA SP-7046(21)

TECHNOLOGY FOR LARGE SPACE SYSTEMS

A BIBLIOGRAPHY WITH INDEXES

Supplement 21

Compiled by
Technical Library Branch
and
Edited by
Space Systems Division
NASA Langley Research Center
Hampton, Virginia

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system between January 1 and June 30, 1989 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*

National Aeronautics and Space Administration
Office of Management
Scientific and Technical Information Division
Washington, DC 1989

NOTE TO AUTHORS OF PROSPECTIVE ENTRIES:

The compilation of this bibliography results from a complete search of the *STAR* and *IAA* files. Many times a report or article is not identified because either the title, abstract, or key words did not contain appropriate words for the search. A number of words are used, but to best insure that your work is included in the bibliography, use the words *Large Space Structures* somewhere in your title or abstract, or include them as a key word.

This supplement is available from the National Technical Information Service (NTIS), Springfield , Virginia 22161 at the price code A09.

INTRODUCTION

This bibliography is designed to be helpful to the researcher and manager engaged in the developing technology within the discipline areas of the Large Space Systems Technology (LSST). Also, the designers of large space systems for approved missions (in the future) will utilize the technology described in the documents referenced herein.

This literature survey lists 745 reports, articles and other documents announced between January 1, 1989 and June 30, 1989 in *Scientific and Technical Aerospace Reports (STAR)*, and *International Aerospace Abstracts (IAA)*.

The coverage includes documents that define specific missions that will require large space structures to achieve their objectives. The methods of integrating advanced technology into system configurations and ascertaining the resulting capabilities is also addressed.

A wide range of structural concepts are identified. These include erectable structures which are earth fabricated and space assembled, deployable antennas which are fabricated, assembled, and packaged on Earth with automatic deployment in space, and space fabricated structures which use pre-processed materials to build the structure in orbit.

The supportive technology that is necessary for full utilization of these concepts is also included. These technologies are identified as analysis and design techniques, structural and thermal analysis, structural dynamics and control, electronics, advanced materials, assembly concepts, and propulsion.

A separate companion document "Space Station Systems Bibliography" (NASA SP-7056) incorporates space station technology not applicable to large space systems. Space station systems technology that is also applicable to large space systems may be documented in both bibliographies.

Robert L. Wright, *Space Systems Division*
John Ferrainolo, *Technical Library Branch*

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TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED
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ACCESSION NUMBER → **N89-15970*#** National Aeronautics and Space Administration. ← CORPORATE SOURCE
Langley Research Center, Hampton, VA.
TITLE → **A COMPARISON OF TWO TRUSSES FOR THE SPACE STATION STRUCTURE**
AUTHORS → THOMAS R. SUTTER and HAROLD G. BUSH Washington, DC
PUBLICATION DATE → Mar. 1989 23 p
REPORT NUMBERS → (NASA-TM-4093; L-16540; NAS 1.15:4093) Avail: NTIS HC ← AVAILABILITY SOURCE
PRICE CODE → A03/MF A01 CSCL 22/2 ← COSATI CODE

The structural performance of two truss configurations, the orthogonal tetrahedral and a Warren-type, are compared using finite element models representing the November Reference Phase 1 Space Station. The truss torsional stiffness properties and fundamental torsion frequency are determined using cantilever truss-beam models. Frequencies, mode shapes, transient response, and truss strut compressive loads are compared for the two space station models. The performance benefit resulting from using a high modulus truss strut is also presented. Finally, assembly and logistics characteristics of the two truss configurations are evaluated. Author

TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

NASA SPONSORED

ACCESSION NUMBER → **A89-16709*** Ohio State Univ., Columbus.
TITLE → **MODEL REFERENCE, SLIDING MODE ADAPTIVE CONTROL FOR FLEXIBLE STRUCTURES**
AUTHORS → S. YURKOVICH, U. OZGUNER, and F. AL-ABBASS (Ohio State University, Columbus) ← AUTHORS' AFFILIATION
Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 36, July-Sept. 1988, p. 285-310. refs ← JOURNAL TITLE
CONTRACT NUMBER → (Contract NASA ORDER L-91188-B) ← JOURNAL DATE

A decentralized model reference adaptive approach using a variable-structure sliding model control has been developed for the vibration suppression of large flexible structures. Local models are derived based upon the desired damping and response time in a model-following scheme, and variable structure controllers are then designed which employ colocated angular rate and position feedback. Numerical simulations have been performed using NASA's flexible grid experimental apparatus. R.R.

TECHNOLOGY FOR LARGE SPACE SYSTEMS

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SEPTEMBER 1989

01

SYSTEMS

Includes mission and program concepts and requirements, focus missions, conceptual studies, technology planning, systems analysis and integration, and flight experiments.

A89-10486

SPACE-FLIGHT PERSPECTIVES - GUIDING PRINCIPLES FOR TECHNOLOGICAL RESEARCH AND DEVELOPMENT [PERSPEKTIVEN DER RAUMFAHRT - LEITKONZEPTE FUER TECHNOLOGISCHE FORSCHUNG UND ENTWICKLUNG]

D. E. KOELLE (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 11-14. In German.
(DGLR PAPER 87-071)

The fundamental goals laid out in the FRG Planning Framework for High Technology and Space Flight (OHR) are examined and illustrated with block diagrams and drawings of proposed spacecraft. The need for long-term planning and coordination on a national level is stressed, and particular attention is given to orbital systems and infrastructure (participation in the International Space Station, polar and GEO platforms, and lunar stations) and space transportation systems (heavy cargo vehicle, hypersonic transport, manned launch vehicle, OTV concepts, and lunar lander). T.K.

A89-10489

STRUCTURES, MATERIALS, AND CONSTRUCTION TECHNIQUES FOR FUTURE TRANSPORT AND ORBITAL SYSTEMS [STRUKTUREN, WERKSTOFFE UND BAUWEISEN FUER ZUKUENFTIGE TRANSPORT- UND ORBITALSYSTEME]

H. LUDWIG (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 32-37. In German.
(DGLR PAPER 87-076)

The findings of the FRG Planning Framework for High Technology and Space Flight (OHR) with regard to advanced materials and structures are summarized in a series of outlines, tables, diagrams, and drawings and briefly discussed. For space transportation systems, the major requirements are structural materials capable of withstanding extremely high temperatures (1400 C without thermal protection and 2000 C with a protective layer), passive and active thermal protection systems, modeling studies of aerothermoelastic and dynamic behavior, advanced CFRP and fiber-reinforced ceramic materials for engines, and improved structural test facilities. For orbital systems, long-term studies of temperature and radiation effects, improved assembly and deployment methods, and meteorite protection systems are required. T.K.

A89-11823* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

U.S. SPACE STATION PLATFORM - CONFIGURATION TECHNOLOGY FOR CUSTOMER SERVICING

JOSEPH A. DEZIO and BARBARA A. WALTON (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 152-157.

Features of the Space Station coorbiting and polar orbiting platforms (COP and POP, respectively) are described that will allow them to be configured optimally to meet mission requirements and to be assembled, serviced, and modified on-orbit. Both of these platforms were designed to permit servicing at the Shuttle using the remote manipulator system with teleoperated end effectors; EVA was planned as a backup and for unplanned payload failure modes. Station-based servicing is discussed as well as expendable launch vehicle-based servicing concepts. K.K.

A89-12696* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

ADVANCED TECHNOLOGY SPACE STATION STUDIES AT LANGLEY RESEARCH CENTER

MELVIN J. FEREBEE, JR. (NASA, Langley Research Center, Hampton, VA) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 1325-1344. refs
(AAS PAPER 87-525)

The paper describes the Advanced Technology Space Station systems studies at Langley Research Center, which were initiated to identify the technologies required for the construction of a high-performance station in the first quarter of the 21st century. Technologies which would maximize the synergistic effects between the subsystems and structural configurations were selected. The ECLSS and propulsion systems show promising synergistic relationships in the areas of oxygen and hydrogen production and attitude control. K.K.

A89-13700

SPACE RESEARCH AND POLICY IN THE UPCOMING DECADES [LA RECHERCHE ET LA POLITIQUE SPATIALE DANS LES PROCHAINES DECENNIES]

Academie des Sciences (Paris), Comptes Rendus, Serie Generale, La Vie des Sciences (ISSN 0762-0969), vol. 5, no. 2, Mar.-Apr. 1988, p. 111-151. In French.

Developments projected for the upcoming decades in space research and technology are reviewed in order to examine the advantages and problems of manned space flight, unmmanned spacecraft, and man-tended platforms. Developments in the French space program including Ariane V, Hermes, and Columbus are considered. It is shown that the majority of projected space programs (including astronomical, geophysical, meteorological, and earth-observing satellites) are hindered by the presence of man. Man's presence may be useful for microgravity and biology experiments in space, and manned flights are essential for programs such as space medicine, the construction of large structures in space, and the collection of planetary samples. The importance of robotics and expert systems in future space activities is emphasized, and recommendations for the future are proposed. R.R.

A89-14966

ARTIFICIAL GRAVITY NEEDED FOR MISSION TO MARS?

Aerospace Engineering (ISSN 0736-2536), vol. 8, Oct. 1988, p. 10-13.

The possibility of providing artificial gravity for a mission to Mars is discussed. The requirements for constructing a Variable Gravity Research Facility are examined. Various approaches to artificial gravity are considered, including intermittent artificial gravity, spinning the spacecraft about its center, and dividing the spacecraft into separable modules connected by a thin structure which would carry the spin-induced mechanical loads. R.B.

A89-15150#

TETHERS - A KEY TECHNOLOGY FOR FUTURE SPACE FLIGHT? [TETHERS - EEN SLEUTELTECHNOLOGIE IN DE RUIMTEVAART VAN MORGEN?]

M. P. M. VAN ROOZENDAAL (Centrale Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek, Instituut voor Produktonwikkeling TNO, Netherlands) Ruimtevaart, vol. 37, Aug. 1988, p. 16-24. In Dutch.

The current development status of tethered spacecraft is surveyed, with an emphasis on projects related to the International Space Station. The history of tether concepts is briefly recalled, and consideration is given to the use of tethers to release payloads for reentry or orbital transport, power generation with electrodynamic tethers, tether-spacecraft dynamics, the selection of high-strength lightweight materials for the tether itself, and the planned scientific missions of the Shuttle-deployable TSS-1 and TSS-2 tethered ionosphere probes. In the Space Station context, it is estimated that the use of tethers to release the Space Shuttle and waste containers for reentry and to release OTVs for flight to higher altitudes could yield savings of up to 89,000 kg of fuel per year (for a cost savings of $1.1-2.1 billion over an 11-year period). T.K.

A89-16541#

SPACE STATION - DESIGNING FOR OPERATIONS AND SUPPORT

JAMES T. KAIDY, WILLIAM G. BASTEDO, JR. (Booz, Allen and Hamilton, Inc., Bethesda, MD), and THOMAS M. CRABB Aerospace America (ISSN 0740-722X), vol. 26, Nov. 1988, p. 18-20.

Design priorities resulting in such characteristics as modularity, orbital servicing and maintenance, standardized elements, and streamlined procedures, are being brought to bear on the definition of the NASA Space Station. Attention is presently given to the consequence of these design concerns for the multivariable optimization problem posed by the Space Station's on-orbit assembly sequence; the Station's hardware design requirements are driven by the assembly sequence defined. O.C.

A89-17633#

TELESCIENCE AND MICROGRAVITY - IMPACT ON FUTURE FACILITIES, GROUND SEGMENTS AND OPERATIONS

R. MONTI (Napoli, Universita, Naples, Italy) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 17 p.

(IAF PAPER 88-015)

The use of telescience as the preparatory phase for the future exploitation of microgravity by means of expert systems is reviewed. Ground segment structure, user support centers organization, and test bedding activities are discussed. Special attention is given to the role of the ground based primary investigator in conducting microgravity experiments on permanent space platforms. The use of telescience in the Columbus project is considered. R.B.

A89-17641*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

TECHNOLOGY REQUIREMENTS FOR AN ORBITING FUEL DEPOT - A NECESSARY ELEMENT OF A SPACE INFRASTRUCTURE

R. M. STUBBS, R. R. CORBAN (NASA, Lewis Research Center, Cleveland, OH), and A. J. WILLOUGHBY (Analex Corp., Cleveland, OH) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. Previously announced in STAR as N88-29845. refs

(IAF PAPER 88-035)

Advanced planning within NASA has identified several bold space exploration initiatives. The successful implementation of these missions will require a supporting space infrastructure which would include a fuel depot, an orbiting facility to store, transfer and process large quantities of cryogenic fluids. In order to adequately plan the technology development programs required to enable the construction and operation of a fuel depot, a multidisciplinary workshop was convened to assess critical technologies and their state of maturity. Since technology requirements depend strongly on the depot design assumptions, several depot concepts are presented with their effect of criticality ratings. Over 70 depot-related technology areas are addressed. Author

A89-17648#

A FLIGHT EXPERIMENT OF FLEXIBLE SPACECRAFT ATTITUDE CONTROL

T. KIDA, I. YAMAGUCHI, Y. OHKAMI (National Aerospace Laboratory, Chofu, Japan), S. ICHIKAWA, and Y. KAWADA (National Space Development Agency of Japan, Tokyo) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p.

(IAF PAPER 88-044)

Plans for a flight experiment of the flexible spacecraft Engineering Test Satellite VI (ETS-IV) are outlined. The ETS-IV is expected to be launched in 1992. The flight experiment is planned to demonstrate the capabilities of the attitude and flexible vibration control and the indentification algorithm of a class of spacecraft with flexible appendages. It is suggested that the results could serve as a base-line of a class of future large space structures modeling and controlling technology. R.B.

A89-17651#

INFLATABLE, SPACE-RIGIDIZED ANTENNA REFLECTORS - FLIGHT EXPERIMENT DEFINITION

M. C. BERNASCONI (Contraves AG, Zurich, Switzerland) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p. refs

(Contract ESA-6244/85/NL/PB)

(IAF PAPER 88-049)

Large structures are of growing importance for space operations. In the near-term advanced expandable structures will see an increased use. The technology of inflatable, chemically-rigidized structures (ISRS) has been studied to enable realization of such large expandables. After a review of the development approach, the concept of a technological flight experiment is introduced and its rationale discussed. The paper presents the experiment philosophy, its concept, instrumentation and initial design. The expected behavior of the experimental object is summarized, to review its impact on the instrumentation. Author

A89-17653*# NASA Space Station Program Office, Reston, VA.

SPACE STATION FREEDOM - TECHNICAL AND MANAGEMENT CHALLENGES

THOMAS L. MOSER (NASA, Space Station Freedom Program Office, Reston, VA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs

(IAF PAPER 88-053)

The development of the Space Station is reviewed, focusing on the technical and managerial aspects of the program. The optimization of the Space Station configuration, utilization impacts on design, technical aspects of the distribution systems, and the problems of designing for a lifetime of 30 years or more are discussed. In addition, cost reduction studies, testing and verification, determining the assembly sequence, and operational communications and support systems are examined. Managerial aspects of the program include organization, program control, management tools and processes, and the integration of elements from the international partners. R.B.

A89-17669*# NASA Space Station Program Office, Reston, VA.
INTERNATIONAL INTERFACE DESIGN FOR SPACE STATION FREEDOM - CHALLENGES AND SOLUTIONS
RICHARD E. MAYO (NASA, Reston, VA), GORDON R. BOLTON, and DANIELE LAURINI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 13 p.
(IAF PAPER 88-085)
The definition of interfaces for the International Space Station is discussed, with a focus on negotiations between NASA and ESA. The program organization and division of responsibilities for the Space Station are outlined; the basic features of physical and functional interfaces are described; and particular attention is given to the interface management and documentation procedures, architectural control elements, interface implementation and verification, and examples of Columbus interface solutions (including mechanical, ECLSS, thermal-control, electrical, data-management, standardized user, and software interfaces). Diagrams, drawings, graphs, and tables listing interface types are provided. T.K.

A89-17677#
ZERO-GRAVITY MASSMETER FOR ASTRONAUTS AND SPACE STATION EXPERIMENTS
JEROME PEARSON (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p.
(IAF PAPER 88-100)
A new device is described for measuring the mass of weightless objects in space vehicles, based on new techniques. The zero-gravity massmeter measures the mass of an unknown object by measuring the change in center of mass between the object and a connected known mass. The new device has advantages over past techniques that depended on the frequency of an unknown mass on a spring. The device can be used over a large range of unknown masses, making it applicable to measuring bone loss in astronauts and the mass of small specimens such as crystal growth experiments. This zero-gravity massmeter technique can also be applied to measure the mass of fuel tanks and other objects tethered to a Space Station, as well as the mass of the station itself. Author

A89-17877#
MALEO - STRATEGY FOR LUNAR BASE BUILD-UP
M. THANGAVELU and G. E. DORRINGTON (MIT, Boston, MA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p. refs
(IAF PAPER ST-88-15)
Module Assembly at Low Earth Orbit (MALEO) is a strategy for building a lunar base. An assembly of four modules are integrated near the Space Station 'Freedom', tested and shipped to low lunar orbit by a large orbital transfer vehicle. A lander stage is sent to dock with the MALEO and the entire spacecraft/base descended to the lunar surface. A superstructure is an integral part of the MALEO strategy and helps to uniformly distribute loads encountered during the touchdown. The base is operational shortly after landing with minimum EVA operations which is considered as undesirable on the lunar surface. Some major advantages of the MALEO strategy are pointed out. Author

A89-18298#
THE IMPACT OF VERY HIGH SPEED INTEGRATED CIRCUIT TECHNOLOGY ON SPACE STATION LOGISTICS
LINCOLN HALLEN (Executive Resource Associates, Inc., Alexandria VA) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 8 p. refs
(AIAA PAPER 88-4714)
The DOD's VHSIC program has generated an electronics technology base that is expected to revolutionize spacecraft on-orbit logistics support processes. It is anticipated that systems will be able to test and recalibrate themselves, as well as repair and reprogram themselves through the active determination of alternative electrical paths. An evaluation is presently made of the maintenance and resupply consequences of these performance capabilities for the NASA Space Station. O.C.

A89-18300#
THE ROLE OF LSAR IN LONG TERM SPACE OPERATIONS AND SPACE MAINTENANCE SUPPORT
STANFORD E. HOFFMAN IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 7 p. refs
(AIAA PAPER 88-4718)
In order to ensure the adequate and timely support required by its Space Station, NASA has undertaken the development, concurrently with Space Station design and development efforts, of the Logistic Support Analysis Record (LSAR) support data-base for planning. MIL-STD-1388-2A is the DOD specification document for SLAR, and will be the point of reference for all contractors involved in the four 'Work Packages' through which the Space Station will be acquired and integrated at the Kennedy Space Center. O.C.

A89-18312*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
FUTURE CIVIL SPACE PROGRAM LOGISTICS
JAMES W. STEINCAMP (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 8 p.
(AIAA PAPER 88-4735)
The NASA Shuttle-C unmanned launch vehicle and the Shuttle/Space Station-based Orbital Maneuver Vehicle will be used in support of NASA Space Station assembly and logistics operations, as well as for the orbital servicing of the Hubble Space Telescope (1989), the Advanced X-ray Astrophysical Facility (1996), and the Space Infrared Telescope Facility (1998). Accounts are presently given of these observatories' configurations, capabilities, and mission scenarios, as well as of the Shuttle-C-based Space Station assembly sequence. O.C.

A89-19921*# Southwest Research Inst., San Antonio, TX.
SPACELAB 1 EXPERIMENTS ON INTERACTIONS OF AN ENERGETIC ELECTRON BEAM WITH NEUTRAL GAS
J. A. MARSHALL, C. S. LIN, J. L. BURCH (Southwest Research Institute, San Antonio, TX), T. OBAYASHI (Tokyo, University, Japan), and C. BEGHIN (CNRS, Laboratoire de Physique et Chimie de l'Environnement, Orleans, France) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Sept.-Oct. 1988, p. 361-367. refs
(Contract NAS8-32488; F19628-85-K-0004)
An unusual signature of return current and spacecraft charging potential was observed during the Spacelab 1 mission launched on November 28, 1983. The phenomenon occurred during neutral gas releases from the SEPAC (Space Experiments with Particle Accelerators) magnetoplasma-dynamic arcjet (MPD) concurrent with firings of the PICPAB (Phenomena Induced by Charged Particle Beams) electron gun and was recorded by the instruments of the SEPAC diagnostic package (DGP). Data from the langmuir probe, floating probes, neutral gas pressure gauge, and the plasma wave probes are reported. As the dense neutral gas was released, the return current measured by the langmuir probe changed from positive to negative and a positive potential relative to the

spacecraft was measured by the floating probe. The anomalous return current is believed to be attributable to secondary electron fluxes escaping from the spacecraft, and the unusual charging situation is attributed to the formation of a double-layer structure between a hot plasma cloud localized to the MPD and the spacecraft. The charging scenario is supported by a computer simulation. Author

A89-20230
NEW TESTBEDS FOR FUTURE SPACE FLIGHT DEVELOPMENTS AND HYPERSONIC FLIGHT VEHICLES [NEUE TESTANLAGEN FUER ZUKUENFTIGE RAUMFAHRT-ENTWICKLUNGEN UND HYPERSCHALL-FLUGZEUGE]
K. AHRENSDORF (Industrieanlagen-Betriebsgesellschaft mbH, Ottobrunn, Federal Republic of Germany) IN: Yearbook 1987 II; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 639-649. In German. refs
(DGLR PAPER 87-113)

Aspects of the most important large testbeds for future space missions are examined. The requirements of these testbeds are reviewed, emphasizing those pertaining to dynamical highly loaded structures. The thermal/mechanical, thermo/acoustic loads of these testbeds are considered, and multiaxis vibration testbeds, large vacuum chambers, and microgravity simulations are addressed. C.D.

A89-22266
TRIBOLOGICAL PROBLEMS IN THE SPACE DEVELOPMENT IN JAPAN
MAKOTO NISHIMURA (National Aerospace Laboratory, Chofu, Japan) JSME International Journal, Series III (ISSN 0914-8825), vol. 31, Dec. 1988, p. 661-670. refs

R&D of launch vehicles, satellites, and the Japanese Experiment Module for the Space Station is described, with special emphasis on the tribological problems encountered. Lubrication, friction, and wear of rolling bearings and seals applied to turbopumps of an LE-5, the first LOX/LH2 engine completed in Japan, are discussed. Performance on orbit of ball bearings supporting the scanning mirrors of the earth sensors launched in 1981 is introduced, including test results of candidate materials used for cages. Compared to conventional rolling bearings, magnetic bearings have the merit of no friction and wear. Author

A89-23252
THE ESSENTIAL STEP
FRANK COLUCCI Space (ISSN 0267-954X), vol. 4, Mar.-Apr. 1988, p. 10-15.

The detailed design and development phase, Phase C/D, of the Space Station program is discussed. The programs of the four work packages involved with Phase C/D are examined. The development of the pressurized modules and research nodes, environmental control systems, propulsion systems, space transfer vehicles, structural framework, habitat module, data management system, the free-flying platforms, power systems, and guidance, navigation, and control systems are reviewed. R.B.

A89-23851
SOVIETS IN SPACE
PETER M. BANKS and SALLY K. RIDE (Stanford University, CA) Scientific American (ISSN 0036-8733), vol. 260, Feb. 1988, p. 32-40. refs

The Soviet space program is discussed, focusing on satellite, space station, and space shuttle programs. The history of Soviet activities in space is reviewed. Soviet launch vehicles and spacecraft are illustrated, including the Soviet space shuttle and the Proton and Energiya launch vehicles. The programs of the Salyut and Mir space stations are examined, including the experiments aboard the Kvant module. R.B.

A89-24662
NATURAL FREQUENCIES AND STABILITY OF IMMISCIBLE CYLINDRICAL Z-INDEPENDENT LIQUID SYSTEMS
HELMUT F. BAUER (Muenchen, Universitaet der Bundeswehr, Neubiberg, Federal Republic of Germany) Applied Microgravity Technology (ISSN 0931-9530), vol. 1, Oct. 1987, p. 11-26. refs

An attempt is made to provide a survey of the vibrational behavior of various immiscible liquid systems which may be used as basic elements in an orbiting space laboratory. The effect of gravity is neglected. Cases are given for nonrotating and rotating liquid bridges consisting of frictionless, viscous, and viscoelastic liquids. K.K.

A89-25211*# NASA Space Station Program Office, Reston, VA.
SPACE STATION FREEDOM AS AN EARTH OBSERVING PLATFORM
RICHARD E. SNYDER and VINCENT J. BILARDO, JR. (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0251)

The Space Station manned base is discussed, focusing on the use of the base as a science platform for earth observation. The program elements of the Space Station are described, including the manned base, the international elements, the Polar Platform, and the Man-tended Frequent Flyer. The accommodation and operational requirements for the earth observation payloads are examined. Candidate missions for the manned base earth observation program are presented, including observations of tropical regions, the Tropical Rainfall Measuring Mission, the tropical regions imaging spectrometer, the Earth Radiation Budget Experiment, and commercial remote sensing. R.B.

A89-25290*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PLANETARY MISSION DEPARTURES FROM SPACE STATION ORBIT
ANDREY B. SERGEYEVSKY (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0345)

The concept of orbital assembly and launch of oversized planetary (or lunar) spacecraft from a Space Station is rapidly coming of age. This prospect raises a host of new problems demanding timely resolution. The one most serious issue involved in launch from a rapidly precessing Space Station orbit (about -7.2 deg/day) is the need to cope with the generally out-of-plane orientation of the V-infinity departure vector. Methods dealing with single or multiple injection maneuvers, deep space plane changes, nodal shift caused by reboost strategy modifications, and departure window duration analysis are discussed. Author

A89-25469#
OMV MISSION OPERATIONS
JAMES SARINA (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 5 p.
(AIAA PAPER 89-0587)

The OMV, a reusable remotely controlled free-flying space vehicle, is capable of performing a wide range of services to orbiting spacecraft. The Design, Development, Test, and Evaluation mission will demonstrate the OMV's capabilities and serve as a precursor for the operational program which will encompass Space Station and space-based mode operations in addition to orbiter-based operations. OMV ground operations include real-time, man-in-the-loop, and remote teleoperations. K.K.

A89-25551#
THE EVOLUTION OF EXTERNAL TANK APPLICATIONS
J. ALEX GIMARC (USAF, Space Studies Institute, Colorado Springs, CO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p. refs
(AIAA PAPER 89-0727)

The External Tank of the Space Shuttle offers unique opportunities for orbital applications. Early interest was oriented toward the on-orbit storage and use of the tank as various habitats. Work during the early 1980s detailed on-orbit applications as tethered bodies, life sciences experiments, cargo carriers, materials resources in space, and the basis of a wide variety of manned platforms. Current interest is primarily in the areas of manned or man-tended platforms and the construction of a large telescope for gamma-ray observation. Author

A89-25552#
THE OUTPOST CONCEPT - A MARKET DRIVEN COMMERCIAL PLATFORM IN ORBIT
THOMAS C. TAYLOR, CHARLES W. COOK, and WILLIAM A. GOOD (Global Outpost, Inc., Alexandria, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0729)

The OUTPOST concept, a platform in LEO derived from the external tank of the Space Shuttle, is examined. The OUTPOST platform is expected to be used for orbital exposure testing, small science and research experiments, and technology testing and development. The use of the external tank and experimental accomodations on the platform are considered and the platform configuration and mission profile are illustrated. Plans for the marketing and commercial use of the platform, and other government contracts involving use of the Space Shuttle external tanks are discussed. R.B.

A89-25574#
THE FUTURE OF SPACE SYSTEMS - THE CHALLENGE OF STANDARDS AND INTEROPERABILITY
JOHN S. MORRISON (USAF, National Test Bed Joint Program Office, Falcon AFB, CO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p.
(AIAA PAPER 89-0777)

Interoperability among space systems will improve capabilities, reduce costs, and create a clear path for technology-insertion. Simplified, standard interfaces will be easier to manage, and will allow new systems to be inserted quickly in order to perform new missions. SDI is noted to be an important region of the total space systems interoperability problem, and may accordingly be taken as the kernel from which an encompassing national policy on this issue can grow. It is presently recommended that interoperability standards be developed, tested, and evaluated in parallel with SDI-related simulations and experiments. O.C.

A89-27882
DESIGN OF A TWO-PHASE CAPILLARY PUMPED FLIGHT EXPERIMENT
D. R. CHALMERS, J. FREDLEY (General Electric Co., Astro-Space Div., Princeton, NJ), J. KU, and E. J. KROLICZEK (OAO Corp., Greenbelt, MD) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p.
(SAE PAPER 881086)

A two-phase capillary pumped system loop (CPL) flight experiment was performed to demonstrate the capability of a capillary pumped system to absorb, transport, control, and reject heat in Space Station application simulation. This experiment was to provide sufficient data for characterization of the CPL system's performance under microgravity and normal environments. The details of the design, analysis, fabrication and test plan of the experiment program are presented. Ground testing verified the predicted heat transport performance. A.A.F.

A89-28450#
A NATIONAL PROGRAM FOR THE SCIENTIFIC AND COMMERCIAL USE OF SHUTTLE EXTERNAL FUEL TANKS IN SPACE
RANDOLPH H. WARE (University Corporation for Atmospheric Research; External Tanks Corp., Boulder, CO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 17 p.
(AIAA PAPER 89-0728)

The possibilities of applying the expended Space Shuttle external fuel tanks to practical uses in space are addressed. The external tanks are described and the history of the use of expended fuel tanks in space is reviewed. Suborbital use of the tanks as experimental sites is examined. The suitability of such a site for thermosphere density measurements, chemical release experiments, hydrogen release, microgravity experiments, epitaxy experiments, space debris detection, remote sensing, tether experiments, and attitude and orbit control is examined. The orbital use of the tanks for synthetic aperture radar and as tended, pressurized platforms is considered, and the storage of the external tanks in orbit is addressed. C.D.

N89-11643# Max-Planck-Inst. fuer Astronomie, Heidelberg (Germany, F.R.).
SPACE OBSERVATIONS FOR INFRARED AND SUBMILLIMETER ASTRONOMY
DIETRICH LEMKE *In* ESA, Space Science and Fundamental Physics p 81-92 May 1988
Avail: NTIS HC A10/MF A01

The Infrared Astronomy Satellite, the infrared telescope on Spacelab, cryogenic telescopes, and the Infrared Space Observatory are described. The Cosmic Background Explorer, Hubble Space Telescope, Shuttle Infrared Telescope Facility, the Far Infrared and Submillimeter Telescope, and the Large Deployable Reflector are introduced. ESA

N89-11760*# National Aeronautics and Space Administration, Washington, DC.
TECHNOLOGY FOR FUTURE NASA MISSIONS: CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI) AND PATHFINDER
Sep. 1988 550 p Conference held in Washington, D.C., 12-13 Sep. 1988; sponsored in part by NASA and AIAA
(NASA-CP-3016; NAS 1.55:3016) Avail: NTIS HC A23/MF A01 CSCL 22/1

Information is presented in viewgraph form on a number of related topics. Information is given on orbit transfer vehicles, spacecraft instruments, spaceborne experiments, university/industry programs, spacecraft propulsion, life support systems, cryogenics, spacecraft power supplies, human factors engineering, spacecraft construction materials, aeroassist, aerobraking and aerothermodynamics.

N89-11765*# National Aeronautics and Space Administration, Washington, DC.
SPACE RESEARCH AND TECHNOLOGY BASE OVERVIEW
LANA M. COUCH *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 107-130 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information in viewgraph form is given on aerothermodynamics, space energy conversion, spacecraft propulsion, spacecraft construction materials, spacecraft communications, spacecraft control, human factors engineering, and systems analysis. R.J.F.

N89-11773*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SYSTEMS AUTONOMY
HENRY LUM, JR. *In* NASA, Washington, Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 247-281 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information on systems autonomy is given in viewgraph form. Information is given on space systems integration, intelligent autonomous systems, automated systems for in-flight mission operations, the Systems Autonomy Demonstration Project on the Space Station Thermal Control System, the architecture of an autonomous intelligent system, artificial intelligence research issues, machine learning, and real-time image processing. R.J.F.

N89-11780*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GROWTH REQUIREMENTS FOR MULTIDISCIPLINE RESEARCH AND DEVELOPMENT ON THE EVOLUTIONARY SPACE STATION
BARRY MEREDITH, PETER AHLF, RUDY SAUCILLO, and DAVID EAKMAN (McDonnell-Douglas Astronautics Co., Rockville, Md.) Sep. 1988 146 p
(NASA-TM-101497; NAS 1.15:101497) Avail: NTIS HC A07/MF A01 CSCL 22/1

The NASA Space Station Freedom is being designed to facilitate on-orbit evolution and growth to accommodate changing user needs and future options for U.S. space exploration. In support of the Space Station Freedom Program Preliminary Requirements Review, The Langley Space Station Office has identified a set of resource requirements for Station growth which is deemed adequate for the various evolution options. As part of that effort, analysis was performed to scope requirements for Space Station as an expanding, multidiscipline facility for scientific research, technology development and commercial production. This report describes the assumptions, approach and results of the study. Author

N89-12065# MATRA Espace, Paris-Velizy (France).
SERVICE VISION SUBSYSTEM (SVS)
Paris, France ESA 8 Feb. 1988 19 p Original contains color illustrations
(Contract ESTEC-6495/85-NL-PB(SC))
(ESA-CR(P)-2643; ETN-88-93172) Avail: NTIS HC A03/MF A01

A service vision subsystem (SVS) for a spaceborne service manipulator (SMS) system was defined. The SVS functions are: proximity sensory function involving camera sensor and requiring image processing capabilities in order to deliver information requested by the control unit; and potential image preprocessing (compression) requested by the telemeasure and telecommand subsystem. The types of image processing are related to the operation to perform. For basic functions, SVS acts as a proximity sensor for the automatic control of the SMS, and as an imaging device (including image compression) for inspection. Extended functions include enhancement of the image, and feature extraction for improving the monitoring and teleoperation; and SVS as a 3-D sensor for less favorable conditions (unlit targets, nonmarked targets, etc.). The basic functions were studied and implemented on the SVS breadboard. The extended functions were studied, requirements analyzed, and algorithms simulated. ESA

N89-12978# British Aerospace Public Ltd. Co., Bristol (England). Space and Communications Div.
EUROPEAN REMOTE SENSING SATELLITE PLATFORMS FOR THE 1990'S
P. TRUSS *In* ESA, Proceedings of the 1988 International Geoscience and Remote Sensing Symposium (IGARSS 1988) on Remote Sensing: Moving Towards the 21st Century, Volume 1 p 171-174 Aug. 1988
Avail: NTIS HC A99/MF E03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 120 US dollars or 250 Dutch guilders

Requirements and constraints on a polar orbiting remote sensing system are reviewed. It is concluded that a series of 2 ton payload multi-mission platforms achieve the defined objectives. ESA

N89-13406# National Aeronautical Establishment, Ottawa (Ontario). Unsteady Aerodynamics Lab.
THE ORBITAL-PLATFORM CONCEPT FOR NONPLANAR DYNAMIC TESTING
M. E. BEYERS and X. Z. HUANG May 1988 41 p
(AD-A199119; NAE-AN-52; NRC-29133) Avail: NTIS HC A03/MF A01 CSCL 01/1

A new concept is introduced for large-amplitude nonplanar testing at high incidence. The dynamic test apparatus is characterized by an annular, orbital platform on which the model support and secondary drive mechanisms are mounted. The device can be used as a rotary apparatus, while arbitrary epicyclic motions (including fixed-plane, orbital modes) and oscillatory motions superimposed on the coning mode may be generated. The system is inherently very rigid and vibration levels can be kept very low. Aerodynamic interference is also very low as there is no need for bulky support hardware and the test section is circular. Accordingly, the system may be used to assess levels of support interference in conventional rotary tests. GRA

N89-13486*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN INTEGRATED IN-SPACE CONSTRUCTION FACILITY FOR THE 21ST CENTURY
MARTIN M. MIKULAS, JR. and JOHN T. DORSEY Nov. 1988 31 p
(NASA-TM-101515; NAS 1.15:101515) Avail: NTIS HC A03/MF A01 CSCL 22/2

Preliminary results are presented of studies being conducted by NASA on the construction of very large spacecraft. The various approaches are discussed for constructing spacecraft and their relative merits. It is observed that the Space Station Freedom has all of the basic design characteristics to permit its growth into an in-space construction facility for very large spacecraft. Also it is noted that if disturbances from construction operations are intolerable to other Space Station experiments, a co-orbiting construction facility could be built using previously developed Space Station truss hardware and systems. A discussion is also presented of a new PATHFINDER research initiative on on-orbit construction. This research effort is aimed at developing construction methods for very large spacecraft and includes the development of a 100 meter long space crane. Author

N89-14245*# National Aeronautics and Space Administration, Washington, DC.
CURRENT ACHIEVEMENTS IN COSMONAUTICS
L. A. YERLYKIN, ed. Nov. 1988 62 p Transl. into ENGLISH from Novoye v Zhizni, Nauke, Tekhnike: Seriya Kosmonavtika, Astronomiya (USSR), no. 12, 1987 p 1-64 Transl. by Scientific Translation Service, Santa Barbara, Calif.
(Contract NASW-4307)
(NASA-TT-20365; NAS 1.77:20365) Avail: NTIS HC A04/MF A01 CSCL 22/1

The articles presented in this collection of works tell the latest achievements in Soviet cosmonautics: the regular expedition of cosmonauts to the Mir orbital space station, and the successful development of USSR international cooperation in the sphere of cosmonautics. Information is alo presented on the start of operation of the Japanese booster rocket. Author

N89-14251*# Boeing Aerospace Co., Huntsville, AL.
SPACE STATION COMMONALITY ANALYSIS
1988 205 p
(Contract NAS8-36413)
(NASA-CR-179422; NAS 1.26:179422) Avail: NTIS HC A10/MF A01 CSCL 22/2

This study was conducted on the basis of a modification to Contract NAS8-36413, Space Station Commonality Analysis, which was initiated in December, 1987 and completed in July, 1988. The objective was to investigate the commonality aspects of subsystems and mission support hardware while technology experiments are accommodated on board the Space Station in the mid-to-late 1990s. Two types of mission are considered: (1) Advanced solar arrays and their storage; and (2) Satellite servicing. The point of departure for definition of the technology development missions was a set of missions described in the Space Station Mission Requirements Data Base. (MRDB): TDMX 2151 Solar Array/Energy Storage Technology; TDMX 2561 Satellite Servicing and Refurbishment; TDMX 2562 Satellite Maintenance and Repair; TDMX 2563 Materials Resupply (to a free-flyer materials processing platform); TDMX 2564 Coatings Maintenance Technology; and TDMX 2565 Thermal Interface Technology. Issues to be addressed according to the Statement of Work included modularity of programs, data base analysis interactions, user interfaces, and commonality. The study was to consider State-of-the-art advances through the 1990s and to select an appropriate scale for the technology experiments, considering hardware commonality, user interfaces, and mission support requirements. The study was to develop evolutionary plans for the technology advancement missions. Author

N89-14901*# Lowell Univ., MA. Dept. of Mechanical and Energy Engineering.
SOME TEST/ANALYSIS ISSUES FOR THE SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT Abstract Only
CHAUR-MING CHOU *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 48-49 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

The Space Station Structural Characterization Experiment (SSSCE) 1,2 is an early space flight experiment that uses the space station as a generic structure to study the dynamic characteristics of Large Space Structures (LSS). On-orbit modal testing will be conducted to determine natural frequencies, mode shapes and damping of dominant structural modes of the space structure assembly. This experiment will utimately support the development of system indentification and analytical modeling techniques for Large Space Structures. In order to ensure the success of SSSCE (in-space validation of modeling techniques for LSS), adequate measurement and instrumentation requirements have to be established during the experiment-definition study. Among the issues affecting these requirements, spatial and modal coverages of the modal test data are of particular interest. Topics such as total number of sensors, type of measurements (translation and rotation), optimal sensor locations (measurement degrees-of-freedom), selection of target modes, effects of modal superposition and truncation, separation of global and local modes, etc., are all a fundamental importance and must be investigated. Author

N89-15972*# Eagle Engineering, Inc., Houston, TX.
TRANSPORTATION NODE SPACE STATION CONCEPTUAL DESIGN
30 Sep. 1988 211 p
(Contract NAS9-17878)
(NASA-CR-172090; NAS 1.26:172090; EEI-88-207) Avail: NTIS HC A10/MF A01 CSCL 22/2

A number of recent studies have addressed the problem of a transportation node space station. How things would change or what addition facilities would be needed to support a major lunar or Mars initiative is a much often asked question. The support of a lunar base, requiring stacks on the order of 200 metric tons each to land 25 m tons on the lunar surface with reusable vehicles is addressed. The problem of maintaining and reusing large single stage Orbit Transfer Vehicles (OTVs) and single stage lander/launchers in space are examined. The required people and equipment needed, to maintain these vehicles are only vaguely known at present. The people and equipment needed depend on how well the OTV and lander/launcher can be designed for easy reuse. Since the OTV and lander/launcher are only conceptually defined at present, the real maintenance and refurbishment requirements are unobtainable. An estimate of what is needed, based on previous studies and obvious requirements was therefore made. An attempt was made to err on the conservative side. Author

N89-18389*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE SPACE STATION
ABRAHAM MUNOZ *In its* NASA Ames Summer High School Apprenticeship Research Program: 1986 Research Papers p 63-67 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

Conceived since the beginning of time, living in space is no longer a dream but rather a very near reality. The concept of a Space Station is not a new one, but a redefined one. Many investigations on the kinds of experiments and work assignments the Space Station will need to accommodate have been completed, but NASA specialists are constantly talking with potential users of the Station to learn more about the work they, the users, want to do in space. Present configurations are examined along with possible new ones. Author

N89-18511*# Michigan Univ., Ann Arbor. Dept. of Aerospace Engineering.
CAMELOT 2 Final Report
1988 263 p
(Contract NGT-21-002-080)
(NASA-CR-184731; NAS 1.26:184731) Avail: NTIS HC A12/MF A01 CSCL 22/2

The design parameters of a space vehicle resulting from studies conducted at the University of Michigan are presented. The vehicle is identified as a Circulating Autonomous Mars-Earth Luxury Orbital Transport (CAMELOT). This report documents the results of the current study based on several key changes in the spacecraft systems and layout. Subjects discussed are propulsion, docking, power systems, habitat design, and orbital assembly. NASA

N89-19323# Technische Univ., Berlin (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.
A MODEL FOR THE GEOSTATIONARY ORBITAL INFRASTRUCTURE, SYSTEM ANALYSIS
H. H. KOELLE and N. MILLIN 1 Aug. 1988 35 p
(ILR-MITT-205; ETN-89-93978) Avail: NTIS HC A03/MF A01

The functions and architecture of an infrastructure in the geostationary orbit (GEO) are discussed. A case study of a typical GEO infrastructure as it may develop during the next century was carried out, emphasizing conceptual design and analysis of a subsystem of this GEO infrastructure: the GEO Regional Transportation Company (GRET) envisaged as a commercial enterprise serving the 39 routes within the GEO complex by 10 different types of robots, taxis, and tugs. Results of simulation runs over a 110 yr life cycle produce timelines of several system performance parameters including prices for services within the market scenario assumed, which includes the acquisition and operation of a solar power system with 500 GW output. ESA

02

ANALYSIS AND DESIGN TECHNIQUES

Includes interactive techniques, computerized technology design and development programs, dynamic analysis techniques, environmental modeling, thermal modeling, and math modeling.

A89-10532
FLIGHT LOADING AND ITS EXPERIMENTAL SIMULATION FOR FUTURE SPACECRAFT SYSTEMS [FLUGLASTEN UND IHRE VERSUCHSTECHNISCHE SIMULATION BEI ZUKUENFTIGEN RAUMFAHRTSYSTEMEN]
HUBA ORY (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 384-394. In German. refs
(DGLR PAPER 87-125)

The test and modeling techniques currently used to simulate and predict the quasi-static, dynamic, and thermal loads encountered by spacecraft and payloads during launch, orbital operations, and reentry are examined in an analytical review. Topics addressed include typical mission profiles, the definition of flight loading, flight measurements, the construction of the mathematical model, the computation of dynamic response, structure identification, and the technical implementation of simulation tests. Extensive diagrams, drawings, and graphs of typical test results are provided. T.K.

A89-10541#

A STUDY ON GROUND TESTING METHOD FOR LARGE DEPLOYMENT ANTENNA

AKIRA MEGURO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 36, no. 414, 1988, p. 326-332. In Japanese, with abstract in English. refs

The ground testing of large antenna deployment is important in verifying it's deployment capability in geostationary orbit. But the exact simulation of deployment motion by ground testing is significantly inhibited due to prominent gravitational or atmospheric effects on deployment motion. As a part of verification activity, the object of this study is to estimate the influence of these ground effects on deployment motion quantitatively and to define the best method for ground deployment tests. Ground testing equipment was constructed in such a way that gravity effects were canceled by means of a suspending reflector from the point at 10 m high. Careful consideration was given to friction torque and air drug torque in simple model tests. Results closely correspond to the results of ground testing for an actual antenna reflector. Author

A89-10595

SIMULATION FACILITIES COMPATIBILITY IN DESIGN FOR COMPATIBILITY IN SPACE

MURDOCH MCKINNON and LES WHITE (CAE Electronics, Ltd., Montreal, Canada) IN: Aerospace Behavioral Engineering Technology Conference, 6th, Long Beach, CA, Oct. 5-8, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 181-187.
(SAE PAPER 871716)

This paper considers simulation facilities related to space development, with special attention given to the major design and performance features of the Canada's Aft Crew Station Simulation Facility SIMFAC (which was built to support the development of the Shuttle Remote Manipulator System) and those of EUROSIUM, which is the simulation facility being currently developed to support the European Space Program. Consideration is also given to the simulation facility of the Mobile Servicing System, which will be required to interact with other elements of the Space Station and which will have both autonomous and telerobotic modes. A parallel is drawn between these simulation facilities and the Crew Station Research and Development Facility developed recently as a design and evaluation tool for future helicopter designs, whose workload and task evaluation facilities and the technology used may serve as examples for space simulation design. I.S.

A89-10650

STRUCTURE DESIGN CONSIDERATIONS OF ENGINEERING TEST SATELITE VI AS LARGE GEOSTATIONARY SATELLITE BUS

HIDEHIKO MITSUMA (National Space Development Agency of Japan, Tokyo) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 281-285.
(SAE PAPER 872431)

The paper considers aspects of the structural design of the Japanese Engineering Test Satellite VI as a large geostationary satellite bus for applications satellites in the 1990s. Particular attention is given to the characteristics of the antenna tower structure, the solar array hold-down points, and the apogee-kick-engine support structure. In addition, the test plan of the structural research model is presented. B.J.

A89-11653#

REDUCED-ORDER CONTROL DESIGN VIA THE OPTIMAL PROJECTION APPROACH - A HOMOTOPY ALGORITHM FOR GLOBAL OPTIMALITY

S. RICHTER (Harris Corp., Melbourne, FL) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 17-30. refs
(Contract F49620-86-C-0038)

A homotopy algorithm for solving the optimal projection equations (OPE) is presented. Questions of existence and the number of solutions are also examined. It is shown that the number of stabilizing solutions to the given optimal projection equations can be determined and that all solutions can be computed via a homotopic continuation from a simple problem. For an important special case where the number of inputs or the number of outputs to the system is less than or equal to the dimension of the compensator, there is only one solution to the OPE, thus guaranteeing that the globally optimum reduced order controller can be computed. Author

A89-11655*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

RECURSIVE DYNAMICS OF TOPOLOGICAL TREES OF RIGID BODIES VIA KALMAN FILTERING AND BRYSON-FRAZIER SMOOTHING

G. RODRIGUEZ (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 45-60. refs

The inverse and forward dynamics problems for a set of rigid bodies connected by hinges to form a topological tree are solved by using recursive techniques from linear filtering and smoothing theory. An inward filtering sequence computes a set of constraint moments and forces. This is followed by an outward sequence to determine a corresponding set of angular and linear accelerations. An inward sequence begins at the tips of all of the terminal bodies of the tree and proceeds inwardly through all of the branches until it reaches the root. Similarly, an outward sequence begins at the root and propagates to all of the tree branches until it reaches the tips of the terminal bodies. The paper also provides an approach to evaluate recursively the composite multibody system inertia matrix and its inverse. Author

A89-11656#

SQUARE ROOT FILTERING FOR CONTINUOUS-TIME MODELS OF LARGE SPACE STRUCTURES

Y. OSHMAN and D. J. INMAN (New York, State University, Buffalo) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 61-75. refs

This paper presents a filtering method which exploits the special properties of large flexible structure models. In particular, a new square root filtering method is presented for a class of second order, continuous-time stochastic models of flexible structures. The method is based on the spectral decomposition of the estimation error covariance matrix into its V-Lambda factors, where V is the matrix whose columns are the covariance eigenvectors and Lambda is the diagonal matrix of eigenvalues. Author

A89-11684#

EQUATIONS OF MOTION OF SYSTEMS OF VARIABLE-MASS BODIES FOR SPACE STRUCTURE DEPLOYMENT SIMULATION

J. E. KEAT and J. D. TURNER (Cambridge Research Associates, MA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 549-562. refs
(Contract F04511-82-K-0038; F04611-86-C-0017)

The paper presents a formulation of the equations of motion of multibody systems with interbody mass flow. An example of a process which can be modeled by the formulation is the common one in which appendages are extended from the main body of a spacecraft. After the Introduction, the paper contains four main parts. The first presents basic material that is used subsequently. The second develops kinetics equations for a single body, such as a deploying boom, with time-varying mass. The third develops the multibody system dynamics equations. The fourth applies the formulation to a sample problem. Author

A89-11810

SYSTEM AUTONOMY HOOKS AND SCARS FOR SPACE STATION

S. A. STARKS and D. W. ELIZANDRO (East Texas State University, Commerce, TX) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 48-52. refs

Some of the more critical hooks and scars which must be inncorporated into the initial operational capability Space Station are addressed. The possible scars required to anticipate implementation of Space Station robots can be characterized into the following areas: locomotion, vision, and manipulation. In a discussion of software hooks for automation and robotics, particular attention is given to: intelligent system access to sensor, actuator, and control data; allowance for processors with parallel or other advanced architectures; synchronization mechanisms for cooperating intelligent systems; object-oriented design; and the modular approach. K.K.

A89-12068* Carnegie-Mellon Univ., Pittsburgh, PA.

PLANNING REPAIR SEQUENCES USING THE AND/OR GRAPH REPRESENTATION OF ASSEMBLY PLANS

L. S. HOMEM DE MELLO (Carnegie-Mellon University, Pittsburgh, PA) and A. C. SANDERSON (Rensselaer Polytechnic Institute, Troy, NY) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 3. Washington, DC, Computer Society Press, 1988, p. 1861, 1862. Research supported by the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico of Brazil, Carnegie-Mellon University, and NASA. refs

A simple modification is shown in the set of goal nodes of the AND/OR graph that allows its use in planning repairs such as the replacement of a part or a subassembly. An algorithm for the generation of all feasible sequences for disassembly and reassembly of parts that will achieve a repair is shown. This approach has been demonstrated for the example of the repair of space-based satellite equipment. I.E.

A89-15548

MODAL ANALYSIS AND BALANCING OF SPACECRAFT TURBOPUMP ROTOR

D. BONDOUX (METRAVIB R.D.S.Co., Ecully, France) and P. FRECHON (Societe Europeenne de Propulsion, Vernon, France) IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 1. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 542-548. Research supported by Societe Europeenne de Propulsion, CNES, and ESA.

The dynamic behavior of a spacecraft turbopump rotor is analyzed on a computer using two finite element models, with one model simulating the rotor in the balancing configuration and the other simulating the rotor in the operating configuration. It is found, in particular, that procedures involving balancing runs under the first direct critical speed are efficient for operating speeds above the second direct critical speed. The sensitivity of the procedures to the location of the initial unbalanced weights and to the measurement noise is analyzed. V.L.

A89-16160#

POLE-ZERO MODELING OF FLEXIBLE SPACE STRUCTURES

BONG WIE (Texas, University, Austin) and ARTHUR E. BRYSON, JR. (Stanford University, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 554-561. refs

Generic models of flexible space structures are investigated from the infinite discrete-spectrum viewpoint of distributed parameter systems. The models are simple enough to treat analytically, yet complicated enough to demonstrate the practical usefulness of the transcendental-transfer-function modeling for the purposes of preliminary control synthesis. Transfer functions of the various generic models are derived analytically, and their pole-zero patterns are investigated. The alternating pole-zero pattern of a transfer function from an actuator to the colocated sensor is well known. It is, however, newly found that in certain colocated cases, each mode has an associated zero of higher frequency than the pole; in fact, the rigid-body mode has an associated zero very close to the origin. This direct transmission property must be taken into consideration when designing large space structures such as the dual-keel Space Station, which has a pole-zero pattern very similar to that of the generic models. The practical significance of such pole-zero patterns on colocated control is discussed. Author

A89-18439

MODELING THE EFFECTS CONNECTED WITH THE INFLUENCE OF THE MAGNETIC AND SOLAR SHADOW FROM SATELLITE STRUCTURAL ELEMENTS ON RESULTS OF MEASUREMENTS OF ELECTRIC FIELDS AND PARTICLE FLUXES [MODELIROVANIE EFFEKTOV, SVIAZANNYKH S VLIIANIEM MAGNITNOI I SOLNECHNOI TENI OT ELEMENTOV KONSTRUKTSII SPUTNIKA NA REZUL'TATY IZMERENII ELEKTRICHESKIKH POLEI I POTOKOV CHASTITS]

M. M. TSONEV and G. A. STANEV (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia za Kosmicheski Izsledvaniia, Sofia, Bulgaria) Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 731-737. In Russian. refs

A89-19943#

TYPICAL APPLICATION OF CAD/CAE IN SPACE STATION PRELIMINARY DESIGN

KATSUHIKO TAKAHASHI and YOSHIHARU HANAI Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 28, July 1988, p. 197-201. In Japanese, with abstract in English.

The role of CAD/CAE in the Japanese Experiment Module (JEM), Japan's contribution to the Space Station project, is examined. It is shown that CAD/CAE is significantly efficient in hardware layout design, component/structure interference analysis, window field of view analysis, manipulator operability analysis in equipment replacement, drawing development, data exchange with NASA and participating companies, and efficiency of data usage. C.D.

A89-20602* North Carolina Univ., Charlotte.

USE OF CAD SYSTEMS IN DESIGN OF SPACE STATION AND SPACE ROBOTS

SUREN N. DWIVEDI, P. YADAV (North Carolina, University, Charlotte), GARY JONES, and ELMER W. TRAVIS (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Robotics and factories of the future '87; Proceedings of the Second International Conference, San Diego, CA, July 28-31, 1987. Berlin and New York, Springer-Verlag, 1988, p. 167-183. refs

The evolution of CAD systems is traced. State-of-the-art CAD systems are reviewed and various advanced CAD facilities and supplementing systems being used at NASA-Goddard are described. CAD hardware, computer software, and protocols are detailed. K.K.

A89-20838

A STEREO-TRIANGULATION APPROACH TO SENSING FOR STRUCTURAL IDENTIFICATION

JOHN L. JUNKINS and GEORGE H. JAMES, III (Texas A & M University, College Station) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 155-165. refs

(AAS PAPER 88-015)

A stereo-optical triangulation approach to making a large number of spatially distributed structural response measurements is discussed. The close-range photogrammetric triangulation achieved in-orbit with the 1984 Shuttle mission is described and means of improving this technique are proposed. Particular attention is given to the incorporation of unique subsystems for analog edge detection and video processing algorithms. K.K.

A89-23510
(M, N)-APPROXIMATION - A SYSTEM SIMPLIFICATION METHOD
AJMAL YOUSUFF (Drexel University, Philadelphia, PA), TIMOTHY E. MCQUADE, and SIVAS S. BANDA (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) International Journal of Control (ISSN 0020-7179), vol. 48, Nov. 1988, p. 1851-1865. refs
(Contract F49620-85-C-0013)

Techniques for reducing the complexity of models of large structural systems are developed analytically. An (M, N) approximation procedure which reduces a system of N interacting subsystems to a model comprising only M subsystems while accounting for all of the original interactions, is derived in detail and applied to the balancing problem of a linear-quadratic Gaussian controller. Numerical results demonstrating the efficiency of the method are presented in graphs and discussed. T.K.

A89-25161*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CONSERVATION OF DESIGN KNOWLEDGE
CECILIA SIVARD, MONTE ZWEBEN (NASA, Ames Research Center, Moffett Field, CA), DAVID CANNON, FRED LAKIN, LARRY LEIFER (Stanford University, Palo Alto, CA) et al. AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(Contract NCC2-342)
(AIAA PAPER 89-0186)

This paper presents an approach for acquiring knowledge about a design during the design process. The objective is to increase the efficiency of the lifecycle management of a space-borne system by providing operational models of the system's structure and behavior, as well as the design rationale, to human and automated operators. A design knowledge acquisition system is under development that compares how two alternative design versions meet the system requirements as a means for automatically capturing rationale for design changes. Author

A89-27175#
STRUCTURAL RELIABILITY IN AEROSPACE DESIGN
A. V. PATKI (ISRO, Satellite Centre, Bangalore, India) ESA Journal (ISSN 0379-2285), vol. 12, no. 3, 1988, p. 397-400.

The concept of a reliability figure is widely used in aerospace design. Though very common and well developed for electronics systems and components, it is not used directly for structural systems. This note attempts to show how reliability estimates can be incorporated in present aerospace design practice. A typical simple case is worked out to show the implicit reliability figures using these margins. Author

A89-27845
FLUIDNET - A THERMAL AND HYDRAULIC SOFTWARE FOR THE PRELIMINARY SIZING OF FLUID LOOP SYSTEMS
S. ANDRE, J. N. CHELOTTI (Aerospatiale, Division Systemes Strategiques et Spatiaux, Cannes, France), J. F. GORY, and T. LAFON (CNES, Toulouse, France) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p.
(SAE PAPER 881045)

The development and features of FLUIDNET, an interactive application computer program for preliminary sizing of fluid loop networks used in spacecraft active thermal control systems, are described. The multiple evolutions of the overall configuration of the Columbus and Hermes projects have made it necessary to quickly dimension new thermal management systems; this has instigated FLUIDNET's development. After a brief description of the program structure, component library, and solution method, an example of FLUIDNET's application to the thermal control subsystem design of the Hermes freon loop is given. S.A.V.

A89-28594* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CLOSED-FORM GRAMMIANS AND MODEL REDUCTION FOR FLEXIBLE SPACE STRUCTURES
TREVOR WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1157, 1158. refs

Analytical expression are derived for the Grammians of a model in modal coordinates for the dynamics of a flexible space structure (FSS). These exact results provide insight into the dynamics of such systems and reduce the known approximate expressions in the case of lightly damped, widely separated modes. A novel algorithm is outlined that uses these to compute a dominant reduced-order model for such a system in an efficient manner. I.E.

A89-28642* Brown Univ., Providence, RI.
BOUNDARY IDENTIFICATION FOR 2-D PARABOLIC PROBLEMS ARISING IN THERMAL TESTING OF MATERIALS
H. T. BANKS (Brown University, Providence, RI) and FUMIO KOJIMA (NASA, Langley Research Center, Hampton, VA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1678-1683. refs
(Contract NSF MCS-85-04316; F49620-86-C-0111; NAS1-18107)

Problems on the identification of two-dimensional spatial domains arising in the detection and characterization of structural flaws in materials are considered. For a thermal diffusion system with external boundary input, observations of the temperature on the surface are used in an output least square approach. Parameter estimation techniques based on the method of mappings are discussed, and approximation schemes are developed based on a finite-element Galerkin approach. Theoretical convergence results for computational techniques are given, and the results are applied to the identification of two kinds of boundary shapes. I.E.

A89-30621
CHAOTIC PHENOMENA TRIGGERING THE ESCAPE FROM A POTENTIAL WELL
J. M. T. THOMPSON (University College, London, England) Royal Society (London), Proceedings, Series A - Mathematical and Physical Sciences (ISSN 0080-4630), vol. 421, no. 1861, Feb. 8, 1989, p. 195-225. Research supported by SERC. refs

The way in which a driven mechanical oscillator escapes from the cubic potential well typical of a metastable system close to a fold is studied to show how the well-known atoms of dissipative dynamics assemble to form molecules of overall response. The results indicated that the cubic energy expression adopted for the well was the universal form encountered by gradient systems as they approach a fold. It is found that, over a substantial range of forcing frequency, an increase in the forcing magnitude generates a period-doubling cascade leading to a two-band chaotic attractor. K.K.

A89-30743#
EXACT STATIC AND DYNAMIC STIFFNESS MATRICES FOR GENERAL VARIABLE CROSS SECTION MEMBERS
MOSHE EISENBERGER (Carnegie-Mellon University, Pittsburgh, PA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 852-858. refs
(AIAA PAPER 89-1258)

This paper concerns the formulation of a new finite element method for the solution of beams with variable cross section. Using only one element it is possible to derive the exact static and dynamic stiffness matrices (up to the accuracy of the computer), for any polynomial variation of axial, torsional, and bending stiffnesses along the beam. Examples are given for the accuracy and efficiency of the method. Author

A89-30787#
DYNAMICS OF COMPLEX TRUSS-TYPE SPACE STRUCTURES
Y. YONG and Y. K. LIN (Florida Atlantic University, Boca Raton) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural

Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1295-1304. refs
(Contract AF-AFOSR-88-005)
(AIAA PAPER 89-1307)

A mathematical procedure developed for the analysis of damped periodic and piecewise periodic structures is extended to more complicated configurations of intersecting arrays. The proposed procedure is a hybrid of finite element, transfer matrix, and wave propagation approaches, with a finite element formulation used to model a periodic truss unit or each type of periodic truss unit in the structure so that the dynamic characteristics of such a unit can be represented as accurately as desired, regardless of its complexity. Traditional transfer matrices for state vectors are transformed to transfer matrices for wave vectors, so that various waves propagating along the structure in different directions can be identified and certain numerical difficulties can be circumvented. An example is given to illustrate the application of the method. V.L.

A89-31921#
EIGENVECTOR DERIVATIVES WITH REPEATED EIGENVALUES
R. LANE DAILEY (TRW, Inc., Redondo Beach, CA) AIAA Journal (ISSN 0001-1452), vol. 27, April 1989, p. 486-491. refs

In this paper an algorithm is derived for computing the derivatives of eigenvalues and eigenvectors for real symmetric matrices in the case of repeated eigenvalues, where the matrices are functions of real parameters such as mass density or moment of inertia. The algorithm is an extension of recent work by I.U. Ojalvo; the key step in this extended derivation is to differentiate the eigenvalue equation twice. The algorithm preserves the symmetry and band structure of the matrices, allowing efficient computer storage and solution techniques. Applications include sensitivity analysis and optimization of the normal modes of finite-element modeled structures, such as large space structures. A cantilever beam finite-element example is included. Author

A89-32163
MATHEMATICAL SUBSTANTIATION OF A THEORY OF ORBITAL CORRECTION USING A SOLAR SAIL [MATEMATICHESKOE OBOSNOVANIE TEORII ORBITAL'NOI KORREKTSII, VYPOLNIAEMOI S POMOSHCH'IU SOLNECHNOGO PARUSA]
E. N. POLIAKHOVA and A. S. SHMYROV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 27, Jan.-Feb. 1989, p. 54-63. In Russian. refs

The paper examines the two-dimensional problem of the optimal correction of the geocentric elliptical orbit of a spacecraft using a solar sail. A combination of the averaging and small-parameter methods is used to obtain an approximately optimal solution. The problem is examined for arbitrary initial conditions in the sense of the orientation of the apsidal lines and the dimensions of the elliptical orbit with fixed constraints on the solar-sail thrust force. B.J.

N89-10114 Virginia Polytechnic Inst. and State Univ., Blacksburg.
SOLUTION OF TWO-POINT BOUNDARY VALUE PROBLEMS IN OPTIMAL MANEUVERS OF FLEXIBLE VEHICLES Ph.D. Thesis
ROGER CLIFTON THOMPSON 1988 172 p
Avail: Univ. Microfilms Order No. DA8804435

Obtaining solutions to nonlinear two point boundary value problems is often a formidable task that is effectively restricted to a relatively small number of numerical methods. An asymptotic perturbation method that can be applied to a large class of nonlinear two point boundary value problems is presented and compared with some of the classical numerical methods available. Simple examples are included to illustrate the application of the perturbation method. Two distinct types of optimal maneuvers of flexible vehicles are examined. An optimal control problem for three dimensional attitude acquisition of a rigid and a flexible spacecraft is formulated, and the perturbation method is used to determine the solution for each problem. For the rigid body attitude maneuvers, large angle solutions are generated. However, the flexible spacecraft optimal maneuvers are solved only for small angular motions and small flexural amplitudes. In the second type of problem, single axis, time optimal maneuvers of a flexible body are considered. A sub-optimal problem is developed, and numerical simulations for controlling multiple modes are presented. The solutions are then parameterized. Dissert. Abstr.

N89-10116# Instituto de Investigacion Tecnologia, Madrid (Spain).
STUDY ON CONCEPTUAL DESIGN OF SPACECRAFT USING COMPUTER-AIDED ENGINEERING TECHNIQUES Final Report
I. J. PEREZ-ARRIAGA, J. J. ALBA, F. CUADRA, J. J. SANGIL, M. ANGULO, and N. BALTEAS Paris, France ESA Dec. 1987 138 p
(Contract ESTEC-6886/85-NL-PP)
(ESA-CR(P)-2615; ETN-88-93149) Avail: NTIS HC A07/MF A01

A formal characterization of the process of conceptual design of spacecraft was derived, and the basic functions and requirements for a Conceptual Design of Spacecraft Tool (CDST) were defined. The major building blocks needed in the CDST were individually analyzed, including: knowledge acquisition procedures; knowledge representation techniques; automatic design approach suitable for computer implementation; decision-making logic adapted to a multiobjective environment; and design process control logic relying on existing artificial intelligence techniques. A possible hardware and software configuration based on existing resources was derived, and a mock-up of a simplified CDST was developed and implemented so that hands-on experience on each major aspect can be obtained. A working plan for a phased/expandable development of the CDST was produced. ESA

N89-13475*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYTIC REDUNDANCY MANAGEMENT FOR SCOLE
RAYMOND C. MONTGOMERY *In its* Proceedings of the 4th Annual SCOLE Workshop p 329-345 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The objective of this work is to develop a practical sensor analytic redundancy management scheme for flexible spacecraft and to demonstrate it using the SCOLE experimental apparatus. The particular scheme to be used is taken from previous work on the Grid apparatus by Williams and Montgomery. Author

N89-13476*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A MATHEMATICAL PROBLEM AND A SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) USED TO EVALUATE CONTROL LAWS FOR FLEXIBLE SPACECRAFT. NASA/IEEE DESIGN CHALLENGE
LAWRENCE W. TAYLOR, JR. and A. V. BALAKRISHNAN (California Univ., Los Angeles.) *In its* Proceedings of the 4th Annual SCOLE Workshop p 347-373 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The problen of controlling large, flexible space systems has been evaluated using computer simulation. In several cases, ground experiments have also been used to validate system performance under more realistic conditions. There remains a need, however, to test additional control laws for flexible spacecraft and to directly compare competing design techniques. A program is discussed which has been initiated to make direct comparisons of control laws for, first, a mathematical problem, then and experimental test article being assembled under the cognizance of the Spacecraft Control Branch at the NASA Langley Research Center with the advice and counsel of the IEEE Subcommittee on Large Space Structures. The physical apparatus will consist of a softly supported dynamic model of an antenna attached to the Shuttle by a flexible beam. The control objective will include the task of directing the line-of-sight of the Shuttle antenna configuration toward a fixed target, under conditions of noisy data, control authority and random disturbances. Author

N89-13482*# Bionetics Corp., Hampton, VA.
SYSTEM DESIGN ANALYSES OF A ROTATING ADVANCED-TECHNOLOGY SPACE STATION FOR THE YEAR 2025 Interim Report, Nov. 1987 - May 1988
M. J. QUEIJO, A. J. BUTTERFIELD, W. F. CUDDIHY, R. W. STONE, J. R. WROBEL, P. A. GARN, and C. B. KING Dec. 1988 250 p
(Contract NAS1-18267)
(NASA-CR-181668; NAS 1.26:181668) Avail: NTIS HC A11/MF A01 CSCL 22/2

Studies of an advanced technology space station configured to implement subsystem technologies projected for availability in the time period 2000 to 2025 is documented. These studies have examined the practical synergies in operational performance available through subsystem technology selection and identified the needs for technology development. Further analyses are performed on power system alternates, momentum management and stabilization, electrothermal propulsion, composite materials and structures, launch vehicle alternates, and lunar and planetary missions. Concluding remarks are made regarding the advanced technology space station concept, its intersubsystem synergies, and its system operational subsystem advanced technology development needs. Author

N89-14170*# Missouri Univ., Rolla. Dept. of Computer Science.
PERFORMANCE EVALUATION OF NASA/KSC CAD/CAE GRAPHICS LOCAL AREA NETWORK
GEORGE ZOBRIST *In* NASA, John F. Kennedy Space Center, NASA/ASEE Summer Faculty Fellowship Program: 1988 Research Reports p 520-557 Oct. 1988
Avail: NTIS HC A24/MF A01 CSCL 09/2

This study had as an objective the performance evaluation of the existing CAD/CAE graphics network at NASA/KSC. This evaluation will also aid in projecting planned expansions, such as the Space Station project on the existing CAD/CAE network. The objectives were achieved by collecting packet traffic on the various integrated sub-networks. This included items, such as total number of packets on the various subnetworks, source/destination of packets, percent utilization of network capacity, peak traffic rates, and packet size distribution. The NASA/KSC LAN was stressed to determine the useable bandwidth of the Ethernet network and an average design station workload was used to project the increased traffic on the existing network and the planned T1 link. This performance evaluation of the network will aid the NASA/KSC network managers in planning for the integration of future workload requirements into the existing network. Author

N89-15414*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
WEAR CONSIDERATION IN GEAR DESIGN FOR SPACE APPLICATIONS
LEE S. AKIN (California State Univ., Long Beach.) and DENNIS P. TOWNSEND 1989 8 p Prepared for presentation at the 5th International Power Transmission and Gearing Conference, Chicao, IL, 25-27 Apr. 1989; sponsored by ASME
(Contract NAG3-20; DA PROJ. 1L1-62209-A-47-A)
(NASA-TM-101457; E-4532; NAS 1.15:101457; AVSCOM-TR-88-C-033) Avail: NTIS HC A02/MF A01 CSCL 13/9

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

N89-15610*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CONSIDERATIONS IN DEVELOPMENT OF EXPERT SYSTEMS FOR REAL-TIME SPACE APPLICATIONS
S. MURUGESAN *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 487-496 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 05/1

Over the years, demand on space systems has increased tremendously and this trend will continue for the near future. Enhanced capabilities of space systems, however, can only be met with increased complexity and sophistication of onboard and ground systems. Artificial Intelligence and expert system techniques have great potential in space applications. Expert systems could facilitate autonomous decision making, improve in-orbit fault diagnosis and repair, enhance performance and reduce reliance on ground support. However, real-time expert systems, unlike conventional off-line consultative systems, have to satisfy certain special stringent requirements before they could be used for onboard space applications. Challenging and interesting new environments are faced while developing expert system space applications. This paper discusses the special characteristics, requirements and typical life cycle issues for onboard expert systems. Further, it also describes considerations in design, development, and implementation which are particularly important to real-time expert systems for space applications. Author

N89-15631*# Computer Sciences Corp., Hampton, VA.
FLEXAN (VERSION 2.0) USER'S GUIDE
SCOTT S. STALLCUP Washington, DC Jan. 1989 41 p
(Contract NAS1-17999)
(NASA-CR-4214; NAS 1.26:4214; TAO-50287) Avail: NTIS HC A03/MF A01 CSCL 09/2

The FLEXAN (Flexible Animation) computer program, Version 2.0 is described. FLEXAN animates 3-D wireframe structural dynamics on the Evans and Sutherland PS300 graphics workstation with a VAX/VMS host computer. Animation options include: unconstrained vibrational modes, mode time histories (multiple modes), delta time histories (modal and/or nonmodal deformations), color time histories (elements of the structure change colors through time), and rotational time histories (parts of the structure rotate through time). Concurrent color, mode, delta, and rotation, time history animations are supported. FLEXAN does not model structures or calculate the dynamics of structures; it only animates data from other computer programs. FLEXAN was developed to aid in the study of the structural dynamics of spacecraft. Author

N89-17615 California Univ., Los Angeles.
SYMBOLIC GENERATION OF EQUATIONS OF MOTION FOR DYNAMICS/CONTROL SIMULATION OF LARGE FLEXIBLE MULTIBODY SPACE SYSTEMS Ph.D. Thesis
SHENG SAM LEE 1988 169 p
Avail: Univ. Microfilms Order No. DA8814809

The formulation of equations of motion has become crucial in the successful design of very large and flexible space vehicles. The derivation is presented of explicit equations of motion for multibody flexible space systems via symbolic manipulation. This methodology generates very efficient computational algorithms in a reasonable amount of time and cost. Kane's dynamical equations are used to formulate the equation of motion. The multibody system is idealized as a collection of interconnected bodies arranged in a topological tree configuration with the option that the bodies can form closed loops. The flexible characteristics of the bodies are described by means of assumed admissible spatial functions. Bodies of the system are interconnected by hinges possessing zero to six degrees of relative motion freedom with unrestricted large rigid body motion. Dissert. Abstr.

N89-19337# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
MANEUVERING EQUATIONS IN TERMS OF QUASI-COORDINATE

LEONARD MEIROVITCH *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 19-21 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The equations for the motion of a flexible spacecraft in space can be described conveniently in terms of quasi-coordinates. The nonlinear equations can be treated by a perturbation approach, resulting in a low-order nonlinear problem for the rigid-body maneuvering and linear time-varying problem for angular perturbations from the rigid-body maneuver and elastic vibration. Author

N89-19355# Naval Postgraduate School, Monterey, CA.
EFFECTS OF REDUCED ORDER MODELING ON THE CONTROL OF A LARGE SPACE STRUCTURE M.S. Thesis
WILLIAM J. PRESTON Sep. 1988 81 p
(AD-A201674) Avail: NTIS HC A05/MF A01 CSCL 22/2

The motion of a large space structure, such as a space station, is described by a large number of coupled, second order differential equations. To effectively control this structure, a mathematical model is required. Both the mathematical model developed directly from the physics of the structure, and the simplified model developed with modal analysis are of extremely high dimension. A reduced order model is therefore required in order to design a control system for the structure. A straightforward approach to the control problem is taken by using linear quadratic optimal control techniques to determine the reduced order control solution for the truncated modal model. The effects of reduced order modeling on the control of the space station will be evaluated by observing the response of the closed loop system to several disturbances. GRA

N89-19361# Katholieke Universiteit te Leuven (Belgium). Werktuigkunde Mechanische Konstructie en Produktie.
ERROR LOCALIZATION AND UPDATING OF SPACECRAFT STRUCTURES MATHEMATICAL MODELS Final Report
P. SAS, W. HEYLEN, T. JANTER, C. LIEFOOGHE, C. STAVRINIDIS, and E. FISSETTE Paris, France ESA Jun. 1988 131 p
(Contract ESTEC-1511/87-NL-PH)
(YMD/EF/0175; ESA-CR(P)-2667; ETN-89-93925) Avail: NTIS HC A07/MF A01

A procedure for updating finite element input data directly was developed. The method is formulated as a minimization problem, that can be approached with a linear, quadratic or nonlinear programming algorithm. For a highly underdetermined problem (far more variables than constraints), the traditional least squares approach is still applicable. The software was evaluated as to error localization, coupling analysis, loads and stress evaluation, and dynamic response computations, using beam, coil, and spacecraft structure examples. For all examples, the updating procedure improves the correlation between experimental and analytical results. The applied updating algorithms seem to be stable, and a limited number of iterations is generally sufficient for improving the finite element model. Although the applied updating technique was not developed especially for error localization, it is possible to draw conclusions from the update results for error localization if enough experimental information is included in the updating process. A substantial improvement for coupling analysis is obtained when using updated models. Dynamic and static response calculations are improved. ESA

N89-19867*# Washington Univ., Seattle. Dept. of Electrical Engineering.
CAD-MODEL-BASED VISION FOR SPACE APPLICATIONS
LINDA G. SHAPIRO *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 361-367 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 09/2

A pose acquisition system operating in space must be able to perform well in a variety of different applications including automated guidance and inspections tasks with many different, but known objects. Since the space station is being designed with automation in mind, there will be CAD models of all the objects, including the station itself. The construction of vision models and procedures directly from the CAD models is the goal of this project. The system that is being designed and implementing must convert CAD models to vision models, predict visible features from a given view point from the vision models, construct view classes representing views of the objects, and use the view class model thus derived to rapidly determine the pose of the object from single images and/or stereo pairs. Author

N89-20063*# Louisiana Tech Univ., Ruston. Dept. of Electrical Engineering.
DEVELOPMENT OF PARALLEL ALGORITHMS FOR ELECTRICAL POWER MANAGEMENT IN SPACE APPLICATIONS Final Report
FREDERICK C. BERRY *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 1 9 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 10/2

The application of parallel techniques for electrical power system analysis is discussed. The Newton-Raphson method of load flow analysis was used along with the decomposition-coordination technique to perform load flow analysis. The decomposition-coordination technique enables tasks to be performed in parallel by partitioning the electrical power system into independent local problems. Each independent local problem represents a portion of the total electrical power system on which a loan flow analysis can be performed. The load flow analysis is performed on these partitioned elements by using the Newton-Raphson load flow method. These independent local problems will produce results for voltage and power which can then be passed to the coordinator portion of the solution procedure. The coordinator problem uses the results of the local problems to determine if any correction is needed on the local problems. The coordinator problem is also solved by an iterative method much like the local problem. The iterative method for the coordination problem will also be the Newton-Raphson method. Therefore, each iteration at the coordination level will result in new values for the local problems. The local problems will have to be solved again along with the coordinator problem until some convergence conditions are met. Author

03

STRUCTURAL CONCEPTS

Includes erectable structures (joints, struts, and columns), deployable platforms and booms, solar sail, deployable reflectors, space fabrication techniques, and protrusion processing.

A89-10648* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LARGE SPACE STRUCTURES - STRUCTURAL CONCEPTS AND MATERIALS
CHARLES P. BLANKENSHIP and ROBERT J. HAYDUK (NASA, Langley Research Center, Hampton, VA) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 243-271. refs
(SAE PAPER 872429)

Large space structures will be a key element of future space activities. They will include spacecraft such as the planned Space Station and large antenna/reflector structures for communications and observations. These large structures will exceed 100 m in length or 30 m in diameter. This paper provides an overview of research in the space construction of large structures including erectable and deployable concepts. Also, an approach to automated, on-orbit construction is presented. Materials research for space applications focuses on high stiffness, low expansion composite materials that provide adequate durability in the space environment. The status of these materials research activities is discussed. Author

A89-11692*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

ANALYSIS AND TEST OF A SPACE TRUSS FOLDABLE HINGE

N. A. NIMMO, G. C. HORNER (NASA, Langley Research Center, Hampton, VA), and J. LAUFER (PRC Kentron, Inc., Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 697-711. refs

The Mini-Mast is a 20-meter long deployable, three-longeron, truss-beam being used to develop analytical and experimental methods for predicting the physical behavior of large space structures. With 57 corner-body hinges and 54 mid-body hinges, the Mini-Mast is highly joint-dominated, necessitating inclusion of the compliance of the joints in analytical models. This study demonstrates an approach for calculating the stiffness properties of a complicated hinge called the mid-body hinge. The process includes detailed modeling with solid-body modeling software and the use of finite element analysis. Load-deflection tests were conducted to determine the axial stiffness of the mid-body hinge. This is compared to the axial stiffness value determined from a finite element analysis. Author

A89-17676#

BALCONY - A EUROPEAN SPACE STATION EXTERNAL STRUCTURE

GILLES DEBAS (Aerospatiale, Les Mureaux, France) and PIERRE DUTTO (CNES, Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p.

(IAF PAPER 88-099)

A proposal for a balcony to provide for the addition of external payloads on the Space Station is presented. A balcony would serve as a link between payloads and the mother platform, and would be adaptable and modular to match the requirements of various payloads. The payload support functions of a balcony and the possible role of a balcony in EVA activites are discussed. Case scenarios for balcony use are given, including a Columbus scenario, and the case of the advanced manned Space Station. Candidate payloads, balcony architecture and operations, and three possible designs for a balcony are examined. R.B.

A89-17754#

CONCEPT OF INFLATABLE ELEMENTS SUPPORTED BY TRUSS STRUCTURE FOR REFLECTOR APPLICATION

SUMIO KATO, YASUHIRO TAKESHITA, 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) et al. IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 15 p. refs

(IAF PAPER 88-274)

A concept of a modularized inflatable space structure which is composed of inflatable elements supported by truss structure for high-precision reflector missions in relatively near future is proposed to avoid some difficulties of conventional inflatable concept, such as the lack of inside hard points and the precisely accurate manufacturing process. Some fundamental characteristics for surface accuracy of inflatable elements are studied, appropriate truss back-up structure is investigated, and the relevant preliminary test results are described. Some aspects of the application of the concept to space VLBI antenna are also introduced. Author

A89-18046

OPTIMUM DESIGN OF NONLINEAR SPACE TRUSSES

M. P. SAKA (University of Bahrain, Isa Town) (Institution of Civil Engineers, Institution of Highways and Transportation, British Computer Society, et al., CIVIL-COMP 87: International Conference on Civil and Structural Engineering Computing, 3rd, London, England, Sept. 22-24, 1987) Computers and Structures (ISSN 0045-7949), vol. 30, no. 3, 1988, p. 545-551. refs

A structural optimization algorithm which takes into account the nonlinear response of a structure beyond the elastic limit is developed and demonstrated. The derivation is given in detail, and results for sample problems involving space truss structures with 9, 24, 42, and 56 bars are presented in extensive tables and graphs. The algorithm is shown to give accurate results while requiring significantly greater computation time than methods without nonlinear analysis. T.K.

A89-20574

STRUCTURAL CONCEPTS FOR FUTURE SPACE SYSTEMS

JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 8, Dec. 1988, p. 10-14.

The NASA Space Station's baseline configuration, at 125 m in length and 100 m in width, exemplifies large space structures for which developments in materials, assembly techniques, and dynamic stability and control methods must be significantly advanced. During the early planning stages, it was determined that a planar truss structure would both meet design requirements and permit growth and versatility; a 5-m strut length has been adopted. Attention is presently given to the beam structures, truss structures, and deployable folding-truss structures that have been devised and evaluated, as well as to the Mobile Remote Manipulator System that has been developed for their erection in orbit. O.C.

A89-24244*# California Inst. of Tech., Pasadena.

IDENTIFICATION OF THE ZERO-G SHAPE OF A SPACE BEAM

GARY J. BALAS (California Institute of Technology, Pasadena) and CHARLES D. BABCOCK (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1, p. 728-736) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Nov.-Dec. 1988, p. 405-412. Research supported by the California Institute of Technology and NASA. Previously cited in issue 14, p. 2115, Accession no. A87-33636.

A89-30805#

DYNAMICS AND CONTROL OF A SPATIAL ACTIVE TRUSS ACTUATOR

H. H. ROBERTSHAW, R. H. WYNN, JR., H. F. KUNG, S. L. HENDRICKS, and W. W. CLARK (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1473-1479. refs

(AIAA PAPER 89-1328)

The methods and the results of an analytical study of the vibration reduction potential of an octahedral, three degree-of-freedom, spatial active truss are presented. The continuum controlled was a 1/4-inch brass rod 75 inches long, intrumented with strain gages to transduce strain. The active truss had extensible links with machine screws driven by dc motors. Good vibration control was achieved with good agreement between the experiment and the analysis. Author

A89-30821#

THE NEW DEPLOYABLE TRUSS CONCEPTS FOR LARGE ANTENNA STRUCTURES OR SOLAR CONCENTRATORS

K. A. TAKAMATSU (Fuji Heavy Industries, Ltd., Tochigi, Japan) and J. ONODA (Tokyo, University, Kanagawa, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1629-1639. refs

(AIAA PAPER 89-1346)

An account is given of the design features and deployment operation of three space frame systems applicable to the formation of large, spacecraft-stowable antennas and solar concentrators; these are designated a 'spatial diagonal-stiffened truss' (SDT), a 'sliding-hinge double-folder-II' (SHDF-II), and a 'deployable solar concentrator' (DSC). The SDT and SHDF-II are two-dimensional deployable truss structures, while the DSC additionally incorporates rigid reflector plates. The most significant feature of the DSC is the capability for automated deployment. Functioning models of all three structures have been successfully constructed and tested. O.C.

N89-10936*# General Dynamics Corp., San Diego, CA. Space Systems Div.
DEVELOPMENT OF A VERIFICATION PROGRAM FOR DEPLOYABLE TRUSS ADVANCED TECHNOLOGY Final Report
JACK E. DYER Sep. 1988 161 p
(Contract NAS1-18274)
(NASA-CR-181703; NAS 1.26:181703) Avail: NTIS HC A08/MF A01 CSCL 22B

Use of large deployable space structures to satisfy the growth demands of space systems is contingent upon reducing the associated risks that pervade many related technical disciplines. The overall objectives of this program was to develop a detailed plan to verify deployable truss advanced technology applicable to future large space structures and to develop a preliminary design of a deployable truss reflector/beam structure for use a a technology demonstration test article. The planning is based on a Shuttle flight experiment program using deployable 5 and 15 meter aperture tetrahedral truss reflections and a 20 m long deployable truss beam structure. The plan addresses validation of analytical methods, the degree to which ground testing adequately simulates flight and in-space testing requirements for large precision antenna designs. Based on an assessment of future NASA and DOD space system requirements, the program was developed to verify four critical technology areas: deployment, shape accuracy and control, pointing and alignment, and articulation and maneuvers. The flight experiment technology verification objectives can be met using two shuttle flights with the total experiment integrated on a single Shuttle Test Experiment Platform (STEP) and a Mission Peculiar Experiment Support Structure (MPESS). First flight of the experiment can be achieved 60 months after go-ahead with a total program duration of 90 months. Author

N89-11794# CSA Engineering, Inc., Palo Alto, CA.
SCALING OF LARGE SPACE STRUCTURE JOINTS Final Report, Jul. 1987 - Feb. 1988
DAVID A. KIENHOLZ Jun. 1988 30 p
(Contract F33615-87-C-3239)
(AD-A197027; CSA-880204; AFWAL-TR-88-3047) Avail: NTIS HC A03/MF A01 CSCL 22/5

Large orbiting spacecraft will often use trusses as primary, load-carrying structure. Favorable strength/weight and stiffness/weight ratios as well as compact stowage make trusses a natural candidate for erectable space structures. However the sheer size of proposed spacecraft raises important questions with respect to verification of their predicted dynamic properties. Assembled orbiting structures will be, in many cases, much too large for ground vibration testing. Some are not even capable of supporting their own weight in the earth's gravity. Various truss structures currently proposed for on-orbit assembly are too large to be tested on the ground. This has led to renewed interest in scale models for verification of predicted structural dynamic properties. However, a realistic scale model truss requires joints whose stiffness and damping properties are in-scale with those of the full-size counterpart. The primary conclusion is that accurate scale modeling of erectable trusses is quite feasible. GRA

N89-18523# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
ADVANCED THERMAL DESIGN ASSESSMENT STUDY. VOLUME 1: EXECUTIVE SUMMARY
C. GUENASSIA, comp., B. MIEDZA, comp., and R. ROHR, comp Paris, France ESA 1988 21 p Prepared in cooperation with Erno Raumfahrttechnik G.m.b.H., Bremen, Fed. Republic of Germany, and MATRA Espace, Paris-Velizy, France
(Contract ESTEC-6519/85-NL-MA(SC))
(MBB-ATA-RP-ER-046-VOL-1; ESA-CR(P)-2660-VOL-1; ETN-89-93921) Avail: NTIS HC A03/MF A01

Technical and economic advantages of active thermal control of spacecraft were assessed. It is concluded that in designing a spacecraft at lowest system cost, communication and scientific satellites should be considered separately because of the potential high savings in the repeater system of communications spacecraft when constant temperatures can be guaranteed throughout all mission phases. For other types of electronic equipment the savings are considerably less. Savings in this area have to be compared with increases in the thermal control subsystem and in some other areas: differences in power demand and influence on the mass budget by the thermal control subsystem, power subsystem, and the consumables of the propulsion subsystem with impact on the launch cost. The investigations show that systems with fluid or two-phase loops demand higher effort, but a concept with feedback controlled variable conductance heat pipes employed on a spacecraft leads to a system which is less expensive than existing designs. A cost saving of 9 pct of the platform cost is evaluated for a communications spacecraft compared with the basic passive concept and 14 percent for a EURECA type spacecraft compared with the fluid loop design. ESA

04

STRUCTURAL AND THERMAL ANALYSIS

Includes structural analysis and design, thermal analysis and design, analysis and design techniques, and thermal control systems.

A89-10119*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RECENT DEVELOPMENTS IN THE EXPERIMENTAL IDENTIFICATION OF THE DYNAMICS OF A HIGHLY FLEXIBLE GRID
RAYMOND C. MONTGOMERY and TERRI LAZARUS (NASA, Langley Research Center, Hampton, VA) ASME, Winter Annual Meeting, 108th, Boston, MA, Dec. 13-18, 1987. 8 p. refs
(ASME PAPER 87-WA/DSC-19)

Control effectiveness tests of reaction wheel actuators attached to a highly flexible grid are reported. Analytic determination of actuator control effectiveness is accomplished with finite-element modeling. Experimental determination is done with a least-square parameter identification algorithm that identifies the control coefficients of the second-order difference equation model of each vibration mode. The algorithm assumes a model with frequency and damping predetermined from free-decay tests for each mode. Accounting for the difference in forced and resonant frequency was necessary to produce control effectiveness estimates that are in reasonable agreement with the analytic predictions. The average error for control effectiveness coefficients greater than 5/sq sec was 6.384 percent. Author

A89-10495
HYBRID THERMAL CIRCULATION SYSTEM FOR FUTURE SPACE APPLICATIONS [HYBRID-THERMALKREISLAUF FUER ZUKUENFTIGE RAUMFAHRT-ANWENDUNGEN]
H. G. WULZ, H. KREEB, and W. FLECK (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 72-77. In German.
(DGLR PAPER 87-092)

The design concept and prototype performance of a hybrid two-phase circulation system for temperature control of large spacecraft are reported. The system comprises a mechanically pumped loop for startup and overload conditions and a capillary-pumped loop capable of normal operation, decoupled from the mechanical system, with no consumption of electrical power. The advantages of the hybrid system include high heat-transfer capacity (10-200 kW m, depending on the media and evaporators employed), self-regulation, vibration and shock resistance, heat-load sharing capability, and long-term maintenance-free operation. A model of the capillary-pumped component is currently being tested and has demonstrated transport of 1-2 kW over 10-15 m. T.K.

A89-10534
DYNAMIC SIMULATION, AN INDISPENSABLE TOOL IN THE CONSTRUCTION AND OPERATION OF FUTURE ORBITAL SYSTEMS [DYNAMISCHE SIMULATION, EIN UNVERZICHTBARES WERKZEUG ZUM BAU UND BETRIEB KUENFTIGER ORBITALSYSTEME]
ST. GRAUL (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 406-413. In German.
(DGLR PAPER 87-127)

The implications of the spacecraft and missions planned for the ESA Columbus program on the International Space Station for structural design and analysis are reviewed and illustrated with extensive drawings, graphs, and diagrams. The important differences between previous single-spacecraft missions and the complex multibody systems of the Columbus orbital infrastructure are discussed, and it is pointed out that actual test simulations of large structures on the ground are not feasible. The numerical algorithms used to simulate the nonlinear behavior of large flexible systems are described, and particular attention is given to the major Columbus components, robotics applications, and orbital-capture and docking tasks. T.K.

A89-15340* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE SOLAR DYNAMIC RADIATOR WITH A HISTORICAL PERSPECTIVE
K. L. MCLALLIN (NASA, Lewis Research Center, Cleveland, OH), M. L. FLEMING (LTV Corp., Missiles and Electronics Group, Dallas, TX), F. W. HOEHN, and R. HOWERTON (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 335-340. refs

A historical perspective on pumped loop space radiators provides a basis for the design of the Space Station Solar Dynamic (SD) power module radiator. SD power modules, capable of generating 25 kWe each, are planned for growth Station power requirements. The Brayton (cycle) SD module configuration incorporates a pumped loop radiator that must reject up to 99 kW. The thermal/hydraulic design conditions in combination with required radiator orientation and packaging envelope form a unique set of constraints as compared to previous pumped loop radiator systems. Nevertheless, past program successes have demonstrated a technology base which can be applied to the SD radiator development program to ensure a low risk, low cost system. Author

A89-15341* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THERMAL DISTORTION ANALYSIS OF THE SPACE STATION SOLAR DYNAMIC CONCENTRATOR
JEFFERY J. TRUDELL, KENT S. JEFFERIES (NASA, Lewis Research Center, Cleveland, OH), JOSEPH F. BAUMEISTER (NASA, Lewis Research Center; Analex Corp., Cleveland, OH), and VITHAL DALSANIA (NASA, Lewis Research Center; W. L. Tanksley and Associates, Inc., Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 341-349. Previously announced in STAR as N88-25475. refs

A method was developed to evaluate the thermal distortion of the Space Station Solar Dynamic Concentrator and the effects of thermal distortion on concentrator optical performance. The analytical method includes generating temperature distributions with TRASYS and SINDA models, interfacing the SINDA results with the SINDA-NASTRAN Interface Program (SNIP), calculating thermal distortion with a NASTRAN/PATRAN finite element model, and providing flux distribution maps within the receiver with the ray tracing OFFSET program. Temperature distributions, thermally induced slope errors, and flux distribution maps within the receiver are discussed. Results during a typical orbit indicate that temperatures of the hexagonal panels and triangular facets range between -18 and 99 C (-1 to 210 F), facet rotations are less than 0.2 mrad, and a change in facet radius due to thermal flattening is less than 5 percent. The predicted power loss with thermal distortion effects was less than 0.3 percent. The thermal distortion of the Solar Dynamic concentrator has negligible effect on the flux distribution within the receiver cavity. Author

A89-15645
DESIGN OF SPACECRAFT VERIFIED BY TEST IN A MODULAR FORM
EBERHARD ERBEN (MBB/ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) and C. STAVRINIDIS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 1721-1729. Sponsorship: European Space Research and Technology Centre. refs
(Contract ESTEC-6891/85/NL/PH(SC))

A modular verification procedure is described whereby the identification and qualification testing of a complete mechanical structure is performed on the modular segment level rather than on the integrated assembly level. The reliability of the modular verification procedure depends to a great extent on the quality of the analytical models describing the modular segments and forming the basis for the synthesis of the integrated assembly model. Synthesis methods for different data sets are examined. V.L.

A89-16161*# Texas Univ., Austin.
BLOCK-KRYLOV COMPONENT SYNTHESIS METHOD FOR STRUCTURAL MODEL REDUCTION
ROY R. CRAIG, JR. (Texas, University, Austin) and ARTHUR L. HALE (General Dynamics Corp., Space Systems Div., San Diego, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 562-570. refs
(Contract NAS9-17254)

A new analytical method is presented for generating component shape vectors, or Ritz vectors, for use in component synthesis. Based on the concept of a block-Krylov subspace, easily derived recurrence relations generate blocks of Ritz vectors for each component. The subspace spanned by the Ritz vectors is called a block-Krylov subspace. The synthesis uses the new Ritz vectors rather than component normal modes to reduce the order of large, finite-element component models. An advantage of the Ritz vectors is that they involve significantly less computation than component normal modes. Both 'free-interface' and 'fixed-interface' component models are derived. They yield block-Krylov formulations paralleling the concepts of free-interface and fixed-interface component modal synthesis. Additionally, block-Krylov reduced-order component models are shown to have special disturbability/observability properties. Consequently, the method is attractive in active structural control applications, such as large space structures. The new fixed-interface methodology is demonstrated by a numerical example. The accuracy is found to be comparable to that of fixed-interface component modal synthesis. Author

A89-17751#
A CONTRIBUTION TO THE STUDY OF THE PRECISE PRESSURIZED STRUCTURES
C. ARDUINI, U. PONZI (Roma I, Universita, Rome, Italy), and M. C. BERNASCONI (Contraves AG, Zurich, Switzerland) IAF,

International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 27 p. refs
(IAF PAPER 88-268)

An analytical study of membrane toroidal inflatable structures for outer space is reported. The analysis determines the most economic configuration for an assembly scheme for a perfect torus. The theoretical models considered include a circular homogeneous isotropic torus reference model, a polygonal approximation model, and a parallel approximation model. The analytical approaches are checked against a numerical Nastran model for the polygonal cut case. C.D.

A89-20129#
THERMALLY-INDUCED BENDING VIBRATION OF THIN-WALLED BOOM WITH TIP MASS CAUSED BY RADIANT HEATING
SEINOSUKE SUMI, MASAHIKO MUROZONO, and TAKAYUKI IMOTO Kyushu University, Technology Reports (ISSN 0023-2718), vol. 61, Aug. 1988, p. 449-455. In Japanese, with abstract in English. refs

The flexural thermal flutter of long spacecraft boom subjected to solar heating is presented. The boom with tip mass is modeled as a thin-walled tube of closed circular cross section. The equation of thermally-induced bending vibration of the system is obtained assuming that the boom is heated by unidirectional solar radiation and that net heat absorption depends on the angle of incidence of heat radiation with respect to the boom. The third-order characteristic equation considering the stability of bending vibration around the statically equilibrium state is evaluated using the Routh-Hurwitz stability criterion. Unstable boundary curves, which are dependent upon three system parameters and the direction of radiant heating, are defined in the parameter planes. Some typical displacement responses based on the numerical solution are also presented. Author

A89-24195
OPTIMIZATION OF SPACECRAFT THERMAL CONTROL SYSTEMS [OPTIMIZATSIIA SISTEM TERMOREGULIROVANIIA KOSMICHESKIKH APPARATOV]
VLADIMIR V. MALOZEMOV and NATAL'IA S. KUDRIAVTSEVA Moscow, Izdatel'stvo Mashinostroenie, 1988, 112 p. In Russian. refs

Mathematical models of spacecraft thermal-control units and systems are presented. A method is developed for solving thermal-control optimization problems. In addition, engineering methods and algorithms are developed for choosing appropriate design parameters for spacecraft thermal-control systems for stationary and nonstationary operating conditions. B.J.

A89-25068#
HEAT-PUMP-AUGMENTED RADIATOR FOR HIGH POWER SPACECRAFT THERMAL CONTROL
B. L. DROLEN (Hughes Aircraft Co., Los Angeles, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(Contract F33615-85-C-2557)
(AIAA PAPER 89-0077)

A simple model of a heat-pump-augmented spacecraft is used to study the effect of the heat pump on the overall mass and total radiator area of spacecraft employing one of four different power sources capable of generating 10-100 kW of electrical power. It is demonstrated that significant radiator area and system mass saving can be achieved with heat pumps having a specific mass of about 10 kg/kW(cooled) or lower. Heat pumps using waste heat generated by the power source provide greater mass savings than those that use the generated electrical energy. R.R.

A89-25271*# NASA Space Station Program Office, Reston, VA.
AN INTEGRATED MODEL OF THE SPACE STATION FREEDOM ACTIVE THERMAL CONTROL SYSTEM
JOHN J. TANDLER (Grumman Corp., Grumman Space Station Freedom Program Support Div., Reston, VA) and VINCENT J. BILARDO, JR. (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0319)

A flexible, generic model of the Space Station Freedom active thermal control system has been developed which is designed to analyze dynamic interactions of the major subsystems of the ATCS. Models are described for the components of the central thermal bus, the radiator external thermal environment, and the internal thermal control system. Two programs are described which facilitate the development of the integrated ATCS model. The first, SIMRAD, simplifies an external thermal environment model given a desired level of accuracy in integrated model performance. The model reduction technique is shown to reduce model execution time significantly while maintaining the desired accuracy. The second, GENFLU, generates SINDA/FLUINT input code for the evaporator and load interface models and automates the integration of load submodels. The component submodels and integration techniques were used to create an integrated model of the thermal control system for an early assembly flight configuration. The results demonstrate the utility of the integrated model in studying dynamic interactions of the ATCS subsystems. Author

A89-25436*# NASA Space Station Program Office, Reston, VA.
PRELIMINARY CONTROL/STRUCTURE INTERACTION STUDY OF COUPLED SPACE STATION FREEDOM/ASSEMBLY WORK PLATFORM/ORBITER
SUDEEP K. SINGH (Grumman Corp., Grumman Space Station Program Support Div., Reston, VA) and ALAN J. LINDENMOYER (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(AIAA PAPER 89-0543)

Results are presented from a preliminary control/structure interaction study of the Space Station, the Assembly Work Platform, and the STS orbiter dynamics coupled with the orbiter and station control systems. The first three Space Station assembly flight configurations and their finite element representations are illustrated. These configurations are compared in terms of control authority in each axis and propellant usage. The control systems design parameters during assembly are computed. Although the rigid body response was acceptable with the orbiter Primary Reaction Control System, the flexible body response showed large structural deflections and loads. It was found that severe control/structure interaction occurred if the stiffness of the Assembly Work Platform was equal to that of the station truss. Also, the response of the orbiter Vernier Reaction Control System to small changes in inertia properties is examined. R.B.

A89-27824
IMPROVEMENTS IN PASSIVE THERMAL CONTROL FOR SPACECRAFT
A. M. WHALLEY (Pilkington PE, Ltd., Space Technology, Bodelwyddan, Wales) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 7 p.
(SAE PAPER 881022)

This paper presents test results and suggestions for improvement as part of an overall optimization program for passive thermal control Optical Solar Reflectors (OSRs). The OSR acts as a thermal control device for satellites by reflecting incident solar radiation while simultaneously radiating internally generated heat harmlessly into the surrounding environment. Options for the enhancement of OSR thermal properties, through the use of thermal control coatings, by either a reduction in the overall solar absorptance or an increase in the IR emittance are discussed. A process of strength enhancement of the OSRs by immersion in an acid solution is also examined. The author concludes by suggesting a reexamination of protective coatings already used on the existing product. S.A.V.

A89-27863* Grumman Aerospace Corp., Bethpage, NY.
PROTOTYPE SPACE ERECTABLE RADIATOR SYSTEM GROUND TEST ARTICLE DEVELOPMENT

JOSEPH P. ALARIO (Grumman Corp., Space Systems Div., Bethpage, NY) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p. refs
(Contract NAS9-17498)
(SAE PAPER 881066)

A prototype heat rejecting system is being developed by NASA-JSC for possible space station applications. This modular system, the Space-Erectable Radiator System Ground Test Article (SERS-GTA) with high-capacity radiator panels, can be installed and replaced on-orbit. The design, fabrication and testing of a representative ground test article are discussed. Acceptance test data for the heat pipe radiator panel and the whiffletree clamping mechanism have been presented. A.A.F.

A89-27865* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION THERMAL TEST BED STATUS AND PLANS
TIMOTHY K. BRADY (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 16 p. refs
(SAE PAPER 881068)

The accomplishments, current status, and future plans of the thermal test bed program for Space Station thermal management are discussed. This program is intended to support the design and development of the thermal control systems for the Space Station. The topics discussed include heat pipe radiator evaluation, modular panel tests, two-phase heat transport, and testing of thermal buses using ammonia as the working fluid. A.A.F.

A89-27866* NASA Space Station Program Office, Reston, VA.
SPACE STATION THERMAL CONTROL DURING ON-ORBIT ASSEMBLY
VINCENT J. BILARDO, JR. (NASA, Space Station Freedom Program Office, Reston, VA) and ALBERT W. CARLSON (Grumman Corp., Space Station Program Support Div., Reston, VA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 17 p. refs
(SAE PAPER 881070)

This paper summarizes the Space Station program requirements for the Thermal Control System (TCS), and outlines the capabilities of the TCS for each assembly configuration. The TCS architecture for the completed assembly configuration is described, consisting of an active TCS (ATCS) and a passive TCS (PTCS). The four ATCS subsystems are described, including the two-phase ammonia central ATCS, photovoltaic power module, attached payload accommodation equipment and the single-phase water internal ATCS. Author

A89-27880* Sundstrand Corp., Rockford, IL.
REDUCED GRAVITY AND GROUND TESTING OF A TWO-PHASE THERMAL MANAGEMENT SYSTEM FOR LARGE SPACECRAFT
D. G. HILL, K. HSU (Sundstrand Corp., Rockford, IL), R. PARISH, and J. DOMINICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p. refs
(Contract NAS9-17195)
(SAE PAPER 881084)

Experiments were performed aboard the NASA-JSC KC-135 aircraft to study the effect of reduced gravity on two-phase (liquid/vapor) flow and condensation. A prototype two-phase thermal management system for a large spacecraft was tested. Both visual observation and photography of the flow regimes were made. Ground test simulations of the KC-135 flight tests were conducted for comparison purposes. Two-phase pressure drops were predictable by the Heat Transfer Research Institute (HTRI) method, or the Friedel correlation. A.A.F.

A89-27898
SOLID/VAPOR ADSORPTION HEAT PUMPS FOR SPACE APPLICATION
SAM V. SHELTON, WILLIAM J. WEPFER, and J. SCOTT PATTON (Georgia Institute of Technology, Atlanta) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 10 p. refs
(SAE PAPER 881107)

A solid/vapor heat pump with its variable temperature and load capabilities is ideal for the thermal and environmental control of space systems. Merits include utilization of safe refrigerants, minimal electric power requirements, and simplicity of components. Heat rejection and cooling is possible over a range of temperatures, and the selection of various refrigerant/absorption pairs enables designs for various applications. This system is being considered for use in the extravehicular mobility units of spacecrews both for maintenance of comfort and waste heat dissipation. A residential testing has proved the feasibility of the solid/vapor concept. A.A.F.

A89-29218#
PROBLEMS OF THERMAL PROTECTION IN SPACE APPLICATIONS [PROBLEMES DE PROTECTION THERMIQUE DANS LES APPLICATIONS SPATIALES]
J. F. STOHR (ONERA, Chatillon-sous-Bagneux, France) (Societe Francaise des Thermiciens, Journee d'Etudes, Paris, France, Apr. 20, 1988) ONERA, TP, no. 1988-36, 1988, 10 p. In French.
(ONERA, TP NO. 1988-36)

Following a review of the flux and temperature conditions encountered by the Hermes vehicle upon reentry, means of thermal protection are discussed. Problems posed by the use of the ceramic-ceramic composites required for thermal protection are considered, with special attention given to the deformation mode and high-temperature oxidation behavior of these materials. Problems related to the thermal protection of the cryogenic tanks are also reviewed. R.R.

A89-30045
FLUENCE EQUIVALENCY OF MONOENERGETIC AND NONMONOENERGETIC IRRADIATION OF THERMAL CONTROL COATINGS [EKVIVALENTNOST' FLIUENSOV MONO- I NEMONOENERGETICHESKOGO VOZDEISTVIIA NA TERMOREGULIRUIUSHCHIE POKRYTIIA]
G. G. SOLOV'EV and A. P. GRASHCHENKO Fizika i Khimiia Obrabotki Materialov (ISSN 0015-3214), Jan.-Feb., p. 54-56. In Russian.

When using monoenergetic irradiation to simulate the effect of irradiation with a wide energy distribution acting on the external surfaces of spacecraft, the fluence of monoenergetic radiation equivalent to that of natural radiation must be calculated. Here, expressions for calculating the equivalent fluences are presented for three types of models of the radiation-optical degradation of thermal control coatings. V.L.

A89-30542
A NOTE ON PLANAR KINETO-ELASTO-DYNAMICS
MARCO GIOVAGNONI (Udine, Universita, Italy) Meccanica (ISSN 0025-6455), vol. 23, Sept. 1988, p. 170-178. Research supported by MPI. refs

Dynamic analyses of flexible linkages are generally performed by considering small displacements from a predefined reference configuration. A reference mechanism is commonly defined for this purpose. The definition of a reference mechanism is subjected to some restricting conditions which are analyzed here for planar articulated linkages. A simplified form of the equations of motion for flexible planar mechanisms is documented. The virtual displacement is approximated in the same way as accelerations, when secondary terms are neglected. A comparison between experimental findings and results of numerical integrations shows that, in the present case-study, the introduced approximation only corresponds to a light stiffening of the mathematical model. Author

A89-30763*# Lockheed Engineering and Sciences Co., Houston, TX.
DYNAMIC ANALYSIS OF THE SPACE STATION TRUSS STRUCTURE BASED ON A CONTINUUM REPRESENTATION
SEGUN THOMAS (Lockheed Engineering and Sciences, Houston,

TX) and NORRIS STUBBS (Texas A & M University, College Station) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1062-1068. refs
(Contract NAS9-17900)
(AIAA PAPER 89-1280)

A mathematical model is developed for the real-time simulation of a Space Station. First, a continuum equivalent representation of the Space Station truss structure is presented which accounts for extensional, transverse, and shear deformations and coupling between them. The procedure achieves a significant reduction in the degrees of freedom of the system. Dynamic equations are then formulated for the continuum equivalent of the Space Station truss structure based on the matrix version of Kane's dynamical equations. Finally, constraint equations are derived for the dynamic analysis of flexible bodies with closed loop configuration. V.L.

A89-30792#
INTEGRATED DIRECT OPTIMIZATION OF STRUCTURE/REGULATOR/OBSERVER FOR LARGE FLEXIBLE SPACECRAFT
JUNJIRO ONODA and NAOYUKI WATANABE (Tokyo, University, Sagamihara, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1336-1344. refs
(AIAA PAPER 89-1313)

An numerical direct approach to design an optimal controller composed of regulator and observer has been proposed for integrated structure/controller optimization of flexible spacecraft. The approach takes account of uncontrolled residual modes. Therefore, it does not only optimize based on an actual performance index degraded by the residual modes but also suppresses the spillover instability. The approach has been applied to a simply supported beam examples first, and the characteristics of the resulting system have been investigated. The examples have demonstrated that the resulting controller is stable even when LQG controller is unstable. Insensitivity of the resulting system to parameter variations is also demonstrated compared with LQG controller. Subsequently, the approach has been incorporated in a structure/controller simultaneous optimization scheme. The practicality and effectiveness of the present scheme has been demonstrated in a beam-like flexible spacecraft example. Author

A89-30819*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PRACTICES IN ADEQUATE STRUCTURAL DESIGN
ROBERT S. RYAN (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1612-1622. refs
(AIAA PAPER 89-1344)

An account is given of the guidelines for safe and reliable space vehicle design, especially in the structural engineering area, which have been formulated by NASA in the aftermath of the Space Shuttle Challenger accident in 1986. Illustrative examples are presented from state-of-the-art, performance-driven hardware whose design ineluctably gives rise to a high sensitivity to small variations and uncertainties. It is recommended that such hardware be designed with a view to easy inspectability and manufacturability, with emphasis on the role played in system structures by fracture mechanics. Static and dynamic coupling effects must be precluded wherever possible. O.C.

A89-30882#
CHARACTERIZING THE DAMAGE POTENTIAL OF RICOCHET DEBRIS DUE TO AN OBLIQUE HYPERVELOCITY IMPACT
WILLIAM P. SCHONBERG (Alabama, University, Huntsville) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 2180-2185. refs
(AIAA PAPER 89-1410)

All long-duration spacecraft are susceptible to impacts by meteoroids and pieces of orbiting space debris. Such impacts are expected to occur at extremely high speeds and are expected to strike the spacecraft structure at oblique angles. High obliquity impacts have an especially high potential to cause damage to external spacecraft systems because of the extremely large volume of ricochet debris that they produce. It is found that the diameter of the most damaging ricochet debris particle can be as large as 40 percent of the original projectile diameter and can travel at speeds between 24 and 36 percent of the original projectile impact velocity. It is concluded that obliquity effects of high-speed impacts must be considered in the design of any structure exposed to the meteoroid and space debris environment. Author

A89-31919*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THERMAL-STRESS-FREE FASTENERS FOR JOINING ORTHOTROPIC MATERIALS
MAX L. BLOSSER (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 27, April 1989, p. 472-478. Previously cited in issue 19, p. 3036, Accession no. A87-44836. refs

N89-10933# Oak Ridge National Lab., TN.
PHASE CHANGE PROBLEM RELATED TO THERMAL ENERGY STORAGE IN THE MANNED SPACE STATION
D. G. WILSON, J. B. DRAKE, and R. E. FLANERY 1988 3 p
Presented at the Institute for Mathematics and Its Applications Seminar, Minneapolis, Minn., 23 Feb. 1988
(Contract DE-AC05-84OR-21400)
(DE88-011390; CONF-880282-1) Avail: NTIS HC A02/MF A01

The system discussed consists of a solar collector lined with small metal canisters filled with a high temperature phase change material (PCM), lithium fluoride salt. The canisters are small enough to fit comfortably in the palm of one's hand and there are a hundred or more of them. A heat transfer fluid, an inert gas such as helium or neon, circulates through the pipes that pass through the metal canisters and carries heat away to turbines, generators, etc. The continual melting and refreezing of the PCM smears out the delivery of the solar energy to the transfer fluid, and hence, to the heat engines beyond. The motivation for using a PCM based thermal energy storage system is that a properly sized such system can store and deliver energy over a narrow temperature range near the melting point of the PCM, thus avoiding extreme temperature variations. DOE

N89-12602*# Analytic Sciences Corp., Washington, DC.
THERMAL/STRUCTURAL DESIGN VERIFICATION STRATEGIES FOR LARGE SPACE STRUCTURES
DAVID BENTON *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 241-252 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

Requirements for space structures of increasing size, complexity, and precision have engendered a search for thermal design verification methods that do not impose unreasonable costs, that fit within the capabilities of existing facilities, and that still adequately reduce technical risk. This requires a combination of analytical and testing methods. This requires two approaches. The first is to limit thermal testing to sub-elements of the total system only in a compact configuration (i.e., not fully deployed). The second approach is to use a simplified environment to correlate analytical models with test results. These models can then be used to predict flight performance. In practice, a combination of these approaches is needed to verify the thermal/structural design of future very large space systems. Author

N89-12603*# Aeritalia S.p.A., Turin (Italy). Space Systems Group.
IRIS THERMAL BALANCE TEST WITHIN ESTEC LSS
PIERO MESSIDORO, MARINO BALLESIO, and J. P. VESSAZ (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 253-267 1988
Avail: NTIS HC A21/MF A01 CSCL 14/2
The Italian Research Interim Stage (IRIS) thermal balance test was successfully performed in the ESTEC Large Space Simulator (LSS) to qualify the thermal design and to validate the thermal mathematical model. Characteristics of the test were the complexity of the set-up required to simulate the Shuttle cargo bay and allowing IRIS mechanism actioning and operation for the first time in the new LSS facility. Details of the test are presented, and test results for IRIS and the LSS facility are described. Author

N89-12613*# Selenia Spazio S.p.A., Rome (Italy).
THE SOLAR SIMULATION TEST OF THE ITALSAT THERMAL STRUCTURAL MODEL Abstract Only
M. GIOMMI, S. LIVERANI, and G. P. SANTIN *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 395-396 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2
The ITALSAT structural/thermal model (STM) was submitted to a solar simulation test in order to verify the spacecraft thermal design and the thermal mathematical model which will be used to predict the on orbit temperatures. The STM was representative of the flight model in terms of configuration, structures, appendages and thermal hardware; dissipating dummy units were used to simulate the electronic units. The test consisted of the main phases: on station (beginning of life), on station (end of life), and transfer orbit. Preliminary results indicate that the test performances were satisfactory. The spacecraft measured temperatures were up to 15 degrees higher than the predicted ones. This imposes a careful correlation analysis in order to have reliable flight temperature predictions. Author

N89-13731*# Grumman Aerospace Corp., Bethpage, NY. Space Systems Div.
SOLAR DYNAMIC HEAT REJECTION TECHNOLOGY. TASK 1: SYSTEM CONCEPT DEVELOPMENT Final Report
ERIC GUSTAFSON and ALBERT W. CARLSON Jun. 1987 120 p
(Contract NAS3-24665)
(NASA-CR-179618; NAS 1.26:179618) Avail: NTIS HC A06/MF A01 CSCL 20/4
The results are presented of a concept development study of heat rejection systems for Space Station solar dynamic power systems. The heat rejection concepts are based on recent developments in high thermal transport capacity heat pipe radiators. The thermal performance and weights of each of the heat rejection subsystems is addressed in detail, and critical technologies which require development tests and evaluation for successful demonstration are assessed and identified. Baseline and several alternate heat rejection system configurations and optimum designs are developed for both Brayton and Rankine cycles. The thermal performance, mass properties, assembly requirements, reliability, maintenance requirements and life cycle cost are determined for each configuration. A specific design was then selected for each configuration which represents an optimum design for that configuration. The final recommendations of heat rejection system configuration for either the Brayton or Rankine cycles depend on the priorities established for the evaluation criteria. Author

N89-14069# Pacific Northwest Labs., Richland, WA.
ROTATING SOLID RADIATIVE COOLANT SYSTEM FOR SPACE NUCLEAR REACTORS
W. J. APLEY and A. L. BABB May 1988 7 p Presented at the 24th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Boston, Mass., 11 Jul. 1988
(Contract DE-AC06-76RL-01830)
(DE88-016312; PNL-SA-15433; CONF-880764-4) Avail: NTIS HC A02/MF A01
The RING power system described in this paper is proposed as a primary or emergency heat rejection system for advanced space reactor power applications. The system employs a set of four (4) counter-rotating, 90 degree offset, coolant-carrying rings. The rings (segmented, corrugated, finned, thin-walled pipes, filled with liquid lithium) pass through a cavity heat exchanger and reradiate the absorbed heat to the space environment. DOE

N89-14392* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
CAPILLARY HEAT TRANSPORT AND FLUID MANAGEMENT DEVICE Patent
JAMES W. OWEN, inventor (to NASA) 13 Sep. 1988 9 p
Filed 30 Jun. 1987 Supersedes N87-29769 (25 - 24, p 3309)
(NASA-CASE-MFS-28217-1; US-PATENT-4,770,238; US-PATENT-APPL-SN-067844; US-PATENT-CLASS-165-104.26; US-PATENT-CLASS-165-104.14; US-PATENT-CLASS-122-366)
Avail: US Patent and Trademark Office CSCL 20/4
A passive heat transporting and fluid management apparatus including a housing in the form of an extruded body member having flat upper and lower surfaces is disclosed. A main liquid channel and at least two vapor channels extend longitudinally through the housing from a heat input end to a heat output end. The vapor channels have sintered powdered metal fused about the peripheries to form a porous capillary wick structure. A substantial number of liquid arteries extend transversely through the wicks adjacent the respective upper and lower surfaces of the housing, the arteries extending through the wall of the housing between the vapor channels and the main liquid channel and open into the main liquid channel. Liquid from the main channel enters the artery at the heat input end, wets the wick and is vaporized. When the vapor is cooled at the heat output end, the condensed vapor refills the wick and the liquid reenters the main liquid channel.
Official Gazette of the U.S. Patent and Trademark Office

N89-15970*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A COMPARISON OF TWO TRUSSES FOR THE SPACE STATION STRUCTURE
THOMAS R. SUTTER and HAROLD G. BUSH Washington, DC Mar. 1989 23 p
(NASA-TM-4093; L-16540; NAS 1.15:4093) Avail: NTIS HC A03/MF A01 CSCL 22/2
The structural performance of two truss configurations, the orthogonal tetrahedral and a Warren-type, are compared using finite element models representing the November Reference Phase 1 Space Station. The truss torsional stiffness properties and fundamental torsion frequency are determined using cantilever truss-beam models. Frequencies, mode shapes, transient response, and truss strut compressive loads are compared for the two space station models. The performance benefit resulting from using a high modulus truss strut is also presented. Finally, assembly and logistics characteristics of the two truss configurations are evaluated. Author

N89-16194*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
REDUCING DISTORTION AND INTERNAL FORCES IN TRUSS STRUCTURES BY MEMBER EXCHANGES
WILLIAM H. GREENE and RAPHAEL T. HAFTKA (Virginia Polytechnic Inst. and State Univ., Blacksburg.) Jan. 1989 26 p
(NASA-TM-101535; NAS 1.15:101535) Avail: NTIS HC A03/MF A01 CSCL 20/11
Manufacturing errors in the length of members or joint diameters of large truss reflector backup structures may result in unacceptable large distortion errors or member forces. However, it may be possible to accurately measure these length or diameter errors. The present work suggests that a member and joint placement strategy may be used to reduce distortion errors and internal

member forces. A member and joint exchange algorithm is used to demonstrate the potential of this approach on several 102-member and 660-member truss reflector structures. It is shown that it is possible to simultaneously reduce the rms of the surface error and the rms of member forces by two orders of magnitude by member and joint exchanges. Author

N89-16445*# Florida Atlantic Univ., Boca Raton. Dept. of Ocean Engineering.
EXTENSION OF VIBRATIONAL POWER FLOW TECHNIQUES TO TWO-DIMENSIONAL STRUCTURES Annual Report No. 1
JOSEPH M. CUSCHIERI Sep. 1988 29 p
(Contract NAG1-685)
(NASA-CR-181710; NAS 1.26:181710) Avail: NTIS HC A03/MF A01 CSCL 20/1

In the analysis of the vibration response and structure-borne vibration transmission between elements of a complex structure, statistical energy analysis (SEA) or finite element analysis (FEA) are generally used. However, an alternative method is using vibrational power flow techniques which can be especially useful in the mid frequencies between the optimum frequency regimes for SEA and FEA. Power flow analysis has in general been used on 1-D beam-like structures or between structures with point joints. In this paper, the power flow technique is extended to 2-D plate-like structures joined along a common edge without frequency or spatial averaging the results, such that the resonant response of the structure is determined. The power flow results are compared to results obtained using FEA results at low frequencies and SEA at high frequencies. The agreement with FEA results is good but the power flow technique has an improved computational efficiency. Compared to the SEA results the power flow results show a closer representation of the actual response of the structure. Author

N89-16447# Air Force Weapons Lab., Kirtland AFB, NM.
METHOD FOR LONG TERM IONIZING RADIATION DAMAGE PREDICTIONS FOR THE SPACE ENVIRONMENT Final Report, Nov. 1982 - Dec. 1987
R. K. MAIER Aug. 1988 108 p
(AD-A199693; AFWL-TR-87-136) Avail: NTIS HC A06/MF A01 CSCL 06/7

The objective of the work is to predict the total dose damage from low level ionizing radiation sources for very long (5 years) exposure times. A prior effort to extrapolate annealing data to long times used linear systems theory or the convolution integral. Problems with the linear systems theory approach are: the damage is assumed to be linear even though the experimental data show a saturation effect; the annealing function, which is to be combined with the dose rate, needs to be known for a very long length of time (i.e., a 5-year observation of the annealing); and to do the integral numerically using data requires large amounts of computation. GRA

N89-18524# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
ADVANCED THERMAL DESIGN ASSESSMENT STUDY. VOLUME 2: SYNTHESIS AND RECOMMENDATIONS Final Report
C. GUENASSIA, comp., B. MIEDZA, comp., and R. ROHR, comp. Paris, France ESA 1988 66 p Prepared in cooperation with Erno Raumfahrttechnik G.m.b.H., Bremen, Fed. Republic of Germany, and MATRA Espace, Paris-Velizy, France
(Contract ESTEC-6519/85-NL-MA(SC))
(MBB-ATA-RP-ER-045-VOL-2; ESA-CR(P)-2660-VOL-2; ETN-89-93922) Avail: NTIS HC A04/MF A01

Technical and economic advantages of active thermal control of spacecraft were assessed. It is concluded that in designing a spacecraft at lowest system cost, communication and scientific satellites should be considered separately because of the potential high savings in the repeater system of communications spacecraft when constant temperatures can be guaranteed throughout all mission phases. For other types of electronic equipment the savings are considerably less. Savings in this area have to be compared with increases in the thermal control subsystem and in some other areas: differences in power demand and influence on the mass budget by the thermal control subsystem, power subsystem, and the consumables of the propulsion subsystem with impact on the launch cost. The investigations show that systems with fluid or two-phase loops demand higher effort, but a concept with feedback controlled variable conductance heat pipes employed on a spacecraft leads to a system which is less expensive than existing designs. A cost saving of 9 pct of the platform cost is evaluated for a communications spacecraft compared with the basic passive concept and 14 pct for a EURECA type spacecraft compared with the fluid loop design. ESA

N89-19519# Naval Postgraduate School, Monterey, CA.
TRANSIENT THREE-DIMENSIONAL HEAT CONDUCTION COMPUTATIONS USING BRIAN'S TECHNIQUE M.S. Thesis
JOHN A. WATSON Sep. 1988 208 p
(AD-A201918) Avail: NTIS HC A10/MF A01 CSCL 20/13

A transient three dimensional heat conduction code was developed using finite differences. A stability restriction on the time step was avoided using a technique proposed by Brian. Computations from the code were validated using both the explicit technique and an available closed from solution for small times. The maximum error was found to be within 0.019 percent for an 11 x 11 x 11 grid and time step of 17.117 seconds. The total CPU time to carry out the computations up to 3,600 seconds using Brian's techniques was six times that required for the explicit technique with the same time step of 17.117 seconds. However, as the time step was increased without altering the heometry, the CPU time using Brian's technique decreased and was less than that used in the explicit technique for time steps larger than 110 seconds. The validated code was also used in the analysis of the transient thermal response of a component on an orbiting spacecraft. GRA

05

STRUCTURAL DYNAMICS AND CONTROL

Includes modeling, systems identification, attitude and control techniques and systems, surface accuracy measurement and control techniques and systems, sensors, and actuators.

A89-10533
STRUCTURAL DYNAMICS PROBLEMS OF FUTURE SPACECRAFT SYSTEMS - NEW SOLUTION METHODS AND PERSPECTIVES [STRUKTURDYNAMISCHE PROBLEME ZUKUENFTIGER RAUMFAHRTSYSTEME - NEUE LOESUNGSKONZEPTE UND PERSPEKTIVEN]
E. BREITBACH and H. HUENERS (DFVLR, Institut fuer Aeroelastik, Goettingen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 395-405. In German. refs
(DGLR PAPER 87-126)

The mechanical and thermal loads imposed on spacecraft and payloads during launch and reentry, the methods used to predict and simulate these loads, and the design implications of typical loading levels are reviewed, with reference to the FRG Planning Framework for High Technology and Space Flight. A typical satellite mission profile is shown; the structural-dynamic qualification process is outlined; system identification methods are described in detail; and the fundamental principles of passive and active vibration control are discussed. Extensive diagrams, drawings, graphs, and photographs are provided. T.K.

A89-10570#
SOME BASIC EXPERIMENTS ON VIBRATION CONTROL OF AN ELASTIC BEAM SIMULATING FLEXIBLE SPACE STRUCTURE
HARUO KIMURA, NORIHIRO GOTO, YOSHIRO OKA, HIDEHIRO

FUKUDA, KAZUO TSUCHIYA et al. Kyushu University, Technology Reports (ISSN 0023-2718), vol. 61, June 1988, p. 301-308. In Japanese, with abstract in English. refs

An experimental apparatus has been developed for testing control strategies for suppressing the vibration of flexible structure model attached to a movable rigid body in connection with the control problems of flexible space structures. The rigid body has a vertical shaft which is magnetically suspended and free to rotate about its axis, and the magnetic bearing is mounted on a table that can be driven linearly by means of a ball-screw and d-c servomotor device. Accordingly, the flexible model, an elastic beam in the present case, can be given rotational and translational motion superimposed to its own elastic deformation. Frictionless sensors and actuators are prepared to measure and control the disturbed motion of the model. Some experimental results are presented which demonstrate the usefulness of the present apparatus for testing interaction between the elastic and the rigid modes of motion by applying the method of displacement and velocity feedback control to the model. Author

A89-10649
VARIABLE STRUCTURE MODEL - FOLLOWING CONTROL OF NONLINEAR SYSTEMS WITH APPLICATION TO FLEXIBLE SPACECRAFT
ZHI-QIANG QU, WEI-BING GAO, and MIAN CHENG (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 273-279. refs
(SAE PAPER 872430)

An approach to the trajectory tracking of the outputs of a certain class of nonlinear systems by variable structure model-following control is studied. It is shown that the nonlinear system may be transformed in the output space into an asymptotically equivalent linear system by using a suitable feedback variable structure control law. This approach is applied to the large-angle rotational maneuver of a spacecraft-beam-tip body configuration. A variable structure model-following control strategy is derived to asymptotically obtain the independent decoupled control of attitude angles, lateral elastic deflections, slopes due to bending, and angular deflection due to torsion at the tip of the beam using torque and force actuators. Author

A89-11094
FLEXIBILITY CONTROL OF FLEXIBLE STRUCTURES - MODELING AND CONTROL METHOD OF BENDING-TORSION COUPLED VIBRATIONS
TOSHIO FUKUDA, FUMIHITO ARAI, HIDEMI HOSOGAI (Tokyo, Science University, Japan), and NOBUYUKI YAJIMA (Tokyo, University, Japan) JSME International Journal, Series III (ISSN 0914-8825), vol. 31, Sept. 1988, p. 575-582. refs

This paper describes a modeling of bending-torsion coupled vibrations of flexible structures, such as solar battery arrays, and a control method based on this model. The bending-torsion coupled vibrations are modeled by the unconstrained mode method in the case that the center of flexure does not coincide with the centroid in the cross section. The system and the observation equations of this system are derived after the modal decomposition. Considering the state feedback control system with the state estimator, we elucidate the effect of the coupling terms in this system. Furthermore, a control method to deal with noise contamination of the sensors is also shown. Finally, some simulation results of the bending-torsion coupled vibration control are presented. Author

A89-11652#
SOME RECENT RESULTS ON ROBUSTNESS OPTIMIZATION FOR CONTROL OF FLEXIBLE STRUCTURES
D. W. REW and J. L. JUNKINS (Texas A & M University, College Station) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 1-16. refs

A novel method is presented for finding control gains which satisfy eigenvalue placement constraints and maximize a measure of closed-loop robustness (minimize the condition number of the closed-loop eigenvectors). Numerical results were obtained for several academic examples and this approach was applied successfully to design a feedback law for the Rapid Retargeting and Precision Pointing (R2P2) experiment. Both analytical and numerical results are presented which demonstrate the application to problems of moderate dimensionality (less than order 12), and some comparisons with existing control design approaches are summarized. Author

A89-11654*# PRC Kentron, Inc., Hampton, VA.
DIGITAL ROBUST ACTIVE CONTROL LAW SYNTHESIS FOR LARGE ORDER FLEXIBLE STRUCTURE USING PARAMETER OPTIMIZATION
V. MUKHOPADHYAY (PRC Kentron, Inc., Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 31-44. NASA-supported research. refs

A generic procedure for the parameter optimization of a digital control law for a large-order flexible flight vehicle or large space structure modeled as a sampled data system is presented. A linear quadratic Guassian type cost function was minimized, while satisfying a set of constraints on the steady-state rms values of selected design responses, using a constrained optimization technique to meet multiple design requirements. Analytical expressions for the gradients of the cost function and the design constraints on mean square responses with respect to the control law design variables are presented. B.J.

A89-11658#
DECENTRALIZED CONTROL OF LARGE-SCALE SYSTEMS
F. M. PITMAN and M. AHMADIAN (Clemson University, SC) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 103-118. Research supported by USAF, Eastman Kodak Co., and Clemson University. refs

Decentralized control of large-scale modular type structures, similar to those intended for use in space, is addressed. A two-level control strategy consisting of local and global controllers is used to control the system. The global controllers are used to minimize the effect of coupling and the local controllers are employed to accomplish optimal performance and stability. A set of stability conditions based on the properties of the subsystems is presented for the overall system. Finally, a system consisting of two simply supported beams coupled by a spring is used to demonstrate the application of the method and the effects of coupling on the proposed control strategy. Author

A89-11660#
EVALUATION OF TWO IDENTIFICATION METHODS FOR DAMAGE DETECTION IN LARGE SPACE TRUSSES
S. WEAVER SMITH and S. L. HENDRICKS (Virginia Polytechnic Institute and State University, Blacksburg) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 127-141.

Two methods of system identification are evaluated with respect to the application of damage detection for large space trusses. The first method, developed by Kabe (1985), uses the known physical connectivity of the structure to preclude unreasonable couplings while identifying the elements of the stiffness matrix. White and Maytum (1976) developed a method that uses linear perturbations of submatrices and an energy distribution analysis to identify the elements of the stiffness matrix. Evaluations of these methods were conducted with three test systems - a spring-mass model, a planar truss model, and a three-dimensional truss model patterned after the Space Station truss. Author

A89-11661#

SYSTEM IDENTIFICATION EXPERIMENTS FOR FLEXIBLE STRUCTURE CONTROL

S. YURKOVICH (Ohio State University, Columbus) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 143-157. refs

Several competing methods for parameter estimation and model identification of flexible mechanical structures are discussed. Primary emphasis in the problem formulation is not on extracting structural or modal information from the identification exercise; rather, the focus is on identification of model parameters which are amenable to control applications and design. On-line and off-line techniques are discussed, and simulation and experimental results are presented. Author

A89-11662#

TIME-VARIABLE REDUCED ORDER MODELS - AN APPROACH TO IDENTIFICATION AND ACTIVE SHAPE-CONTROL OF LARGE SPACE STRUCTURES

J. MARCZYK (Tecnomare S.p.A., Milan, Italy) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 159-170. refs

The paper describes an approach to the identification/active configuration-control problem of exceptionally large space structures (LSS) characterized by low and clustered eigenfrequencies. A time-dependent compensator is suggested for control of such systems. A large number of discrete displacement and velocity sensors are employed to determine uniquely the excited states which become the basis of a control-design reduced order model (ROM). Combining this approach with local feedback leads to an efficient distribution of the control effort in both frequency and space. The suggested control strategy is tested by computer simulations of a free-free beam. Author

A89-11663*# Virginia Polytechnic Inst. and State Univ., Blacksburg.

A RAYLEIGH-RITZ APPROACH TO STRUCTURAL PARAMETER IDENTIFICATION

L. MEIROVITCH, M. A. NORRIS (Virginia Polytechnic Institute and State University, Blacksburg), and J. P. WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 171-183. refs

(Contract NAG1-225)

This paper is concerned with the identification of parameter distributions in large space structures. The formulation is based on a Rayleigh-Ritz type approach working with the actual displacement at a given number of points in the structure. The parameter distributions are expanded in terms of known admissible functions multiplied by unknown coefficients, and the identification process reduces to the determination of these coefficients. The procedure uses a perturbation approach, beginning with a postulated set of parameters and iterating to the actual values in an incremental fashion. Author

A89-11664#

'DAISY' - A LABORATORY FACILITY TO STUDY THE CONTROL OF LARGE FLEXIBLE SPACECRAFT

G. B. SINCARSIN, W. G. SINCARSIN (Dynacon Enterprises, Ltd., Downsview, Canada), P. C. HUGHES (Toronto, University, Downsview, Canada), and A. H. REYNAUD (CDC, Communications Research Centre, Ottawa, Canada) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 185-200. CDC-NSERC-supported research.

Approximately five years ago, the Canadian Department of Communications began to fund the design and construction of Daisy - a structure suitable for carrying out laboratory experiments on the control of flexible structures. Now completed, the Daisy structure has three rigid and 20 elastic degrees of freedom, very low frequencies (about 0.1 Hz), very low damping (about 0.6 percent), 'clustered' modes, and the potential to study both attitude control and shape control. This paper briefly describes Daisy and the sensors and actuators with which it is currently endowed. Sensors include digital encoders for 'attitude' measurements, and accelerometers; actuators include three reaction wheels, and thrusters. Author

A89-11665#

THE CONTROL OF LINEAR PROOF-MASS DAMPERS

J. K. HAVILAND, H. POLITANSKY, T. W. LIM, and W. D. PILKEY (Virginia, University, Charlottesville) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 201-216. USAF-supported research. refs

The problem of designing a control system for a small laboratory model of a linear proof-mass damper for large space structures is considered. Initially a linear control law was developed. Although adequate damping could be achieved at high frequencies, very little damping could be obtained at frequencies of one Herz or less with the linear law, because the motion of a proof-mass had to be constrained within the physical limits set by the stops. In an attempt to improve on this performance, recent efforts have been concentrated on alternative control laws. A limiting performance formulation was combined with a minimum time solution to achieve the goal of rapid suppression of disturbances. Author

A89-11666*# Catholic Univ. of America, Washington, DC.

OPTIMUM VIBRATION CONTROL OF FLEXIBLE BEAMS BY PIEZO-ELECTRIC ACTUATORS

A. BAZ, S. POH (Catholic University of America, Washington, DC), and P. STUDER (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 217-234. Previously announced in STAR as N87-18880. refs

(Contract NAG5-520)

The utilization of piezoelectric actuators in controlling the structural vibrations of flexible beams is examined. A Modified Independent Modal Space Control (MIMSC) method is devised to enable the selection of the optimal location, control gains and excitation voltage of the piezoelectric actuators in a way that would minimize the amplitudes of vibrations of beams to which these actuators are bonded, as well as the input control energy necessary to suppress these vibrations. The developed method accounts for the effects that the piezoelectric actuators have on changing the elastic and inertial properties of the flexible beams. Numerical examples are presented to illustrate the application of the developed MIMSC method in minimizing the structural vibrations of beams of different materials when subjected to different loading and end conditions using ceramic or polymeric piezoelectric actuators. The obtained results emphasize the importance of the devised method in designing more realistic active control systems for flexible beams, in particular, and large flexible structures in general. Author

A89-11667#

A LABORATORY FACILITY FOR FLEXIBLE STRUCTURE CONTROL EXPERIMENTS

U. OZGUNER, S. YURKOVICH, J. MARTIN, and P. KOTNIK (Ohio State University, Columbus) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia

Polytechnic Institute and State University, 1988, p. 235-250. Research supported by Whirlpool Co. refs
(Contract NSF DMC-85-06143)

A laboratory facility to study various control problems related to flexible mechanical structures has been developed. Various experimental configurations that address generic problems in large flexible space structures and flexible robotic manipulators have been, and are being, developed. While problems in vibration damping and slewing are being considered from the view point of modeling, identification and control, a major part of the effort is also directed toward true actuation, sensing, and feedback implementation issues. Author

A89-11668*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ATTITUDE CONTROL SYSTEM TESTING ON SCOLE
J. SHENHAR, D. SPARKS, JR., J. P. WILLIAMS, and R. C. MONTGOMERY (NASA, Langley Research Center, Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 251-273. refs

This paper presents implementation of two control policies on SCOLE (Space Control Laboratory Experiment), a laboratory apparatus representing an offset-feed antenna attached to the Space Shuttle by a flexible mast. In the first case, the flexible mast was restrained by cables, permitting modeling of SCOLE as a rigid-body. Starting from an arbitrary state, SCOLE was maneuvered to a specified terminal state using rigid-body minimum-time control law. In the second case, the so called single step optimal control (SSOC) theory is applied to suppress vibrations of the flexible mast mounted as a cantilever beam. Based on the SSOC theory, two parameter optimization algorithms were developed. Author

A89-11669*# Florida Univ., Gainesville.
PRACTICAL IMPLEMENTATION ISSUES FOR ACTIVE CONTROL OF LARGE FLEXIBLE STRUCTURES
D. C. ZIMMERMAN (Florida, University, Gainesville) and H. H. CUDNEY (New York, State University, Buffalo) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 275-290. refs
(Contract NGT-33-183-801; NGT-33-183-802)

The effect of quantization due to the finite wordlength of microprocessors, analog-to-digital, and digital-to-analog converters, on the desired control law for large flexible structures is investigated. Additionally, the practical effect of actuator dynamics on the stability and performance of the control law is addressed. Finally, an active control experiment is reported which takes into account and demonstrates some of the previously discussed practical considerations. Author

A89-11670#
EFFICIENCY OF STRUCTURE-CONTROL SYSTEMS
H. OZ, K. FARAG (Ohio State University, Columbus), and V. B. VENKAYYA (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 291-311. refs
(Contract F33615-86-C-3212)

The paper examines a nondimensional measure, called the efficiency, of structure-control system (SCS) performance which has the potential to characterize both quantitatively and qualitatively the designer's ability to deal with some of the problem areas such as the assessment of spillover effects, model order reduction, input configuration, and the interaction between structural and control variables from the SCS point of view. The efficiency of the system is defined as the ratio of two control cost functionals pertinent to the structure-control problem where each functional represents an average control power consumed during the control period. This concept is illustrated by investigating the efficiency of various linear quadratic regulator solutions for the ACOSS-4 tetrahedral truss structure. B.J.

A89-11671*# Howard Univ., Washington, DC.
STABILITY ANALYSIS OF LARGE SPACE STRUCTURE CONTROL SYSTEMS WITH DELAYED INPUT
A. S. S. R. REDDY and P. M. BAINUM (Howard University, Washington, DC) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 313-321. refs
(Contract NSG-1414)

Large space structural systems, due to their inherent flexibility and low mass to area ratio, are represented by large dimensional mathematical models. For implementation of the control laws for such systems a finite amount of time is required to evaluate the control signals; and this time delay may cause instability in the closed loop control system that was previously designed without taking the input delay into consideration. The stability analysis of a simple harmonic oscillator representing the equation of a single mode as a function of delay time is analyzed analytically and verified numerically. The effect of inherent damping on the delay is also analyzed. The control problem with delayed input is also formulated in the discrete time domain. Author

A89-11672*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
OPTIMAL LOCATION OF ACTUATORS FOR CORRECTING DISTORTIONS DUE TO MANUFACTURING ERRORS IN LARGE TRUSS STRUCTURES
R. BURDISSO and R. T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 323-342. refs
(Contract NAG1-224)

A continuum approximation to the calculation of the statistical properties of the corrected shape of a beam truss is presented, and results of a comparison with the exact statistical analysis were found to be very good. In addition, the position of the actuators was optimized to minimize the weighted rms of the distortion using the continuum analysis. The optimal design is shown to be 13.6 percent better than a uniform design for a parabolic weighting function. It was also found that actuators located on the beam face elements were more effective than actuators located on the diagonal elements. B.J.

A89-11673*# Ohio State Univ., Columbus.
ADAPTIVE CONTROL TECHNIQUES FOR THE SCOLE CONFIGURATION
K. OSSMAN, S. YURKOVICH, and U. OZGUNER (Ohio State University, Columbus) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 343-358. refs
(Contract NAG1-720)

Two adaptive controllers designed for the Spacecraft Control Laboratory Experiment (SCOLE) at NASA Langley Research Center are discussed. The first controller is an adaptive model following variable structure controller and the second is an indirect LQ adaptive controller. For each technique, the design of the controller is outlined and simulation results are presented. Plans for future studies are also discussed. Author

A89-11674#
ON THE ACTIVE VIBRATION CONTROL OF DISTRIBUTED PARAMETER SYSTEMS
P. HAGEDORN and J. T. SCHMIDT (Darmstadt, Technische Hochschule, Federal Republic of Germany) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg,

VA, Virginia Polytechnic Institute and State University, 1988, p. 359-373. Research supported by the Stiftung Volkswagenwerk. refs

In this paper the traveling wave approach is discussed for the vibration control of networks of slender flexible structural components. The results previously obtained for the wave equation with the traveling wave approach are reviewed. After the discussion of the wave equation, an active vibration control is then designed for the Timoshenko beam in a similar way. To this end, the equations of motion of the Timoshenko beam are used in the normal form of a hyperbolic system. Results of numerical simulations are also presented. Author

A89-11675#
OBSERVABILITY OF A BERNOULLI-EULER BEAM USING PVF2 AS A DISTRIBUTED SENSOR
S. E. MILLER and J. HUBBARD (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 375-390. refs

A theoretical model for spatially distributed sensors on a flexible beam was derived without the necessity of modeling the beam in terms of its component vibrational modes. The model provides insight into the observability of beams with nearly arbitrary boundary conditions. The sensor distribution may be spatially shaped so as to function similar to point sensors or to produce a signal in which certain vibrational modes of the structure are weighted more than others. The model was verified for the first three modes of a cantilever beam. Spatially uniform and linear-varying sensors constructed from polyvinylidene fluoride (PVF2) were applied to a clamped-free beam. In further experimentation both PVF2 sensors and actuators were used as the active components of a vibration isolation system. Author

A89-11676#
AN INVESTIGATION OF THE TIME REQUIRED FOR CONTROL OF STRUCTURES
J. K. BENNIGHOF and R. L. BOUCHER (Texas, University, Austin) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 391-406. refs

The minimum time required for accomplishing rigid-body translation of a flexible structure by means of a finite number of unbounded inputs is investigated. It is found that, for less than a certain time interval for control, it is not possible to decrease the amount of spillover energy by driving more flexible modes to zero at the end of the control interval when a minimum-effort control strategy is used. This time interval is identified as the minimum time required for control of flexible structures, and it is closely related to the time required for waves to travel through the structure. For one-dimensional second-order systems, the minimum time is equal to the time required for waves to travel between adjacent pairs of actuators. A similar result is found for fourth-order systems. Author

A89-11677#
OPTIMAL CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES USING DISTRIBUTED GYRICITY
C. J. DAMAREN and G. M. T. D'ELEUTERIO (Toronto, University, Downsview, Canada) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 407-422. NSERC-supported research. refs

An optimal formulation for the shape control of flexible spacecraft using gyric actuators is proposed whereby the structure is modeled as a continuum in mass, stiffness, and gyricity (i.e., stored angular momentum). The equations of motion are formulated in continuum form, and the optimal control problem is treated using distributed-parameter concepts. The advantages of the concept of a continuous distribution of gyricity in modeling the dynamics and control of large flexible spacecraft with many control moment gyros is demonstrated by a numerical example. V.L.

A89-11678#
THE EFFECT OF TIME DELAY AND PLACEMENT OF ACTUATORS ON BEAM FLEXURE DURING NONLINEAR SLEW OF SCOLE
S. FISHER (U.S. Navy, Naval Research Laboratory, Washington, DC) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 423-438. refs

A flexible-body control methodology for performing nonlinear slew of the mathematical model version of the spacecraft laboratory experiment (SCOLE) is presented. The effects of the placement of proof-mass actuators on the beam connecting the shuttle body to the reflector is evaluated, with degree of controllability methods used as guidelines for actuator placement strategies. Kalman-Bucy filter methods are used to estimate beam flexure amplitude in the presence of simulated sensor noise; the effect of time delay in actuator response is investigated. It is shown that proof-mass actuators are effective in reducing the maximum amount of flexure and in damping flexure oscillations; damping of flexure oscillations is sensitive to changes in actuator placement. It is also shown that actuator performance degradation with time delay presents a serious problem. V.L.

A89-11679#
ON A MODAL APPROACH TO THE CONTROL OF DISTRIBUTED PARAMETER SYSTEMS
H. H. E. LEIPHOLZ (Waterloo, University, Canada) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 439-452.
(Contract NSERC-A-7297)

In this paper it is shown that elastic systems may become nonself-adjoint by automatic control. It is also shown that if the control term that causes nonself-adjointness has a range of regularity, the modal approach is applicable to the nonself-adjoint problem within the range of regularity. Finally, it is shown how the range of regularity or a subrange of it can be determined.
Author

A89-11681*# Catholic Univ. of America, Washington, DC.
MODIFIED INDEPENDENT MODAL SPACE CONTROL METHOD FOR ACTIVE CONTROL OF FLEXIBLE SYSTEMS
A. BAZ, S. POH (Catholic University of America, Washington, DC), and P. STUDER (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 477-493. Previously announced in STAR as N87-23980. refs
(Contract NAG5-520; NAG5-749)

A modified independent modal space control (MIMSC) method is developed for designing active vibration control systems for large flexible structures. The method 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 energy. 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 are presented to illustrate the application of the method to generic flexible systems. The results obtained suggest the potential of the devised method in designing efficient active control systems for large flexible structures. Author

A89-11685#

OPTIMAL VIBRATION CONTROL OF A FLEXIBLE SPACECRAFT DURING A MINIMUM-TIME MANEUVER

L. MEIROVITCH and Y. SHARONY (Virginia Polytechnic Institute and State University, Blacksburg) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 579-601. refs

(Contract F33615-86-C-3233)

This paper is concerned with the simultaneous maneuver and vibration control of a flexible spacecraft. The problem is solved by means of a perturbation approach whereby the slewing of the spacecraft regarded as rigid represents the zero-order problem and the control of vibration, as well as of perturbations from the rigid-body maneuver, represents the first-order problem. The zero-order control is to be carried out in minimum time, which implies bang-bang control. On the other hand, the first-order control is a time-dependent linear quadratic regulator including integral feedback and prescribed convergence rate. Author

A89-11686#

MODULAR LARGE SPACE STRUCTURES DYNAMIC MODELING WITH NONPERFECT JUNCTIONS

F. B. ZAZZERA, A. E. FINZI, and P. MANTEGAZZA (Milano, Politecnico, Milan, Italy) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 603-618. refs

The dynamics of modular repetitive structures is investigated with emphasis on the effect of structural damping and imperfections in the junctions between successive modules on the dispersion relations. The structural transfer matrix is computed, and the solution of the eigenvalue problem derived from the application of Floquet's theory of partial differential equations with periodic coefficients yields dispersion relations for the structure. It is shown that a periodic structure behaves like a mechanical filter and that junction imperfections can modify the passing and stopping bands but do not eliminate the filtering properties. A control system is proposed which allows the elimination of propagating waves. V.L.

A89-11689#

DYNAMICS SIMULATION OF SPACE STRUCTURES SUBJECT TO CONFIGURATION CHANGE

Y. OHKAMI, O. OKAMOTO, T. KIDA, and I. YAMAGUCHI (National Aerospace Laboratory, Tokyo, Japan) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 647-659. refs

The unified matrix approach is used to develop a computer algorithm capable of simulating the dynamics of complex large space structures with variable configuration. This capability is realized through the use of a generic hinge and constraint index matrices that can handle kinetic and kinematic constraints in a unified manner. The algorithm has been successfully used to simulate a series of manipulator operations including changes in topology and constraint conditions. V.L.

A89-11690*# Massachusetts Inst. of Tech., Cambridge.

ANALYSIS OF LIMIT CYCLES IN CONTROL SYSTEMS FOR JOINT DOMINATED STRUCTURES

M. MERCADAL and W. E. VANDER VELDE (MIT, Cambridge, MA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 661-680.

(Contract NAG1-126)

An approach to the modeling of limit cycles due to joint nonlinearities in large joint dominated space structures is presented which makes it possible to predict limit cycles and determine their stability. An actively controlled truss structure with nonlinear joints is modeled as a linear system with nonlinear feedback by separating the joint load-displacement characteristics into a linear part, which prevails at large displacements, and a nonlinear part. By replacing the joints by their linear parts, it is possible to perform a standard model decomposition which yields a reduced order linear model. Linear control laws can be easily included into the linear part of the system; nonlinear control laws can be implemented but they must be fed back to the linear model. The modeling approach described here allows straightforward limit cycle analysis. V.L.

A89-11691*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

LQC CONTROL FOR THE MINI-MAST EXPERIMENT

R. C. MONTGOMERY and D. GHOSH (NASA, Langley Research Center, Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 681-696.

The Mini-Mast system is briefly reviewed, and results of a simulation study of the LQG control for the Mini-Mast experiment are reported. In particular, attention is given to problems and limitations related to the testing of control laws using reaction mass actuators, such as accounting for force and stroke limits of these devices. The local controller used in the study and the algorithm for converting the force commands of the LQG algorithm to position commands for the reaction mass device are described. It is shown that the LQG generated damping is reduced when a local controller is used and the position command is not saturated; it drops still further when the position command is saturated. V.L.

A89-11693*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

DESIGN OF GROUND TEST SUSPENSION SYSTEMS FOR VERIFICATION OF FLEXIBLE SPACE STRUCTURES

V. M. COOLEY, J. N. JUANG (NASA, Langley Research Center, Hampton, VA), and P. GHAEMMAGHAMI (Old Dominion University, Norfolk, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 713-725. refs

A simple model demonstrates the frequency-increasing effects of a simple cable suspension on flexible test article/suspension systems. Two passive suspension designs, namely a negative spring mechanism and a rolling cart mechanism, are presented to alleviate the undesirable frequency-increasing effects. Analysis methods are provided for systems in which the augmentations are applied to both discrete and continuous representations of test articles. The damping analyses are based on friction equivalent viscous damping. Numerical examples are given for comparing the two augmentations with respect to minimizing frequency and damping increases. Author

A89-11812

SENSOR INTEGRATION BY SYSTEM AND OPERATOR

DEWEY RUNDUS (South Florida, University, Tampa, FL) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 64-68. refs

Maintenance of proper functioning of the Space Station will require monitoring of a large number of sensors. This task will include not only state monitoring, but also the need to recognize trends which might lead to fault states. Both types of monitoring would be aided if groups of sensor values could be reduced to a single value which preserved their important characteristics. Multidimensional scaling is proposed as a technique to achieve such a goal. This approach, in addition to being useful in the creation of aids to a human operator, would also have characteristics which would make it a useful sensor integration approach for automated systems. Author

A89-11814* Illinois Univ., Urbana.
AUTOMATICALLY RECONFIGURABLE CONTROL FOR RAPID RETARGETING OF FLEXIBLE POINTING SYSTEMS
THOMAS A. W. DWYER, III (Illinois, University, Urbana) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 75-82. Research supported by Lockheed Missiles and Space Co. refs
(Contract NAG1-613)

A reconfigurable nonlinear control system design methodology is proposed to automatically correct computed slew torque commands of space-based pointing systems for the effects of slew-induced structural deformations. The possibility of forcing an elastic structure, such as that of a space-based instrument frame, to deform in a preselected way in response to rapid slews is demonstrated. To accomplish this, a supervisory controller must select a pair of algorithms, one for structural counterexcitation and the other for slew torque correction. It is shown how the reachability and subsequent tracking of the appropriate 'slow manifold', where the control algorithms are valid, can be ensured by a fast tracking loop, with time-varying gain dependent only on the commanded angular acceleration. K.K.

A89-11905
MODELLING OF A 5-BAR-LINKAGE MANIPULATOR WITH ONE FLEXIBLE LINK
DAVID WANG and M. VIDYASAGAR (Waterloo, University, Canada) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 1. Washington, DC, Computer Society Press, 1988, p. 21-26. refs

A model of a five-bar-linkage robot is examined where the top link is flexible. The modeling process is described and applied to the simpler problem of a single link beam. The model of the five-bar-linkage robot with the top link flexible is derived and then simplified using various assumptions which are discussed. It is shown that under these assumptions, it may be possible to control two joints using a typical rigid-body controller while using the third joint to control the vibrations. This greatly simplifies the control problem. I.E.

A89-12005* Massachusetts Inst. of Tech., Cambridge.
TRACKING AND STATIONKEEPING FOR FREE-FLYING ROBOTS USING SLIDING SURFACES
CRAIG R. CARIGNAN (STX Corp., Lanham, MD) and DAVID L. AKIN (MIT, Cambridge, MA) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 2. Washington, DC, Computer Society Press, 1988, p. 969-974. refs
(Contract NAGW-21)

The authors use the concept of sliding surfaces for generating two types of tracking control laws for a free-flying robot engaged in zero-gravity assembly tasks. Suction control, developed elsewhere for controlling manipulators with stationary bases, is used here to track workspace trajectories for manipulators mounted on mobile platforms. Zone control is formulated for the purpose of stationkeeping a robot maneuvering unit during payload manipulation. Experimental results are described for tests performed on an air-bearing robot tracking payload trajectories along a glass surface. I.E.

A89-12069*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AUTOMATED ORBITAL RENDEZVOUS CONSIDERATIONS
ROBERT N. LEA (NASA, Johnson Space Center, Houston, TX) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 3. Washington, DC, Computer Society Press, 1988, p. 1871, 1872. refs

The control of the rendezvous vehicle during proximity operations is considered. It is shown how fuzzy sets can be used for autonomous vehicle control to model the human capability of common sense reasoning. Such models are integrated with expert systems and engineering control systems technology to create a system that performs comparably to a manned system. I.E.

A89-12134
GEOMETRIC NON-LINEAR SUBSTRUCTURING FOR DYNAMICS OF FLEXIBLE MECHANICAL SYSTEMS
SHIH-CHIN WU and EDWARD J. HAUG (Iowa, University, Iowa City) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 26, Oct. 1988, p. 2211-2226. refs

A procedure for including individual-member geometric nonlinearities in standard FEM analytical models of flexible multibody structures is developed and demonstrated. The limitations imposed by multibody analyses based on linear-elastic small-deformation models of components are discussed, and a unified substructure formulation is derived for small-strain geometric nonlinearities. The procedure is based on the convected-coordinates approach of Belytschko and Hsieh (1973) and Housner (1984), but is independent of the type of finite element employed. The compatibility constraints, the substructure synthesis method, and the selection of the deformation mode are discussed, and numerical results for a rotating beam and a truss space structure are presented in extensive graphs and characterized in detail. T.K.

A89-12635 Howard Univ., Washington, DC.
ORIENTATION AND SHAPE CONTROL OF OPTIMALLY DESIGNED LARGE SPACE STRUCTURES
PETER M. BAINUM and K. SATYANARAYANA (Howard University, Washington, DC) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 133-143. Research supported by Howard University and NASA. refs
(AAS PAPER 87-415)

In this study, the vibration and orientation control of large space structures using the linear quadratic regulator technique is investigated. Emphasis is placed on the control of both a class of optimally designed structures and uniform structures meeting the mission requirements using a long free-free beam in orbit as an example. The open loop and closed loop dynamics are compared and the transient responses are obtained to determine the effectiveness of the control system design. Author

A89-12636
OPTIMAL CONFIGURATION AND TRANSIENT DYNAMIC ANALYSES OF STATICALLY DETERMINATE ADAPTIVE TRUSS STRUCTURES FOR SPACE APPLICATION
KAZUO YAMAMOTO, MASAKI TABATA (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan), and KORYO MIURA (Tokyo, University, Japan) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 145-160.
(AAS PAPER 87-417)

Numerical procedures on optimal configuration and transient dynamics are developed for a statically determinate adaptive truss called Variable Geometry Truss. The equations of optimization are formulated so that the change in a geometrical amount from the initial state may be minimized, with constraint conditions relating to the configuration of the truss. Then, transient dynamics toward the optimal configuration is formulated using the energy method with and without consideration of the elasticity of members. Solutions of the nonlinear algebraic and differential equations are successfully obtained by use of the iterative numerical schemes. Author

A89-12637 Howard Univ., Washington, DC.
THE OPTIMAL CONTROL OF ORBITING LARGE FLEXIBLE BEAMS WITH DISCRETE-TIME OBSERVATIONAL DATA AND RANDOM MEASUREMENT NOISE
GUANGQIAN XING and PETER M. BAINUM (Howard University, Washington, DC) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13,

1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 161-183. Research supported by Howard University and NASA. refs
(AAS PAPER 87-418)
The analysis and design of LQR optimal digital controllers and LQG optimal digital controllers and observers are presented for the case of an orbiting long, slender flexible free-free beam system, for which the output are the discrete-time noise-corrupted observational data, and both the overall orientation as well as the shape of some of the subsystems will be controlled. The effect of the sampling period on the transient response for the LQR problem and relationships between the locations of the controller poles and the locations of observer poles have been studied. The simulations certify the analysis and design of digital optimal controllers and observers. Author

A89-12647
FLEXIBILITY MODELING METHODS IN MULTIBODY DYNAMICS
R. R. RYAN (Michigan, University, Ann Arbor) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 365-385. refs
(AAS PAPER 87-431)
Methods used in multibody dynamics formalisms to model flexible bodies undergoing large overall motions and small deformations are studied with the aid of a simple example problem. Limitations in the most common modeling approach, involving assumed modes, are pointed out and ramifications are discussed. Two new procedures are presented and the relative merits of computer implementation of each of these are considered. Author

A89-12648
DYNAMICS OF GRAVITY ORIENTED SATELLITES WITH THERMALLY FLEXED APPENDAGES
A. C. NG and V. J. MODI (British Columbia, University, Vancouver, Canada) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 387-410.
(Contract NSERC-G-1547)
(AAS PAPER 87-432)
Equations are presented for the motion of a satellite with a rigid central body and a pair of appendages deforming due to thermal effects of solar radiation. It is shown that, for a circular orbit, the flexible system can become unstable under critical combinations of system parameters and initial conditions although the corresponding rigid system continues to be stable. In the case of eccentric orbits, depending on the initial conditions, thermally flexed appendages can stabilize or destabilize the system. K.K.

A89-12661* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MODEL REDUCTION IN THE SIMULATION OF INTERCONNECTED FLEXIBLE BODIES
FIDELIS O. EKE and GUY K. MAN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 603-612. refs
(AAS PAPER 87-455)
Given the control system specifications for a system of interconnected rigid and flexible bodies, methods now exist for determining the system modes that do not interact 'strongly' with the controller. Once these important system modes are known, there still remains the problem of determining the modes of individual bodies that should be retained, since, in the final analysis, it is the modal information at the component level that must be fed into any multibody simulation code. Systematic identification of these component modes is achieved through a two-phase matrix diagonalization process starting with judiciously chosen submatrices of the system modal matrix. Author

A89-12674
DEPLOYMENT, POINTING, AND SPIN OF ACTIVELY-CONTROLLED SPACECRAFT CONTAINING ELASTIC BEAM-LIKE APPENDAGES
R. R. RYAN (Michigan, University, Ann Arbor) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 853-876. refs
(AAS PAPER 87-478)
A comprehensive theory and equations of motion are presented for a free-flying rigid body with flexible beamlike appendages. It is shown that, in order to accurately simulate general aerospace structures undergoing large overall motions and small deformations, it is necessary to treat each distinct type of structural element comprising the system in a special way. The advantage of this modal theory over nonlinear finite element techniques is discussed. K.K.

A89-12675
EFFECT OF OFFSET OF THE POINT OF ATTACHMENT ON THE DYNAMICS AND STABILITY OF SPINNING FLEXIBLE APPENDAGES
SERDAR KALAYCIOGLU IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 877-894. refs
(AAS PAPER 87-479)
The general three-dimensional rotational and structural dynamics of spinning beams with root offsets are considered. Particular attention is given to the effect of root offsets on the dynamics and stability of the flexible base/appendages. Angular acceleration is accounted for and results are obtained pertaining to the root offsets and angular acceleration. K.K.

A89-12676
ON-ORBIT BALANCING OF A SPINNING ANTENNA
M. M. TONG, C. H. SMITH, and P. H. MAK (Aerospace Corp., El Segundo, CA) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 895-914.
(Contract F04701-85-C-0086)
(AAS PAPER 87-480)
A method for balancing a spinning payload aboard a three-axis stabilized satellite is presented. The antenna structure is flexible and its size is comparable to that of the rest of the spacecraft. The method involves the use of two balance masses moving on linear tracks mounted parallel to one another on the antenna structure. Simulation results demonstrated the feasibility of using the proposed method to balance the low-frequency microradiometer aboard the Navy Remote Ocean Sensing System vehicle. K.K.

A89-12677
DYNAMICS DURING SLEWING AND TRANSLATIONAL MANEUVERS OF THE SPACE STATION BASED MRMS
H. W. MAH, V. J. MODI (British Columbia, University, Vancouver, Canada), Y. MORITA, and H. YOKOTA (Tokyo, University, Japan) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 915-933.
(Contract NSERC-G-1547)
(AAS PAPER 87-481)
A formulation for studying the librational dynamics of a flexible platform supporting a mobile base connected to a series of slewing flexible appendages is presented. This formulation is ideally suited for the dynamics and control analysis of the Space Station based Mobile Remote Manipulator System (MRMS); it should prove useful during preliminary planning of the Space Station integration and operation. It is shown that the translational motion and the slewing maneuver of the MRMS influence the librational response of the platform due to a shift in the system center of mass and the transient character of the satellite inertia matrix. K.K.

A89-12678
DYNAMICS AND CONTROL ANALYSIS OF A SATELLITE WITH A LARGE FLEXIBLE SPINNING ANTENNA
P. H. MAK, M. M. TONG, and A. B. JENKIN (Aerospace Corp., Control Analysis Dept., El Segundo, CA) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 935-951.
(Contract F04701-85-C-0086)
(AAS PAPER 87-482)

A feasibility study was carried out on a low-frequency microwave radiometer (LFMR) with a 20-ft diameter deployable truss antenna spinning asymmetrically at 15.8 rpm onboard a 3-axis stabilized spacecraft for the N-ROSS mission. No significant interactions were observed between the attitude control system and the flexible structures. The attitude pointing requirement can be met if the LFMR is properly balanced. The spin-induced deformation in the flexible structure is indicative of a relatively small sensor boresight pointing error. K.K.

A89-14762
DYNAMICS OF TETHERED SPACE SYSTEMS [DINAMIKA KOSMICHESKIKH TROSOVYKH SISTEM]
V. V. BELETSKII IN: Mechanics and scientific-technological progress. Volume 1. Moscow, Izdatel'stvo Nauka, 1987, p. 226-241. In Russian. refs

The history and the current status of theoretical and applied research in the field of tethered space systems are briefly reviewed. In particular, attention is given to equations of motion of an orbital tethered system, stationary configurations in a gravitational field, systems with weightless and ponderable tethers, and a tethered system deployment model. The discussion also covers pendulum motions of a tethered system, modes and frequencies of small vibrations of a radial tethered system, stationary motion and stability of an atmospheric probe, and an electromagnetic orbital tethered system. V.L.

A89-15544* Texas Univ., Austin.
SOME APPLICATIAONS OF LANCZOS VECTORS IN STRUCTURAL DYNAMICS
ROY R. CRAIG, JR., HYOUNG M. KIM, and TZU-JENG SU (Texas, University, Austin) IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 1. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 501-506. refs
(Contract NAS8-35338; NAS9-17254)

This paper summarizes several applications of Lanczos vectors and Krylov vectors. Lanczos vectors or Krylov vectors for use in component synthesis, Lanczos vectors for systems with unsymmetric damping (unsymmetric Block-Lanczos method), and the use of Lanczos vectors to obtain reduced-order models for control of flexible structures. For each of the above applications the theoretical background is briefly summarized and a numerical example is given. Author

A89-15562
ANALYSIS AND TEST IN MODELLING OF SPAR STRUCTURE ASSESSMENT AND REVIEW
MAN MOHAN SAXENA IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 1. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 673-678. refs

The spars and subreflector of the 10 m diameter parabolic antenna which required modifications for support of the Indian remote sensing satellite mission are described in detail. The effect of vibration on X-band frequency reception performance is evaluated. K.K.

A89-15587
ACTIVE VIBRATION CONTROL OF FLEXIBLE STRUCTURE BY EIGENSTRUCTURE ASSIGNMENT TECHNIQUE
Q. ZHANG, JIM Y. H. LIU, RANDALL J. ALLEMANG, and Y. G. TSUEI (Cincinnati, University, OH) IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 1015-1019. refs

A method to control the dynamic response of flexible structures from experimental modal data is investigated. Based on sensitivity analysis, locations of actuators are predetermined. By applying the Eigenstructure Assignment Technique, the desired frequencies, the damping and the mode shapes can be chosen to calculate the feedback gain matrix. From the calculated feedback gain matrix, the feedback loop control system can be designed. Even under unknown external excitation, vibration of some critical points can be suppressed, or constrained to vibrate within certain bounds by the Eigenstructure Assignment Technique. Numerical examples are presented to support this approach. Author

A89-15617
A COMPARISON BETWEEN SINGLE POINT EXCITATION AND BASE EXCITATION FOR SPACECRAFT MODAL SURVEY
YUICHI MURAKOSHI and FUMIHIRO KUWAO (Toshiba Corp., Komukai Works, Kawasaki, Japan) IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 1365-1370.

For large, complex spacecraft structural systems, it is very important to obtain structural dynamic characteristics by modal survey. For obtaining accurate modal parameters, a suitable excitation method, data acquisition method, and data analysis method in the modal survey should be selected. In particular, accurate results will be obtained by good selection of the excitation method. Thsi paper presents a comparison of modal parameters obtained by single point excitation and base excitation in a modal survey of the truss structure. Author

A89-15848* Fairchild Space and Electronics Co., Germantown, MD.
DUAL KEEL SPACE STATION PAYLOAD POINTING SYSTEM DESIGN AND ANALYSIS FEASIBILITY STUDY
TOM SMAGALA, BRIAN F. CLASS (Fairchild Space Co. Germantown, MD), FRANK H. BAUER, and DEBORAH A. LEBAIR (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Acquisition, tracking, and pointing II; Proceedings of the Meeting, Los Angeles, CA, Jan. 14, 15, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 2-10. refs

A Space Station attached Payload Pointing System (PPS) has been designed and analyzed. The PPS is responsible for maintaining fixed payload pointing in the presence of disturbance applied to the Space Station. The payload considered in this analysis is the Solar Optical Telescope. System performance is evaluated via digital time simulations by applying various disturbance forces to the Space Station. The PPS meets the Space Station articulated pointing requirement for all disturbances except Shuttle docking and some centrifuge cases. Author

A89-16117#
ADAPTIVE STRUCTURE CONCEPT FOR FUTURE SPACE APPLICATIONS
KORYO MIURA (Tokyo, University, Kanagawa, Japan) and HIROSHI FURUYA (Nagoya University, Japan) AIAA Journal (ISSN 0001-1452), vol. 26, Aug. 1988, p. 995-1002. refs

A concept of an adaptive structure for future space applications is investigated. The definition of the adaptive structure is that the structure can purposefully vary its geometric configuration as well as its physical properties. It is shown that the variable geometry (VG) truss is the basic form of the adaptive structure. It consists of a repetition of an octahedral truss module in which some of the truss members can vary their lengths continuously using actuators. By this mechanism, the VG truss can change its configuration arbitrarily in three-dimensional space while inherent high stiffness is maintained during the transformation. The basic formulations for its geometry, structural errors, and vibrational properties are established. Some applications, including a second-generation manipulator arm, support architecture for a space station, and others, are discussed. The functional model controlled by a computer demonstrates satisfactorily the basic motions of the VG truss. Author

A89-16121#
ACTIVE VIBRATION ISOLATION BY POLYMERIC PIEZOELECTRET WITH VARIABLE FEEDBACK GAINS
HORN S. TZOU and MALIND GADRE (Kentucky, University, Lexington) AIAA Journal (ISSN 0001-1452), vol. 26, Aug. 1988, p. 1014-1017. Research supported by the University of Kentucky. refs
(Contract NSF RII-86-10671)
A theoretical and experimental study is conducted for active piezoelectric vibration isolation using polymeric piezoelectric polyvinylidence fluoride (PVDF) with variable feedback gains and a constant base excitation. The active PVDF piezoelectric isolation is a linear function of feedback voltages at a given frequency and a quadratic function of frequency at constant voltage. O.C.

A89-16152#
EXACTLY SOLVING THE WEIGHTED TIME/FUEL OPTIMAL CONTROL OF AN UNDAMPED HARMONIC OSCILLATOR
MARCELO LOPES DE OLIVEIRA E SOUZA (Instituto de Pesquisas Espaciais, Sao Jose dos Campos, Brazil) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 488-494. Research supported by the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico and Instituto de Pesquisas Espaciais. refs
The exact solution presented for the weighted time/fuel optimal control of an undamped harmonic oscillator having one bounded control and any initial state is motivated by the desire to improve the final behavior of Vander Velde (1983) trajectories for large space structures' on-off control. An investigation is accordingly made of the existence, normality, and uniqueness of both the extremals and the optimal solution; numerical comparisons are then made between the approximate and exact solutions according to three criteria. O.C.

A89-16159*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
MANEUVER AND VIBRATION CONTROL OF SCOLE
R. D. QUINN and L. MEIROVITCH (Virginia Polytechnic Institute and State University, Blacksburg) (Guidance, Navigation and Control Conference, Williamsburg, VA, Aug. 18-20, 1986, Technical Papers, p. 115-129) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 542-553. Previously cited in issue 23, p. 3426, Accession no. A86-47415. refs
(Contract NAG1-225)

A89-16162#
IDENTIFICATION METHOD FOR LIGHTLY DAMPED STRUCTURES
NELSON G. CREAMER (General Research Corp., Arlington, VA) and JOHN L. JUNKINS (Texas A & M University, College Station) (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 2A, p. 163-171) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 571-576. Previously cited in issue 14, p. 2171, Accession no. A87-33669. refs

A89-16508*# Auburn Univ., AL.
ANALYSIS OF COILS OF WIRE ROPE ARRANGED FOR PASSIVE DAMPING
M. A. CUTCHINS, J. E. COCHRAN, JR., K. KUMAR (Auburn University, AL), N. G. FITZ-COY, and M. L. TINKER International Conference on Recent Advances in Structural Dynamics, 3rd, Southampton, England, July 18-22, 1988, Paper. 12 p. refs
(Contract NAG8-532; NAG8-647)
Vibration dampers constructed with multiple loops of wire rope are studied. The literature on such devices is reviewed briefly, and dynamic and static models of them are examined. Fundamental and advanced NASTRAN models for wire rope damping are considered. C.D.

A89-16709* Ohio State Univ., Columbus.
MODEL REFERENCE, SLIDING MODE ADAPTIVE CONTROL FOR FLEXIBLE STRUCTURES
S. YURKOVICH, U. OZGUNER, and F. AL-ABBASS (Ohio State University, Columbus) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 36, July-Sept. 1988, p. 285-310. refs
(Contract NASA ORDER L-91188-B)
A decentralized model reference adaptive approach using a variable-structure sliding model control has been developed for the vibration suppression of large flexible structures. Local models are derived based upon the desired damping and response time in a model-following scheme, and variable structure controllers are then designed which employ colocated angular rate and position feedback. Numerical simulations have been performed using NASA's flexible grid experimental apparatus. R.R.

A89-16964
DISTRIBUTED ACTUATOR CONTROL DESIGN FOR FLEXIBLE BEAMS
SHAWN E. BURKE and JAMES E. HUBBARD, JR. (Charles Stark Draper Laboratory, Inc., Cambridge, MA) Automatica (ISSN 0005-1098), vol. 24, Sept. 1988, p. 619-627. Research supported by Charles Stark Draper Laboratory, Inc. refs
The application of a piezoelectric film actuator to the active vibration control of beams is studied for general boundary conditions and nonuniform film spatial distributions. It is shown that, while for most boundary configurations a spatially uniform control is appropriate, pinned-pinned, free-free, clamped-sliding, and clamped-clamped beams require nonuniform spatial distributions to be controllable. B.J.

A89-17642#
THE ROLE OF PILOT AND AUTOMATIC ONBOARD SYSTEMS IN FUTURE RENDEZVOUS AND DOCKING OPERATIONS
W. FEHSE, A. TOBIAS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), A. GETZSCHMANN (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany), M. CALDICHOURY (Matra, S.A., Toulouse, France), P. MAUTE (Aerospatiale, Cannes, France) et al. IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 12 p.
(IAF PAPER 88-037)
The planned European Space Infrastructure with its elements, e.g., the Hermes Spaceplane and the Columbus Man-Tended Free Flyer (MTFF) requires for Europe novel space operations such as rendezvous and docking (RVD) or berthing of manned spacecraft. The European Space Agency (ESA), therefore, decided to investigate the role of a pilot during RVD operations within a highly automated spacecraft. An analysis of requirements, of the tasks to be performed on-board during RVD operations, of the possibilities of interaction by a pilot with an automated Guidance, Navigation and Control (GNC) system, and of the necessary Man-Machine Interfaces (MMI) had to be performed to arrive at first answers to the questions of man-machine interaction in modern spacecraft control. The results of this analysis are presented and discussed for the example of a Hermes mission to service the Columbus MTFF. Proposals for specific MMI displays and their arrangement in the cockpit, which could be useful during rendezvous operations for GNC and mission management are presented. Author

A89-17660#
IDENTIFICATION OF MODAL PARAMETERS IN LARGE SPACE STRUCTURES
M. SEETHARAMA BHAT (Indian Institute of Science, Bangalore, India) and THOMAS LANGE (DFVLR, Oberpfaffenhofen, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p. refs
(IAF PAPER 88-066)
A method for estimating modal parameters in large space structures from transfer function data using the sequential linear

least square estimation/conjugate gradient algorithm is studied. The mode shape functions are determined from experimental data using the conjugate gradient algorithm for the best curve fit to the experimental data. The mode shape functions are used to determine the control influence, the output, and the optimal positioning of sensor and actuators. Possible applications of the method are considered. R.B.

A89-17761#
VIBRATION CONTROL OF TRUSS STRUCTURES USING ACTIVE MEMBERS
MICHIHIRO NATORI (Tokyo, University, Sagamihara, Japan), SHOICHI MOTOHASHI (Toshiba Corp., Spacecraft Mechanical Engineering Dept., Kawasaki, Japan), and SOICHI OGURA IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER 88-290)

The vibration control of truss structures has attracted increasing attention due to their possible use in space applications such as Space Station structures. Since the members of truss structures are subjected to axial force, a concept of vibration control by the use of axial active members is expected to give a new feature on vibration control of truss structures compared with the conventional external force control. The various possibilities of stiffness and damping control are demonstrated through the numerical simulation of a two-dimensional truss beam and a beam structure model. Author

A89-17762#
AIR EFFECTS ON THE STRUCTURE VIBRATION AND THE CONSIDERATIONS TO LARGE SPACECRAFT GROUND TESTING
T. YASAKA and S. ODA (Nippon Telegraph and Telephone Public Corp., Radio Communication Systems Laboratories, Yokosuka, Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p.
(IAF PAPER 88-291)

Examples are presented of air effects on large space structures. The fluid around a vibrating structure influences the apparent vibration characteristics of the structure, first by decreasing the eigen frequencies and then by increasing the damping. The apparent air mass and its effect on eigen frequencies is studied. K.K.

A89-17767#
DYNAMIC SIMULATION OF BIFURCATION IN VIBRATION MODES FOR A CLASS OF COMPLEX SPACE STRUCTURES
YOSHIAKI OHKAMI, OSAMU OKAMOTO, TAKASHI KIDA, and ISAO YAMAGUCHI (National Aerospace Laboratory, Chofu, Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p.
(IAF PAPER 88-317)

Dynamics behavior of Large Space Systems (LSS) may pose unexpected phenomena due to complex mechanical configurations, particularly if the system has a closed kinematical loop. Among such phenomena, bifurcation of vibration modes is investigated in this paper. Using an idealized spacecraft with four rigid links, it is demonstrated by computer simulation that bifurcation can take place at a singular point depending upon the angular velocity relations of the body and point and depending upon the angular velocity relations of the body and the links. It is also described in some detail how the system changes in terms of condition number, degree of freedom, and mode shapes of vibration at the passage of this singular point. Author

A89-17775#
ATTITUDE STABILITY OF A SPINNING SPACECRAFT WITH LIQUID PROPELLANT AND FLEXIBLE WIRE ANTENNAS
M. HINADA, K. NINOMIYA, I. NAKATANI (Tokyo, University, Sagamihara, Japan), T. OKAMOTO, N. MURANAKA (NEC Corp., Space Development Div., Yokohama, Japan) et al. IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p.
(IAF PAPER 88-333)

Attitude stability analysis is presented for a spinning spacecraft with liquid propellant and flexible radial wire antennas. The position-offsets from the system's center-of-mass-plane of the propellant tanks and of the wire antennas tend to destabilize the spacecraft attitude. The stability condition for such spacecraft system is newly derived, which relates the amounts of the offsets to the central body mass-properties. The application to the Geotail spacecraft, as an example, is shown. Author

A89-18432
MOTION OF A GRAVITY GRADIENT SATELLITE WITH HYSTERESIS RODS IN A POLAR-ORBIT PLANE [DVIZHENIE GRAVITATSIONNO-ORIENTIROVANNOGO SPUTNIKA S GISTEREZISNYMI STERZHNIAMI V PLOSKOSTI POLIARNOI ORBITY]
V. A. SARYCHEV, V. I. PEN'KOV, M. IU. OVCHINNIKOV, and A. D. GERMAN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 654-668. In Russian. refs

The small oscillations of a three-axis gravity gradient satellite are analyzed. The energy of its oscillations is dissipated in hysteresis rods as they are magnetized in the geomagnetic field. Various oscillation damping laws depending on the orientation of the rods in the body are obtained. B.J.

A89-18433
NONLINEAR OSCILLATIONS OF A SYSTEM OF TWO BODIES CONNECTED BY A FLEXIBLE ROD IN A CENTRAL FORCE FIELD [NELINEINYE KOLEBANIIA SISTEMY DVUKH TEL, SOEDINENNYKH GIBKIM STERZHNEM, V TSENTRAL'NOM SILOVOM POLE]
V. I. GULIAEV, V. L. KOSHKIN, P. P. LIZUNOV, and N. N. PRUDENKO Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 669-674. In Russian. refs

An analysis is made of the oscillations of two bodies connected by a flexible rod with respect to their mass center moving in an elliptical Keplerian orbit. The effect of the reduced mass of the system and the stiffness of the rod on the stability and mode of the relative motion is investigated. B.J.

A89-18436
DYNAMICS OF A SPACECRAFT WITH DIRECT ACTIVE CONTROL OF THE GRAVITY GRADIENT STABILIZER [DINAMIKA KOSMICHESKOGO APPARATA S PRIAMYM AKTIVNYM UPRAVLENIEM GRAVITATSIONNYM STABILIZATOROM]
E. M. POTAPENKO Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 699-708. In Russian. refs

Equations of spacecraft motion are obtained with allowance for an arbitrary but finite number of tons of elastic oscillations of a controlled gravity gradient stabilizer. A dynamic controller is used to optimize the spacecraft attitude control and stabilization system with allowance for the first tone of the elastic oscillations. B.J.

A89-19716
MODAL TESTING AN IMMENSE FLEXIBLE STRUCTURE USING NATURAL AND ARTIFICIAL EXCITATION
T. G. CARNE, J. P. LAUFFER, A. J. GOMEZ (Sandia National Laboratories, Albuquerque, NM), and H. BENJANNET (Shawinigan Engineering Co., Montreal, Canada) International Journal of Analytical and Experimental Modal Analysis (ISSN 0886-9367), vol. 3, Oct. 1988, p. 117-122. refs

Results are presented from a modal test of the 110-m tall EOLE wind turbine which had four modal frequencies below 1.0 Hz. The structure was excited by step relaxation and wind. It was possible to extract modal data from measured frequency response functions using step relaxation in spite of high winds. K.K.

A89-19796#
SOME PROPERTIES OF NONLINEAR VARIABLE STRUCTURE SYSTEMS
MIAN CHENG (Beijing Institute of Aeronautics and Astronautics,

People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 9, July 1988, p. A361-A367. In Chinese, with abstract in English. refs

Some properties of nonlinear variable structure systems (VSSs) are studied. First, a synthesis method for VSSs is considered, and two kinds of controller are given. Consideration is given to the study of properties of the sliding mode of VSS, including the relation between the vector fields of a system and its sliding mode, the properties of the VSS of mechanical systems, and the pole assignment of the sliding mode of linear variable systems. Author

A89-19913*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

ON-ORBIT DAMAGE ASSESSMENT FOR LARGE SPACE STRUCTURES

JAY-CHUNG CHEN and JOHN A. GARBA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) (Structures, Structural Dynamics and Materials Cenference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1, p. 714-721) AIAA Journal (ISSN 0001-1452), vol. 26, Sept. 1988, p. 1119-1126. Previously cited in issue 14, p. 2169, Accession no. A87-33634. refs

A89-19920#

MODELING AND ANALYSIS OF NONLINEAR SLEEVE JOINTS OF LARGE SPACE STRUCTURES

ALDO A. FERRI (Georgia Institute of Technology, Atlanta) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Sept.-Oct. 1988, p. 354-360. Research supported by Honeywell, Inc. refs

(Contract NSF MSM-87-07846)

A nonlinear sleeve joint model that accounts for the presence of clearances, impact damping, and dry (Coulombic) friction is developed. By studying the free and forced response of this model, it is seen that the overall damping appears to be predominantly viscous-like in nature. This is found to be true even for the cases studied in which dry friction is the sole source of energy dissipation. In addition, the nonlinear behavior of a rigid beam inserted into a sleeve joint is investigated and discussed. Author

A89-20193*# Carnegie-Mellon Univ., Pittsburgh, PA.

TRANSIENT RESPONSE OF JOINT-DOMINATED SPACE STRUCTURES - A NEW LINEARIZATION TECHNIQUE

J. H. GRIFFIN, J. BIELAK (Carnegie-Mellon University, Pittsburgh, PA), and G. A. FOELSCHE (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3, p. 1423-1432) AIAA Journal (ISSN 0001-1452), vol. 26, Oct. 1988, p. 1278-1285. Previously cited in issue 12, p. 1909, Accession no. A88-32325. refs

(Contract NAG1-612)

A89-20582

A COVARIANCE CONTROL THEORY

ANTHONY F. HOTZ and ROBERT E. SKELTON (Purdue University, West Lafayette, IN) IN: Control and dynamic systems. Volume 26. Part 2. San Diego, CA, Academic Press, Inc., 1987, p. 225-276. refs

A theory for designing feedback controllers is developed which assigns a specified covariance to the closed loop system. The theory is restricted to linear time-invariant systems with constant gain state feedback or state-estimate feedback controllers. The principal theorems and a design example are presented. V.L.

A89-20587

TECHNIQUES FOR THE IDENTIFICATION OF DISTRIBUTED SYSTEMS USING THE FINITE ELEMENT APPROXIMATION

K. Y. LEE (Pennsylvania State University, University Park) IN: Control and dynamic systems. Volume 27. Part 3. San Diego, CA, Academic Press, Inc., 1988, p. 183-215. refs

Two approaches to the parameter identification of distributed systems is considered. The first is the infinite-dimensional formulation of the identification problem, while the second is the finite-dimensional formulation of the identification problem. It is found that the finite-element method is a very useful tool in solving the parameter identification problem. K.K.

A89-20607

CONTROLLER DESIGN AND DYNAMIC SIMULATION OF ELASTIC ROBOT ARM MOUNTED IN SPACECRAFT IN PRESENCE OF UNCERTAINTY

SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IN: Robotics and factories of the future '87; Proceedings of the Second International Conference, San Diego, CA, July 28-31, 1987. Berlin and New York, Springer-Verlag, 1988, p. 347-354. refs

The paper presents an approach to the control of an uncertain nonlinear flexible robotic system. A robot arm (PUMA-type) with three rotational joints is considered. The third link is assumed to be elastic. A torquer control law is derived for controlling the joint angles. For damping of the elastic vibration, a force control law using modal velocity feedback is synthesized. Simulation results are presented to show that combination of the torque and force control law accomplishes reference joint angle trajectory tracking and elastic mode stabilization in spite of the uncertainty in the system. Author

A89-20845

CONTROL MOMENT GYROSCOPE CONFIGURATIONS FOR THE SPACE STATION

MARC MEFFE (Honeywell, Inc., Satellite Systems Div., Glendale, AZ) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 269-292.

(AAS PAPER 88-040)

Thirteen control moment gyroscope (CMG) arrays were analyzed to parametrically determine penalties in weight, power, volume, safety, maintainability, verification requirements, control requirements, and life-cycle costs. One of the single-gimbal CMG arrays provided the best solution for the Space Station's active momentum exchange. When compared on an equal reliability basis, single-gimbal CMG arrays outperformed equivalent double-gimbal arrays. K.K.

A89-20847* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

MOMENTUM MANAGEMENT STRATEGY DURING SPACE STATION BUILDUP

LYNDA BISHOP (NASA, Johnson Space Center, Houston, TX), HARVEY MALCHOW, and PHILIP HATTIS (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 315-336. refs

(Contract NAS9-17560)

(AAS PAPER 88-042)

The use of momentum storage devices to control effectors for Space Station attitude control throughout the buildup sequence is discussed. Particular attention is given to the problem of providing satisfactory management of momentum storage effectors throughout buildup while experiencing variable torque loading. Continuous and discrete control strategies are compared and the effects of alternative control moment gyro strategies on peak momentum storage requirements and on commanded maneuver characteristics are described. K.K.

A89-20848

OVERVIEW OF SPACE STATION ATTITUDE CONTROL SYSTEM WITH ACTIVE MOMENTUM MANAGEMENT

JOHN A. YEICHNER, JOHN F. L. LEE (Honeywell, Inc., Space and Strategic Div., Clearwater, FL), and DAVE BARROWS (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA,

Univelt, Inc., 1988, p. 355-372. refs
(AAS PAPER 88-044)

An approach to the development and implementation of the Space Station's attitude control system (ACS) is presented. Problems such as controllability during build-up, multibody flexure stabilization, and attitude control impact during mobile service center operations are addressed. An ACS with an active momentum management system whose design is based on an integrated control moment gyro and reaction-jet control system concept is described. K.K.

A89-20849* Ohio Univ., Athens.
FORMULATION AND VERIFICATION OF FREQUENCY RESPONSE SYSTEM IDENTIFICATION TECHNIQUES FOR LARGE SPACE STRUCTURES
JERREL R. MITCHELL (Ohio University, Athens), VICTORIA L. JONES (Control Dynamics Co., Huntsville, AL), and CHARLES P. PLANT IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 373-398. refs
(Contract NAS8-35835)
(AAS PAPER 88-045)

The advantages of designing control systems for large space structures (LSS) using frequency-domain models extracted from empirical time data are discussed. Techniques for performing MIMO system identification from test data are presented as well as techniques for improving the performance of the system identification process in the presence of noise. The utility of the proposed system identification scheme is demonstrated on the basis of experimental data obtained at the LSS Ground Test Facility at Marshall Space Flight Center. K.K.

A89-20850
QUIET STRUCTURES FOR PRECISION POINTING
P. A. STUDER (Magnetic Concepts, Silver Spring, MD) and H. W. DAVIS (Ball Corp., Ball Aerospace Systems Div., Boulder, CO) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 399-416. refs
(AAS PAPER 88-046)

The feasibility of immediately implementing quiet structures for the Space Station Polar Orbiting Platforms and other generic platform applications is demonstrated. The quiet structure system will provide both distortion control and dynamic control to accommodate a wide range of disturbance frequencies. Challenges to traditional design approaches are discussed with attention given to the shortcomings of flexible spacecraft structures. K.K.

A89-21804* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AUTOMATED SPACE VEHICLE CONTROL FOR RENDEZVOUS PROXIMITY OPERATIONS
ROBERT N. LEA (NASA, Johnson Space Center, Houston, TX) (NASA, 1988 Goddard Conference on Space Applications of Artificial Intelligence, Greenbelt, MD, May 24, 1988) Telematics and Informatics (ISSN 0736-5853), vol. 5, no. 3, 1988, p. 179-185. Previously announced in STAR as N88-30335. refs

Rendezvous during the unmanned space exploration missions, such as a Mars Rover/Sample Return will require a completely automatic system from liftoff to docking. A conceptual design of an automated rendezvous, proximity operations, and docking system is being implemented and validated at the Johnson Space Center (JSC). The emphasis is on the progress of the development and testing of a prototype system for control of the rendezvous vehicle during proximity operations that is currently being developed at JSC. Fuzzy sets are used to model the human capability of common sense reasoning in decision-making tasks and such models are integrated with the expert systems and engineering control system technology to create a system that performs comparably to a manned system. Author

A89-22505*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRANSMISSION-ZERO BOUNDS FOR LARGE SPACE STRUCTURES, WITH APPLICATIONS
TREVOR WILLIAMS (NASA, Langley Research Center, Hampton, VA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 33-38. Research supported by SERC. refs

Many large space structure control problems lead quite naturally to the application of an optimal regulator, so the transmission zeros of the open-loop system give fundamental information about the speed of response achievable by the closed-loop system. Despite the importance of this and other well-known zeros properties, little attention has been given to the transmission zeros of large space structures, except for the special case of a rigid spacecraft with flexible appendages. The object of this paper is to remedy this deficiency. In particular, it is proved that the zeros of a structure with colocated sensors and actuators must lie in a region of the complex plane that is defined by its natural frequencies and damping ratios. This generic result, a consequence of the special form of the equations of motion of structural dynamics, admits a very simple graphical interpretation: it is the generalization of the classical pole-zero interlacing property of undamped single-input/single-output structures. The number of sensor/actuator pairs, and their locations, specify where in the permissible region transmission zeros actually lie, thus quantifying the effect of sensor/actuator placement on closed-loop system performance. These points are illustrated by simple examples. Author

A89-22510#
PLANAR, TIME-OPTIMAL, REST-TO-REST SLEWING MANEUVERS OF FLEXIBLE SPACECRAFT
GURKIRPAL SINGH, PIERRE T. KABAMBA, and N. HARRIS MCCLAMROCH (Michigan, University, Ann Arbor) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 71-81. refs

The control problem of time-optimal, rest-to-rest slewing of a flexible spacecraft through a large angle is considered. The flexible spacecraft is modeled as a linear, elastic, undamped, nongyroscopic system suitable for analysis of planar rotational maneuvers. Minimum-time open-loop planar maneuvers are studied. The control histories are found to be bang-bang with multiple switches in each control variable. The optimal control history is shown to have an important time symmetry property. The switching times, final time, and costates at midmaneuver satisfy a system of nonlinear algebraic equations that can be solved using a homotopy method. An upper bound on attitude error due to control spillover is obtained. This helps to determine, a priori, the number of vibrational modes that need to be actively suppressed at the final time such that a prespecified pointing accuracy is guaranteed after the maneuver has been completed. A time-optimal slewing example is discussed to demonstrate the applicability of the results. Author

A89-22511#
NEAR-MINIMUM TIME OPEN-LOOP SLEWING OF FLEXIBLE VEHICLES
R. C. THOMPSON, J. L. JUNKINS, and S. R. VADALI (Texas A & M University, College Station) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 82-88. refs

Minimum time, open-loop, optimal controls are calculated for single-axis maneuvers of a flexible structure. By shaping the control profiles with two independent parameters, a wide variety of control histories can be produced. Based on the dynamics of the model, with a normalized time scale, the resulting Pontryagin's necessary conditions yield a nonlinear fixed final time, fixed final state, two-point boundary value problem with the maneuver time as a control parameter. Upon generating numerical solutions to the problem, the final maneuver time and residual flexural energy are compared to the bang-bang solution as a measure of the success of a given maneuver. Examples presented illustrate near-minimum time maneuvers with control of flexible modes in addition to the rigid body modes, as well as the qualitative and quantitative effect of the torque shaping parameters. Author

A89-22519#
METHOD FOR STABILITY ANALYSIS OF AN ASYMMETRIC DUAL-SPIN SPACECRAFT
HAI XING YANG (Shanghai Jiao Tong University, People's Republic of China) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 123-125. refs

The present nutational stability analysis method for an asymmetric, dual-spin spacecraft is directly derived from the first-order differential equations of the system. The behavior of nutational motion is investigated with the aid of the energy integral of the system. The method can be expanded to consider the nutational stability of a dual-spin spacecraft composed of two axisymmetric bodies. O.C.

A89-22520*# Massachusetts Inst. of Tech., Cambridge.
SENSOR FAILURE DETECTION USING GENERALIZED PARITY RELATIONS FOR FLEXIBLE STRUCTURES
MATHIEU MERCADAL (MIT, Cambridge, MA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 125-127. refs
(Contract NAG1-126)

Analytical redundancy may be preferable to hardware redundancy in failure detection/isolation tasks for such large-scale systems as space structures. Generalized single-sensor parity relations are presently applied to this problem; they are noted to yield a very simple isolation logic, and their generation is found to be extremely rapid, even in the case of extremely complex systems, provided only that the eigenstructure of the system be known. Their implementation is, however, extremely sensitive to modeling errors and noise. O.C.

A89-22619#
A NEW GENERATION OF SPACECRAFT CONTROL SYSTEM - 'SCOS'
C. MAZZA and J. F. KAUFELER (ESA, Computer Dept., Darmstadt, Federal Republic of Germany) ESA Bulletin (ISSN 0376-4265), no. 56, Nov. 1988, p. 19-23.

A software package, the Spacecraft Control and Operations System (SCOS), has been developed as a new control system for Hipparcos, Eureca, ERS-1, and all future missions to be supported by the Dedicated Mission-Support system. The system supports packetized and fixed TDM telemetry. The SCOS architecture, including the functional and mission-specific subsystems of the application layer and the middleware subsystems of the support layer, is described in detail. R.R.

A89-23719
QUALITY INDEX EXCHANGE DIAGRAM OF SPACECRAFT APPROACH AND DOCKING TRAJECTORIES UNDER ABNORMAL OPERATING CONDITIONS [DIAGRAMMA OBMENA POKAZATELEI KACHESTVA SOPRIAZHENIIA TRAEKTORII SBLIZHENIIA I PRICHALIVANIIA KOSMICHESKOGO APPARATA V NESHTATNYKH SITUATSIIAKH]
N. S. GUBONIN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Nov.-Dec. 1988, p. 946-949. In Russian.

A89-23815
THE MULTIAXIS VIBRATION SIMULATOR MAVIS - A NEW STRUCTURALLY DYNAMIC TEST BED [DER MEHRACHSENVIBRATIONSSIMULATOR MAVIS - EINE NEUE STRUKTURDYNAMISCHE TESTANLAGE]
ELMAR BREITBACH, HORST HUENERS, and JEAN-LUC REBIERE (DFVLR, Institut fuer Aeroelastik, Goettingen, Federal Republic of Germany) DFVLR-Nachrichten (ISSN 0011-4901), Nov. 1988, p. 40-43. In German.

The need for a new, structurally dynamic test concept for air and space flight structures is discussed, and the multiaxis vibration simulator MAVIS is addressed as an answer to this need. The design of MAVIS is depicted and described. The application of MAVIS in air and space technology is examined. C.D.

A89-24176* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPUTING THE TRANSMISSION ZEROS OF LARGE SPACE STRUCTURES
TREVOR WILLIAMS (NASA, Langley Research Center, Hampton, VA) IEEE Transactions on Automatic Control (ISSN 0018-9286), vol. 34, Jan. 1989, p. 92-94. Research supported by SERC. refs

The transmission zeros of a large space structure are frequently computed by means of the general-purpose algorithm of Emami-Naeini and Van Dooren (1982). It is shown that careful exploitation of the special form of the equations of motion of structural dynamics leads to an algorithm that is at least 60 times as fast as this when applied to an undamped structure, and 15 times as fast for a lightly damped one. I.E.

A89-24477
OPTICAL SENSORS FOR RELATIVE TRAJECTORY CONTROL
A. S. MENARDI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: Automatic control; Proceedings of the Tenth Triennial World Congress of IFAC, Munich, Federal Republic of Germany, July 27-31, 1987. Volume 6. Oxford, England and Elmsford, NY, Pergamon Press, 1988, p. 1-4. refs

The current development status of optical sensors for spacecraft applications is surveyed, with a focus on sensors used to determine spacecraft orientation relative to celestial objects. Topics addressed include optoelectronic detectors for IR and visible sensors, sun and earth sensors, star trackers and mappers, and planetary and cometary sensors. Particular attention is given to sensors for automated rendezvous and docking operations and for space robotics. T.K.

A89-24482
DECENTRALIZED FREQUENCY SHAPING AND MODAL SENSITIVITIES FOR OPTIMAL CONTROL OF LARGE SPACE STRUCTURES
U. OZGUNER and S. YURKOVICH (Ohio State University, Columbus) IN: Automatic control; Proceedings of the Tenth Triennial World Congress of IFAC, Munich, Federal Republic of Germany, July 27-31, 1987. Volume 6. Oxford, England and Elmsford, NY, Pergamon Press, 1988, p. 43-48. Research supported by the Ohio State University. refs

Methods from the area of decentralized control which have emerged for analysis and control of large flexible space structures are reviewed. Many critical issues remain for consideration in control problems of flexible spacecraft, including the need for incorporation of actuator dynamics in the system model, the need for an initial stabilizing feedback solution to initiate computation in optimal controller design, and the need for inclusion of frequency domain constraints into the state-space formulation. Author

A89-24496
FAILURE DETECTION AND IDENTIFICATION IN THE CONTROL OF LARGE SPACE STRUCTURES
H. OKUBO, Y. MUROTSU, and F. TERUI (Osaka Prefecture, University, Sakai, Japan) IN: Automatic control; Proceedings of the Tenth Triennial World Congress of IFAC, Munich, Federal Republic of Germany, July 27-31, 1987. Volume 6. Oxford, England and Elmsford, NY, Pergamon Press, 1988, p. 175-180. refs

Numerical techniques for detecting and isolating faults in structural control systems are described and demonstrated. The governing equations for a linear dynamical system are derived, and a procedure based on the combined use of a decoupled Kalman bias filter and a generalized-likelihood-ratio method is outlined. Results from a simulation of tendon control of a large beam structure (Murotsu et al., 1985) are presented in tables and graphs and briefly characterized. T.K.

A89-25335*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

THE EFFECT OF INITIAL VELOCITY ON MANUALLY CONTROLLED REMOTE DOCKING OF AN ORBITAL MANEUVERING VEHICLE (OMV) TO A SPACE STATION

ADAM R. BRODY (NASA, Ames Research Center; Sterling Software, Aerospace Human Factor Research Div., Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0400)

Simulated docking maneuvers were performed to assess the effect of initial velocity on docking failure rate, mission duration, and total impulse (fuel consumption). The effect of the removal of the range and rate displays was also examined. Since duration and impulse decrease and increase respectively with increases in initial velocity, two parameters were created by subtracting a reference value from each. These values were termed 'reserve time' and 'radial impulse'. Naive subjects were capable of achieving a high success rate in performing simulated docking maneuvers without extensive experience, and failure rate did not significantly increase with increased velocity. The amount of time pilots reserved for final approach increased with starting velocity. Piloting of docking maneuvers was not significantly affected in any way by the removal of range and rate displays. Values for reserve time, and radial impulse were lowest for docking maneuvers begun at the lowest initial velocity. Author

A89-25372#

A CAD METHOD FOR THE DETERMINATION OF FREE MOLECULE AERODYNAMIC AND SOLAR RADIATION FORCES AND MOMENTS

C. A. SEDLUND (General Dynamics Corp., Space Systems Div., San Diego, CA) and L. H. SENTMAN (Illinois, University, Urbana) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by Lockheed Missiles and Space Co., Inc.
(AIAA PAPER 89-0455)

A CAD program to calculate free molecule and solar force and moment coefficients was developed and applied to the Space Station with three different approximations of the structural truss. The primary result is that the geometrical model of the spacecraft, rather than the parameters such as the temperature of the reflected molecules or reflectance of the surface, is the major factor in calculating accurate force and moment coefficients for a complicated spacecraft such as the Space Station. The effect of the truss approximation on the force coefficients is predictable, with the magnitudes of the coefficients ranked by the size of the truss approximation. The effect of the truss approximation on the moment coefficients is more complex and shading effects cause significant irregularities in the moment coefficients as the angle of attack varies. Author

A89-25433#

DYNAMICS OF THE ORBITER BASED WISP EXPERIMENT

V. J. MODI and A. M. IBRAHIM (British Columbia, University, Vancouver, Canada) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p.
(Contract NSERC-A-2181)
(AIAA PAPER 89-0540)

A methodology for formulating equations of motion applicable to a large class of systems with interconnected flexible deployable members is briefly outlined. Effectiveness of the formulation is illustrated through its application to a problem of contemporary interest, the WISP (Waves In Space Plasma) dipole antenna aboard the Space Shuttle. The parametric study suggests that under critical combinations of parameters, the system is susceptible to instability. The information is fundamental to the planning of the WISP experiment. Author

A89-25434#

ADAPTIVE IDENTIFICATION AND MODEL TRACKING BY A FLEXIBLE SPACECRAFT

J. M. SKOWRONSKI (Southern California, University, Los Angeles, CA; Queensland, University, Brisbane, Australia) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0541)

A rigid-flexible spacecraft structure subject to bounded uncertainty in structural parameters and payload, with large articulation angles, is modeled by a hybrid multidimensional system with high (untruncated) geometric nonlinearity and Coriolis forces. It is to be controlled adaptively to track a rigid body reference model with desired dynamics. To this aim, the system is replaced by a nonlinear adaptive, state and parameter identifier with considerably reduced number of DOF and made exactly integrable, i.e. with solutions in closed form. The technique allows for the tracking to occur with stipulated precision obtained in stipulated real time. The reduced dynamics and the exact integrability of the identifier and the adaptive laws make on-line computation of the algorithms simple enough to be made sufficiently fast on a small on-board computer. Author

A89-25437#

MODAL IDENTITIES FOR MULTIBODY ELASTIC SPACECRAFT - AN AID TO SELECTING MODES FOR SIMULATION

HARI B. HABLANI (Rockwell International Corp., Seal Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0544)

This paper answers the question: which set of modes furnishes a higher fidelity math model of dynamics of a multibody, deformable spacecraft - the hinges-free or hinges-locked vehicle modes? Two sets of general, discretized, linear equations of motion of a spacecraft with an arbitrary number of deformable appendages, each articulated directly to the core body, are obtained using the above two families of modes. By comparing these equations, ten sets of modal identities are constructed which involve modal momenta coefficients and frequencies associated with both classes of modes. By applying the above identities to a four-body spacecraft, the hinges-locked vehicle modes are found to yield a higher fidelity model than hinges-free modes, because the latter modes have nonconverging modal coefficients. Author

A89-25512*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

DRAG MEASUREMENTS ON A MODIFIED PROLATE SPHEROID USING A MAGNETIC SUSPENSION AND BALANCE SYSTEM

DAVID A. DRESS (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0648)

Low-speed wind tunnel drag force measurements were taken on a modified prolate spheroid free of support interference. This body was tested at zero incidence in the NASA Langley 13 inch Magnetic Suspension and Balance System. This shape was one of two bodies tested to determine the drag force measuring capabilities of the 13 inch MSBS. In addition, support interference on this shape at zero incidence was quantified by using a dummy sting. The drag force calibrations and wind-on repeatability data make it possible to assess the drag force measuring capabilities of the 13 inch MSBS. Comparisons with and without the sting showed differences in the drag coefficients with the dummy sting case resulting in lower drag coefficients. Author

A89-25613*# Florida Univ., Gainesville.

GLOBAL SENSITIVITY ANALYSIS IN CONTROL-AUGMENTED STRUCTURAL SYNTHESIS

CHRISTINA L. BLOEBAUM (Florida, University, Gainesville) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract NAG1-688)
(AIAA PAPER 89-0844)

In this paper, an integrated approach to structural/control design is proposed in which variables in both the passive (structural) and active (control) disciplines of an optimization process are changed

simultaneously. The global sensitivity equation (GSE) method of Sobieszczanski-Sobieski (1988) is used to obtain the behavior sensitivity derivatives necessary for the linear approximations used in the parallel multidisciplinary synthesis problem. The GSE allows for the decoupling of large systems into smaller subsystems and thus makes it possible to determine the local sensitivities of each subsystem's outputs to its inputs and parameters. The advantages in using the GSE method are demonstrated using a finite-element representation of a truss structure equipped with active lateral displacement controllers, which is undergoing forced vibration.
I.S.

A89-25873* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST MULTIVARIABLE CONTROL OF LARGE SPACE STRUCTURES
SURESH M. JOSHI (NASA, Langley Research Center, Hampton, VA) IN: International Conference on Advances in Communication and Control Systems, 1st, Washington, DC, June 18-20, 1987, Proceedings. New York, Optimization Software, Inc., 1988, p. 111-122. refs

The problem of designing attitude-control systems for large flexible space structures is considered. The difficulties which arise because of special dynamic characteristics are described, and methods for overcoming them using two type of controllers are presented. The first type of controller considered is a model-based compensator (MBC) and the second is the 'dissipative' controller which employs output feedback. Based on the analytical and numerical results obtained, the MBC can offer good performance under normal conditions, while the dissipative controller offers more robustness but perhaps reduced performance in situations involving larger uncertainties. Author

A89-26192
ANALYTIC METHODS FOR THE MODELING OF FLEXIBLE STRUCTURES
J. M. SCHUMACHER (Stichting Mathematisch Centrum, Centrum voor Wiskunde en Informatica, Amsterdam, Netherlands) IN: Analysis and optimization of systems; Proceedings of the Eighth International Conference, Juan-les-Pins, France, June 8-10, 1988. Berlin and New York, Springer-Verlag, 1988, p. 461-471. refs

The modeling of structures built up by interconnecting a moderate number of distributed elements, each of which can be described by the classical equations of mathematical physics, is discussed. Techniques for operations on analytic matrices are considered which may be applied to obtain methods for specific computational goals. Three such methods for the computation of natural frequencies are examined. C.D.

A89-26383#
ON THE ORBITER BASED CONSTRUCTION OF THE SPACE STATION AND ASSOCIATED DYNAMICS
V. J. MODI and A. M. IBRAHIM (British Columbia, University, Vancouver, Canada) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 96-113. refs
(Contract NSERC-67-1547)

The interactions between deployment, attitude dynamics, and flexural rigidity for two configurations representing beam and tether type deployment are examined using a relatively general formulation procedure. The results suggest that the flexibility, deployment velocity, initial conditions, and appendage orientation have substantial influence on the system response. It is shown that the system can become unstable under critical combinations of parameters. It is suggested that the research is relevant to the design of control systems for communications satellites, orbiter-based experiments, and the evolutionary transient and postconstruction operational phases of the Space Station. R.B.

A89-26717
POINTING AND STABILIZATION ISSUES OF LARGE SPINNING ANTENNAS
P. H. MAK (Aerospace Corp., Control Analysis Dept., El Segundo, CA) IN: PLANS '88 - IEEE Position Location and Navigation Symposium, Orlando, FL, Nov. 29-Dec. 2, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 230-235.
(Contract F04701-85-C-0086)

Three dynamics, control, and calibration issues concerning the integration of a large spinning antenna onboard a three-axis stabilized vehicle are discussed. Since this antenna development was the key driver for the NROSS program, the issues of spacecraft/antenna dynamic interactions, on-orbit balancing, and boresight pointing were some of the technologies identified very early in the program. Methodologies developed and preliminary results obtained to resolve the feasibility of the baseline antenna design are also discussed. No major problems were identified and the preliminary results indicated that spinning the large antenna was feasible. I.E.

A89-26869
ACTIVE VIBRATION SUPPRESSION FOR THE MAST FLIGHT SYSTEM
FREDRIC M. HAM, SCOTT W. GREELEY, and BEN L. HENNIGES (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IEEE Control Systems Magazine (ISSN 0272-1708), vol. 9, Jan. 1989, p. 85-90.

Active vibration suppression of a large flexible space structure is addressed. The system (experimental test bed), performance requirements, and system simulations and models are described. The structure is a 60-m truss beam attached to the Shuttle Orbiter. A baseline control system is required to provide 5 percent structural damping for the first ten structural (flexible) modes of the truss beam. The control design approach used to achieve the damping is a decentralized velocity feedback type. Collocated actuator and sensor locations are given, with details of the model for the proof-mass actuating device, the linear dc motor. I.E.

A89-27698#
LOCALIZATION OF VIBRATIONS IN LARGE SPACE REFLECTORS
ODDVAR O. BENDIKSEN (Princeton University, NJ) and PHILLIP J. CORNWELL (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. 925-935) AIAA Journal (ISSN 0001-1452), vol. 27, Feb. 1989, p. 219-226. Previously cited in issue 14, p. 2117, Accession no. A87-33745. refs

A89-27699#
STRONG MODE LOCALIZATION IN NEARLY PERIODIC DISORDERED STRUCTURES
CHRISTOPHE PIERRE (Michigan, University, Ann Arbor) and PHILIP D. CHA AIAA Journal (ISSN 0001-1452), vol. 27, Feb. 1989, p. 227-241. Research supported by the University of Michigan. refs
(Contract NSF MSM-87-00820)

An investigation of the effects of disorder on the dynamics of nearly periodic structures is presented. Emphasis is placed on the study of mode localization and vibration-confinement phenomena for mistuned assemblies of coupled, multi-degree-of-freedom component systems. Perturbation methods are developed and applied to predict the occurrence of localized modes and analyze their characteristics. Strong localization is shown to occur for weak coupling between component systems. Furthermore, a 'modal' coupling parameter is defined that governs the possibility for localization in a given mode. Generally speaking, higher modes are shown to be more susceptible to localization than lower ones, and localization is unavoidable if the mode number is large enough. The occurrence of localization is also shown to be dependent upon the location of the coupling constraint between the component systems. Author

A89-28481
STRUCTURAL AND CONTROL OPTIMIZATION OF SPACE STRUCTURES
RAMANA V. GRANDHI (Wright State University, Dayton, OH) Computers and Structures (ISSN 0045-7949), vol. 31, no. 2, 1989, p. 139-150. Research supported by USAF. refs

A simultaneous structural and control optimization of flexible structures is presented in this paper. Behavior constraints are imposed on the closed-loop eigenvalue distribution and the damping parameters. Optimum results are obtained with three different optimization algorithms, and the nonunique nature of the optimum solutions is discussed. Also, the minimization of the Frobenious norm is investigated. A two-bar truss and an ACOSS four structure were designed and numerical comparisons are presented. The qualitative aspects of the optimum solutions are discussed with the transient response and control effort simulations. Author

A89-28500
ANALYSIS AND SIMULATION OF A CONTROLLED RIGID SPACECRAFT - STABILITY AND INSTABILITY NEAR ATTRACTORS
CHRISTOPHER I. BYRNES (Arizona State University, Tempe), SALVATORE MONACO (L'Aquila, Universita, Italy), ALBERTO ISIDORI (Roma I, Universita, Italy), and STORNELLI SABATINO (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 81-85. Research supported by USAF, NSF, MPI, and Telespazio S.p.A. refs

The authors give an analysis and simulation of the asymptotic properties of various closed-loop trajectories of the rigid-body model of a controlled spacecraft. Recent results are described which show that the rigid body for a spacecraft controlled by two independent pairs of gas jets is locally controllable but not locally asymptotically stabilizable about reference attitudes. The authors analyze, in the context of feedback stabilization about an attractor, the asymptotic properties of closed-loop trajectories when a feedback law driving the motion to a revolute cycle about a principal axis is implemented. Simulations support such convergence but indicate that convergence is quite slow, due to the fact that this cycle lies, as it must, on an invariant center manifold for this system. In particular, while the design is based on a nonlinear enhancement of root-locus theory, such attractors have no linear analogue. I.E.

A89-28552#
SPACE STRUCTURE CONTROL USING MOVING BANK MULTIPLE MODEL ADAPTIVE ESTIMATION
ROBERT W. LASHLEE, JR. (U.S. Air Force Academy, Colorado Springs, CO) and PETER S. MAYBECK (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 712-717. refs

The authors investigate the feasibility of applying moving-bank multiple-model adaptive estimation algorithms to flexible space-structure control. This form of estimation/control is an attempt to reduce the computational loading associated with the implementation of a full-scale multiple-model adaptive estimator/controller. It is shown that the moving-bank controller performs nearly identically to a benchmark controller and substantially better than a fixed-bank controller with a coarse discretization level that covers the entire range of parameter variation. I.E.

A89-28553
SLIDING MODE CONTROL OF FLEXIBLE SPACECRAFT UNDER DISTURBANCE TORQUE
ASHOK IYER and SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 718-723. refs
(Contract DAAL03-87-G-0004)

The authors present a control system design for large-angle rotational maneuvers of a spacecraft-beam-tip body (an antenna or a reflector) configuration. It is assumed that an unknown but bounded disturbance torque is acting on the spacecraft. A sliding-mode attitude-control law is derived for the slewing of the space vehicle. This slewing control law requires only attitude error and its derivative for feedback and does not need any information on the elastic motion of the system. For the damping of the elastic motion, a stabilizer is designed separately based on the asymptotically decoupled system describing the elastic deflections in two orthogonal planes. Simulation results are presented to show that precise large rotational maneuvers can be performed using the attitude controller and the elastic mode stabilizer in spite of the uncertainty in the system. I.E.

A89-28572
PARAMETER ESTIMATION OF SPACECRAFT STRUCTURAL DYNAMICS FROM FLIGHT TEST DATA
JERRY L. SUN and KENNETH M. KESSLER (Systems Control Technology, Inc., Palo Alto, CA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 867, 868. refs

The authors describe a technique in which measurements from only two sensors are used in estimating the structural bending modes as well as the forced harmonics of a large space structure. A step-by-step approach is used to identify structural flexing via the filter error method of the maximum-likelihood formulation with a minimum number of sensors. The methodology was applied to actual spacecraft flight data and satisfactory results were obtained. I.E.

A89-28613
COMPUTATION OF THE STABILITY ROBUSTNESS OF LARGE STATE SPACE MODELS WITH REAL PERTURBATIONS
L. QIU and E. J. DAVISON (Toronto, University, Canada) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1380-1385. refs
(Contract NSERC-A-4396)

The authors address the computational problem encountered by a novel method of stability robustness analysis previously outlined, when it is applied to large systems. An iterative procedure is developed to compute the singular values and singular vectors of certain classes of large composite matrices; such a procedure can be used to solve problems which, because of dimensionality, cannot be solved by applying the QR transformation method. The procedure is then applied to the determination of stability robustness bounds of large-state-space systems with real perturbations. Various numerical examples, including a 46th-order spacecraft system, are given to illustrate the results obtained. I.E.

A89-28631
OPTIMAL REGULATION OF FLEXIBLE STRUCTURES GOVERNED BY HYBRID DYNAMICS
SAROJ K. BISWAS (Temple University, Philadelphia, PA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1613-1618. refs

The author considers the problem of optimal control of flexible structures governed by a coupled system of ordinary differential equations and hyperbolic partial differential equations (hybrid dynamics). Necessary conditions are presented for determining the control torque and control forces for optimal regulation of the structure along with simultaneous suppression of its elastic vibrations. Illustrative numerical results for the control of a one-link flexible robot are presented. I.E.

A89-28632
BOUNDED INPUT FEEDBACK CONTROL OF LINEAR SYSTEMS WITH APPLICATION TO THE CONTROL OF A FLEXIBLE SYSTEM
H. KRISHNAN and M. VIDYASAGAR (Waterloo, University, Canada) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1619-1626. refs

The design of discrete-time H2 optimal controllers in the presence of constraints in the plant input is presented. The method is applied to the model of an experimental flex-arm, which has some nonminimum-phase zeros and all its poles on the unit circle. Experimental and simulation results on the performance of a fifth-order controller thus obtained are presented. The results suggest that this method of controller design ensures good performance of the closed-loop system. I.E.

A89-28633* Ohio State Univ., Columbus.
A FREQUENCY DOMAIN IDENTIFICATION SCHEME FOR FLEXIBLE STRUCTURE CONTROL
ANTHONY P. TZES and STEPHEN YURKOVICH (Ohio State University, Columbus) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1627-1632. refs
(Contract NAG1-720)

The authors present a novel method called time-varying transfer function estimation (TTFE) in which time-domain parameters are computed through identification in the frequency domain. The method is particularly well suited for flexible structure control problems. An example of a flexible manipulator system is presented for which a self-tuning control law with frequency shaping is derived and demonstrated. I.E.

A89-28634
REST-TO-REST SLEWING OF FLEXIBLE STRUCTURES IN MINIMUM TIME
ENRIQUE BARBIERI (Tulane University, New Orleans, LA) and UMIT OZGUNER (Ohio State University, Columbus) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1633-1638. refs

The rest-to-rest slewing of flexible structures in minimum time is considered via phase-plane techniques. The trajectories are shown to exhibit a mirror-image symmetry in the phase plane. The advantage of this approach is that the switching control law can be expressed in terms of the rigid body states only, thereby resulting in a closed-loop strategy. Simulations are included for a one-bending model of a flexible slewing structure. I.E.

A89-28636
CONTROL AND STABILIZATION OF A FLEXIBLE BEAM ATTACHED TO A RIGID BODY - PLANAR MOTION
C. A. DESOER and O. MORGUL (California, University, Berkeley) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1643, 1644. refs
(Contract NSF ECS-85-00993)

The authors consider a flexible spacecraft modeled as a rigid body constrained to rotate around its prinicipal axis D1, fixed 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. I.E.

A89-28637*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ON THE DESIGN OF THE DISSIPATIVE LQG-TYPE CONTROLLERS
R. LOZANO-LEAL and S. M. JOSHI (NASA, Langley Research Center, Hampton, VA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1645, 1646. refs

The design of dissipative linear-quadratic-Gaussian-type compensators for positive real plants is considered. It is shown that if the noise covariance matrices (used as weighting matrices) satisfy certain conditions, the compensator has a strictly positive real transfer function matrix. The stability of the resulting closed-loop system is guaranteed regardless of modeling errors as long as the plant remains positive real. In view of this property, the controller is expected to be useful for vibration suppression in large, flexible space structures. I.E.

A89-28640
IDENTIFICATION OF FLEXIBLE STRUCTURES USING AN ADAPTIVE ORDER-RECURSIVE METHOD
FARYAR JABBARI (California, University, Irvine) and J. S. GIBSON (California, University, Los Angeles) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1668-1673. refs
(Contract AF-AFOSR-87-0373)

The authors present adaptive parameter identification results for a complex flexible structure with many closely packed natural frequencies. Least-squares lattice filters are used to estimate the number of excited modes, natural frequencies and damping ratios from input/output data. One-step-ahead output prediction also is generated by the lattice filters. I.E.

A89-28641* Brown Univ., Providence, RI.
SPATIAL VERSUS TIME HYSTERESIS IN DAMPING MECHANISMS
H. T. BANKS, R. H. FABIANO, Y. WANG (Brown University, Providence, RI), D. J. INMAN, and H. CUDNEY, JR. (New York, State University, Buffalo) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1674-1677. refs
(Contract NAG1-517; NGT-33-183-802; AF-AFOSR-84-0398; AF-AFOSR-85-0220; AF-AFOSR-85-0119; NSF MSM-83-51807; F49620-86-C-0111)

A description is given of continuing investigations on the task of estimating internal damping mechanisms in flexible structures. Specifically, two models for internal damping in Euler-Bernoulli beams are considered: spatial hysteresis and time hysteresis. A theoretically sound computational algorithm for estimation is described, and experimental results are discussed. It is concluded that both models perform well in the sense that they accurately predict response for the experiments conducted. I.E.

A89-28646
NONLINEAR DYNAMICS AND CONTROL ISSUES FOR FLEXIBLE SPACE PLATFORMS
H. G. KWATNY and W. H. BENNETT (Techno-Sciences, Inc., Greenbelt, MD) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1702-1707. Research supported by SDIO. refs
(Contract F49620-87-C-0103)

A description is given of the early results of an ongoing research program into the control of the nonlinear dynamics of large, flexible space structures. An approach to the modeling of generic space platforms is described, and the design of nonlinear feedback control systems via extract input-output linearization and decoupling as applied to this class of systems is also discussed. The role of nonlinear system zeros is highlighted. An example is given. I.E.

A89-28647* Illinois Univ., Urbana.
SLEW-INDUCED DEFORMATION SHAPING
T. A. W. DWYER, III (Illinois, University, Urbana) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1708-1713. Research supported by SDIO. refs
(Contract F49620-87-C-0103; NAG1-613)

Computed torques for pointing and tracking require compensation for slew-induced structural, forebody/aftbody, or optical train alignment deformations. Thus even if only line-of-sight variables are to be commanded, full state feedback is needed. The solution proposed is to decouple by feedforward of the line-of-sight slew dynamics into the deformation control loop. It is shown how arbitrarily few actuators are needed for such deformation shaping, at the cost of higher differentiability of the reference line-of-sight dynamics. The low-rate, single-axis case is developed in detail, and its extension to high rates and multiple axes by global feedback linearization is outlined. I.E.

A89-28651
NONLINEAR DYNAMICS OF FLEXIBLE STRUCTURES - GEOMETRICALLY EXACT FORMULATION AND STABILITY
J. C. SIMO and T. A. POSBERGH (Stanford University, CA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1732-1737. Research supported by USAF. refs

The stability of flexible structures coupled with rigid bodies performing large overall motions is investigated. The analysis is based on geometrically exact models which have no restriction on the degree of flexibility and satisfy of all invariance requirements under superposed rigid body motions. For these models there is a natural decomposition which decouples the dynamics into a space of rigid-body motions and its complement. The stability of relative equilibria are then explored by a method referred to as the energy-momentum method, which incorporates the conserved quantities of the system. By exploiting these invariants along with the underlying structure, stability criteria for the relative equilibria can be found. I.E.

A89-28652
NONLINEAR STABILIZATION OF TETHERED SATELLITES
D.-C. LIAW and E. H. ABED (Maryland, University, College Park) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1738-1745. refs
(Contract AF-AFOSR-87-0073; NSF ECS-86-57561; NSF CDR-85-00108)

A set of dynamic equations governing the dynamics of a tethered satellite system (TSS) and stabilizing tension control laws in feedback form are derived. The tether is assumed rigid and massless, and the equations of motion are derived using the system Lagrangian. It is observed that tools from stability analysis of critical nonlinear systems must be applied to stabilize the system. Tools related to the Hopf bifurcation theorem are used in the construction of the stabilizing control laws, which may be taken as purely linear. Simulations illustrate the nature of the conclusions, and show that nonlinear terms in the feedback can be used to improve the transient response significantly. I.E.

A89-29107#
ROBUST HYBRID ADAPTIVE CONTROLLER OF CONTINUOUS PLANT WITH PRESENCE OF UNMODELED DYNAMICS CONSIDERED
YANJUN LI (Northwestern Polytechnical University, Xian, People's Republic of China) Northwestern Polytechnical University, Journal (ISSN 1000-2758), vol. 7, Jan. 1989, p. 57-66. In Chinese, with abstract in English. refs

This paper presents a robust hybrid adaptive controller for a continuous plant with unmodeled dynamics. A class of unmodeled dynamics consisting of both additive and multiplicative plant perturbations is considered. The additive plant perturbations are assumed to be small at all frequencies, but the multiplicative ones are required to be small only at the low frequency range. A hybrid adaptive law is proposed for the class of unmodeled dynamics. This law combines normalization with usual adaptive control algorithm to assure robust stability of the control system. It is shown that, for this class of unmodeled dynamics, the proposed algorithm guarantees boundedness for all signals in the closed loop and the residual tracking error between output of the closed loop plant and output of the desired model is small in the mean. This controller may be useful for the design of control systems in a wide variety of space structures. C.D.

A89-29200#
MOTION AND DEFORMATION OF VERY LARGE SPACE STRUCTURES
RAMESH B. MALLA (Connecticut, University, Storrs), WILLIAM A. NASH, and THOMAS J. LARDNER (Massachusetts, University, Amherst) AIAA Journal (ISSN 0001-1452), vol. 27, March 1989, p. 374-376.
(Contract AF-AFOSR-83-0025)

The equations of motion for a very large axially flexible structure orbiting the earth with planar motion in a general noncircular orbit are developed. The equations are used to study the effects of the orbit eccentricity on the motion and deformation of a large space structure under the action of the earth's gravitational forces. It is shown that an increase in orbit eccentricity disturbs the attitude motion of the space structure. Although the orbit eccentricity produces only small magnitude structural deformation, it is found that, for highly eccentric orbits, the structure may tumble continuously. R.B.

A89-30652*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADAPTIVE STRUCTURES
BEN K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1-11. refs
(AIAA PAPER 89-1160)

The fundamental principles of the adaptive structures concept and its applications to current and planned space missions are reviewed and illustrated with diagrams, drawings, graphs, and photographs. An adaptive structure is defined as one which can be modified to meet mission requirements, either by remote commands or automatically in response to external stimuli. Topics addressed include the need for adaptive structures, analytical models, ground testing, sensor/actuator-structure interactions, structural concepts, active damping, wave propagation in large structures, the selection of active member locations, and on-orbit system identification. Particular attention is given to adaptive structures being developed for the NASA Large Deployable Reflector and Optical Interferometer projects. T.K.

A89-30653*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MULTIPLE BOUNDARY CONDITION TESTING ERROR ANALYSIS
R. J. GLASER, C. P. KUO, and B. K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 12-20. refs
(AIAA PAPER 89-1162)

Techniques for interpreting data from multiple-boundary-condition (MBC) ground tests of large space structures are developed analytically and demonstrated. The use of MBC testing to validate structures too large to stand alone on the ground is explained; the generalized least-squares mass and stiffness curve-fitting methods typically applied to MBC test data are reviewed; and a detailed error analysis is performed. Consideration is given to sensitivity coefficients, covariance-matrix theory, the correspondence between test and analysis modes, constraints and step sizes, convergence criteria, and factor-analysis theory. Numerical results for a simple beam problem are presented in tables and briefly characterized. The improved error-updating capabilities of MBC testing are confirmed, and it is concluded that reasonably accurate results can be obtained using a diagonal covariance matrix. T.K.

A89-30654#
SELECTIVE MODAL EXTRACTION FOR DYNAMIC ANALYSIS OF SPACE STRUCTURES
Y. C. YIU (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 21-31. Research supported by Lockheed Missiles and Space Co., Inc. refs
(AIAA PAPER 89-1163)

For problems with fixed spatial load distributions, the Load Dependent Ritz Vector basis provides a Ritz subspace for dynamic response evaluation. The eigensolution of this subspace provides the approximate modes shapes, hence the selected modes, to the original problem for modal superposition. In this paper, the mathematical basis of selective modal extraction is explained in terms of the conventional engineering analysis methods. The method is extended to structural systems with positive semidefinite stiffness matrices and hence suitable for dynamic analysis of space structures. Author

A89-30660#
EXPERIMENTAL ACTIVE VIBRATION DAMPING OF A PLANE TRUSS USING HYBRID ACTUATION
WILLIAM L. HALLAUER, JR. and STEVEN E. LAMBERSON (U.S. Air Force Academy, Colorado Springs, CO) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 80-90. Research sponsored by USAF. refs
(AIAA PAPER 89-1169)

The active vibration damping of a truss structure by the simultaneous use of air-jet thrusters (for low frequencies) and reaction-mass/force actuators (for high frequencies) is investigated analytically and experimentally. The characteristics of typical hardware components are reviewed and illustrated with drawings and photographs; the equations governing truss vibration and active damping are derived; and results for a beamlike plane truss are presented in graphs. Good damping is demonstrated using simple analog-computer controllers which integrate servo accelerometer signals to obtain velocity feedback. T.K.

A89-30671#
FORCED VIBRATIONS IN LARGE SPACE REFLECTORS WITH LOCALIZED MODES
ODDVAR O. BENDIKSEN (Princeton University, NJ) and PHILLIP J. CORNWELL IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 188-198. refs
(AIAA PAPER 89-1180)

The forced vibrational response of a large space reflector structure to (1) impulsive in-plane loading of one substructure or (2) out-of-plane displacement of a rigid member is investigated analytically, considering perfect and imperfect reflectors with 18 radial ribs and subject to both localized and extended modes. The approach of Cornwell and Bendiksen (1987) is extended to multi-DOF substructures. Numerical results are presented in extensive graphs and discussed in detail. In case (1), it is demonstrated that the disturbance does not propagate throughout the structure if the first mode group (primarily the first bending mode) is localized. In case (2), the motion of the ribs in an imperfect structure is found to have variable amplitude. T.K.

A89-30684*# CSA Engineering, Inc., Palo Alto, CA.
VERY LOW FREQUENCY SUSPENSION SYSTEMS FOR DYNAMIC TESTING
DAVID A. KIENHOLZ (CSA Engineering, Inc., Palo Alto, CA), EDWARD F. CRAWLEY (MIT, Cambridge, MA), and T. JEFFREY HARVEY (AEC-Able Engineering, Inc., Goleta, CA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 327-336. Research supported by NASA and Lockheed Missiles and Space Co., Inc.
(AIAA PAPER 89-1194)

Specifications for a Space Station suspension system which can provide rigid-body translation frequencies on the order of 0.1-0.2 Hz for a 50-foot payload weighing about 3400 lb and having a number of highly flexible appendages are discussed. Two suspension devices are considered, an all-mechanical passive device based on coil springs and a device using a combination of a passive pneumatic system and an active electromagnetic system. Test results show that both devices meet the initial requirements. R.R.

A89-30691#
NONLINEAR FINITE ELEMENT SIMULATION OF THE LARGE ANGLE MOTION OF FLEXIBLE BODIES
LEE D. PETERSON (Sandia National Laboratories, Albuquerque, NM) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 396-404. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-1201)

A nonlinear large-strain-displacement structural finite element program is used to simulate the large-angle motions of flexible bodies. Results are presented for three examples: (1) a large-angle maneuver of a cantilevered flexible robot arm; (2) the nutation of a rotating free-free beam observed from a rotating frame; and (3) the spin-up of a cantilevered beam from rest. The spin-up problem is used to test for the false divergence of the beam above a critical spin rate. R.R.

A89-30692#
NON-LINEAR STRAIN-DISPLACEMENT RELATIONS AND FLEXIBLE MULTIBODY DYNAMICS
A. H. VON FLOTOW (MIT, Cambridge, MA) and C. E. PADILLA IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 405-413. refs
(AIAA PAPER 89-1202)

The dynamics of chains of flexible bodies undergoing large rigid body motions and small elastic deflections is investigated, with emphasis on the role of nonlinear strain-displacement relations in the development of the motion equations for the deflections of these systems. Numerical results are presented for a two-link chain constrained to move in the plane and subject to hinge torques. Slew maneuver simulations have been performed for models with and without properly modeled kinetics of deformation. R.R.

A89-30699#
INSTABILITY OF A ROTATING BLADE SUBJECTED TO SOLAR RADIATION PRESSURE
MICHIHIRO NATORI (Tokyo, University, Sagamihara, Japan), S. NEMAT-NASSER (California, University, La Jolla), and JIN MITSUGI (Nippon Telegraph and Telephone Public Corp., Radio Communication Systems Laboratories, Yokosuka, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics

and Astronautics, 1989, p. 468-475. refs
(AIAA PAPER 89-1210)
A problem concerning the interaction between a rotating blade and external forces in space is studied. Instability characteristics of the flap-lag-pitch motion of a blade subjected to solar radiation pressure are presented through the stability analysis and direct numerical integration of the fundamental equations with complicated coefficients. Divergence instability occurs for a blade with zero collective pitch angle, and the flap-pitch flutter happens with the increase of the collective pitch angle. Author

A89-30701#
THE FRACTIONAL ORDER STATE EQUATIONS FOR THE CONTROL OF VISCOELASTICALLY DAMPED STRUCTURES
R. L. BAGLEY and R. A. CALICO (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 487-496. refs
(AIAA PAPER 89-1213)
The fractional order state equations are developed to predict the effects of feedback intended to reduce motion in damped structures. The mechanical properties of damping materials are modeled using fractional order time derivatives of stress and strain. These models accurately describe the broad-band effects of material damping in the structure's equations of motion. The resulting structural equations of motion are used to derive the fractional order state equations. Substantial differences between the structural and state equations are seen to exist. The mathematical form of the state equations suggests the feedback of fractional order time derivatives of structural displacements to improve control system performance. Several other advantages of the fractional order state formulation are discussed. Author

A89-30704*# California Univ., Los Angeles.
CONTROL AUGMENTED STRUCTURAL SYNTHESIS WITH DYNAMIC STABILITY CONSTRAINTS
H. L. THOMAS and L. A. SCHMIT, JR. (California, University, Los Angeles) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 521-531. refs
(Contract NSG-1490)
(AIAA PAPER 89-1216)
Dynamic stability constraints are included in a computer program that simultaneously synthesizes a structure and its control system. Two measures of stability, the real part of the system complex eigenvalues and the damping ratio, are examined. The procedure for calculating the sensitivities of the two measures of stability to changes in the structure and its control system is explained. The sensitivities are used to formulate an approximate problem that is solved at each design iteration. The effects of structural damping and noncollated controllers on the synthesis process are discussed. Author

A89-30722*# Texas Univ., Austin.
MODEL REDUCTION AND CONTROL OF FLEXIBLE STRUCTURES USING KRYLOV SUBSPACES
ROY R. CRAIG, JR. (Texas, University, Austin) and TZU-JENG SU IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 691-700. refs
(Contract NAS9-17254)
(AIAA PAPER 89-1237)
Krylov vectors and the concept of parameter-matching are combined to develop a model reduction algorithm for a damped structural dynamics system. The reduced-order model obtained matches a certain number of low-frequency moments of the full-order system. The major application of the present method is to the control of flexible structures. It is shown that, in the control of flexible structures, there generally exist three types of control energy spillover, namely, the control spillover, the observation spillover, and dynamic spillover. The formulation based on Krylov subspaces can eliminate the control and the observation spillover, while leaving only the dynamic spillover to be considered. Two examples are used to illustrate the efficacy of the Krylov method. Author

A89-30724#
MASS CONSERVATION IN THE IDENTIFICATION OF SPACE STRUCTURES
MENAHEM BARUCH (Virginia Polytechnic Institute and State University, Blacksburg) and YORAM ZEMEL IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 710-712. refs
(AIAA PAPER 89-1239)
In the identification process of space structures it is extremely important to keep the rigid body characteristics of the structure uncorrupted. The Methods of Reference Basis (MRB) achieve this by using a Law of Mass Conservation. In line with the law a proper definition for isolation of the measured elastic modes from rigid body movements is also introduced. Author

A89-30726*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ON THE STATE ESTIMATION OF STRUCTURES WITH SECOND ORDER OBSERVERS
W. KEITH BELVIN (NASA, Langley Research Center, Hampton, VA) and K. C. PARK (Colorado, University, Boulder) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 721-727. refs
(Contract F49620-87-C-0074)
(AIAA PAPER 89-1241)
The use of the linear quadratic regulator control synthesis techniques implies the availability of full state feedback. For vibration control of structures, usually only a limited number of states are measured from which an observer model reconstructs the full state. This paper shows that using second-order observers is a viable technique for reconstructing the unmeasured states of structures under mildly restrictive conditions. Moreover, the computational advantages of the second-order observer, as compared to a first-order observer, indicate that significantly larger observer models may be utilized. Numerical examples are used to demonstrate the performance of second-order observers. The implications of second-order observers in the development of the control/structures interaction technology is discussed. Author

A89-30727#
AUTOMATING THE IDENTIFICATION OF STRUCTURAL MODEL PARAMETERS
JAMES J. ALLEN and DAVID R. MARTINEZ (Sandia National Laboratories, Albuquerque, NM) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 728-736. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-1242)
An implementation of a tool for the system identification of large structural model based on the integration of commercial software packages is presented. The method integrates commercial software for finite element modeling (MSC/NASTRAN), mathematical programming techniques (ADS), and general linear system analysis (PRO-MATLAB). The use of the automated parameter identification software is illustrated for the following two applications: estimation of the material constants and support stiffness of a truss structure and estimation of the stiffness and mass properties of an electronics package. V.L.

A89-30734#
DAMPING AND VIBRATION OF BEAMS WITH VARIOUS TYPES OF FRICTIONAL SUPPORT CONDITIONS
ALDO A. FERRI (Georgia Institute of Technology, Atlanta) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 782-787. refs
(Contract NSF MSM-87-07846)
(AIAA PAPER 89-1249)

The damping characteristics of a flexible beam with various types of frictional supports is considered. For each configuration studied, the only source of damping is dry friction at one support. The study considers supports with constant normal forces and supports for which the normal force varies with beam displacement. It is seen that the nature of the damping depends on whether the frictional interface is transverse to or in line with the beam. It is also seen that the equivalent viscous damping of the system can be inversely proportional to, invariant with respect to, directly proportional to, or directly proportional to the square of the displacement amplitude. Author

A89-30761#
SECANT-METHOD ADJUSTMENT FOR STRUCTURAL MODELS
SUZANNE WEAVER SMITH and CHRISTOPHER A. BEATTIE (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1041-1051. refs
(Contract NSF DMS-88-07483; F49620-87-C-0116)
(AIAA PAPER 89-1278)

Optimal-update stiffness matrix adjustment methods are ideally suited to the on-orbit identification of large space structures, Here, new methods of stiffness matrix adjustment are presented which generalize optimal-update secant methods from quasi-Newton approaches for nonlinear optimization. One of the new methods, the MSMT method, is shown to preserve realistic structural connectivity with minimal storage and computational effort, while an extension of the MSMT method allows compensation for errors in measured data. Comparisons of the performance of the new methods with that of other methods are presented. V.L.

A89-30768*# Duke Univ., Durham, NC.
CONTROL OF A SLOW MOVING SPACE CRANE AS AN ADAPTIVE STRUCTURE
S. UTKU, A. V. RAMESH, S. K. DAS (Duke University, Durham, NC), B. K. WADA, and G. S. CHEN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1119-1126. refs
(AIAA PAPER 89-1286)

Assuming that the space crane is an adaptive structure with length-adjustable bars and taking as controls the length-adjustments of these bars, the computation of the incremental controls corresponding to the motion of a payload along its minimum-energy trajectory is given in terms of the inverse-transpose of matrix B of the joint equilibrium equations Bs = p, where s lists the bar forces and p lists the nodal loads. The compensation of the controls for elastic deformations and support movements are shown. It is also shown that the computations may be done automatically and in real time by an attached processor once the characteristics of the crane's maneuver are keyed in. Author

A89-30769*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SELECTION OF ACTIVE MEMBER LOCATIONS IN ADAPTIVE STRUCTURES
G.-S. CHEN, R. BRUNO, and M. SALAMA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1127-1135. refs
(AIAA PAPER 89-1287)

The effective use of multiple passive and active members in adaptive structures necessitates that these members be optimally distributed throughout the structure. In truss structures, the problem falls into the class of combinatorial optimization for which the solution becomes exceedingly intractable as the problem size increases. This is overcome by using the simulated annealing algorithm to obtain near optimal locations for passive and/or active members. The maximization of the rate of energy dissipation over a finite time period as the measure of optimality is adopted. The selection of optimal locations for both passive and active members is consistently treated through the use of the energy dissipation rate criterion within the simulated annealing algorithm. Numerical examples are used to illustrate the effectiveness of the methodology for large truss structures. Author

A89-30770#
VIBRATION CHARACTERISTICS AND SHAPE CONTROL OF ADAPTIVE PLANAR TRUSS STRUCTURES
FUMIHIRO KUWAO, MAKOTO YOSHIHARA, SHOICHI MOTOHASHI, KENICHI TAKAHARA (Toshiba Corp., Kawasaki, Japan), and MICHIHIRO NATORI (Tokyo, University, Sagamihara, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1136-1144. refs
(AIAA PAPER 89-1288)

The vibration characteristics of a planar truss structure are evaluated by conducting a modal survey of the function model and analyzing the mathematical model. The effectiveness of shape control for the compensation of the deformation due to the gravity force is demonstrated. The implications of the results for the adaptive planar truss structures of large space antennas are briefly discussed. V.L.

A89-30772*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SYSTEM IDENTIFICATION TEST USING ACTIVE MEMBERS
JAY-CHUNG CHEN and JAMES L. FANSON (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1154-1163. refs
(AIAA PAPER 89-1290)

A 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. 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

A89-30804*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
EXPERIMENTAL STUDIES OF ADAPTIVE STRUCTURES FOR PRECISION PERFORMANCE
G.-S. CHEN, B. J. LURIE, and B. K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1462-1472. refs
(AIAA PAPER 89-1327)

An experimental study was made of the adaptive structure concept. Experimental data were obtained for a three-longeron, thirteen-bay truss-type test structure. This test structure can be softly suspended as well as rigidly clamped at the central bay. The load-carrying active member consists of a stack of concentric piezoelectric wafers, an eddy current displacement sensor, and a strain gage force sensor. A bridge (or compound) feedback technique developed in communication engineering is applied to the problem of active damping augmentation in adaptive structures. Using collocated force and velocity feedback around the active member, a desired output mechanical impedance can be implemented to maximize energy absorption by the active members. In addition, large gains can be implemented to linearize the active member's nonlinear behavior. Good agreements with linear finite element analysis was found for both static and dynamic structural responses. An 11 percent damping in the first bending mode was demonstrated in the closed-loop damping experiment. Author

A89-30806*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

ACTIVE-MEMBER CONTROL OF PRECISION STRUCTURES

J. L. FANSON, G. H. BLACKWOOD, and C. C. CHU (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1480-1494. refs

(AIAA PAPER 89-1329)

This paper presents the results of closed loop experiments that use piezoelectric active-members to control the flexible motion of a precision truss structure. These experiments are directed toward the development of high performance structural systems as part of the Control/Structure Interaction program at JPL. Order of magnitude reductions in dynamic response are achieved with relatively simple control techniques. The practical implementation of high stiffness, high bandwidth active-members in a precision structure highlights specific issues of importance relating to the modelling and implementation of active-member control. Author

A89-30807*# Virginia Polytechnic Inst. and State Univ., Blacksburg.

A PLANAR COMPARISON OF ACTUATORS FOR VIBRATION CONTROL OF FLEXIBLE STRUCTURES

WILLIAM W. CLARK, HARRY H. ROBERTSHAW, and THOMAS J. WARRINGTON (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1495-1503. refs

(Contract NAG1-570)

(AIAA PAPER 89-1330)

The methods and results of an analytical study comparing the effectiveness of four actuators in damping the vibrations of a planar clamped-free beam are presented. The actuators studied are two inertia-type actuators, the proof mass and reaction wheel, and two variable geometry trusses, the planar truss and the planar truss proof mass (a combination variable geometry truss/inertia-type actuator). Actuator parameters used in the models were chosen based on the results of a parametric study. A full-state, LQR optimal feedback control law was used for control in each system. Numerical simulations of each beam/actuator system were performed in response to initial condition inputs. These simulations provided information such as time response of the closed-loop system and damping provided to the beam. This information can be used to determine the 'best' actuator for a given purpose. Author

A89-30809#

ACTIVE ACCURACY ADJUSTMENT OF REFLECTORS THROUGH THE CHANGE OF ELEMENT BOUNDARY

MICHIHIRO NATORI (Tokyo, University, Sagamihara, Japan), YUZO SHIBAYAMA, and KOHJI SEKINE (NEC Corp., Yokohama, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1514-1521. refs

(AIAA PAPER 89-1332)

In future space reflector technology, active surface accuracy control is important to adapt the precise accuracy requirement. A concept of an active accuracy control of reflector surface through the change of element boundary planar shape for both an inflatable rigidized surface and a mesh surface augmented with elastic strips is introduced. The effectiveness of the concept is demonstrated through the deflection analysis of initially curved beam strips. It is shown that an appropriate change of element boundary distance improves the accuracy error very much. Author

A89-30811#

A SYSTEMATIC DETERMINATION OF LUMPED AND IMPROVED CONSISTENT MASS MATRICES FOR VIBRATION ANALYSIS

K. C. PARK and DANIEL D. JENSEN (Colorado, University, Boulder) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1532-1540. refs

(Contract N00014-87-K-2118)

(AIAA PAPER 89-1335)

A systematic procedure for determining the lumped mass matrix and improved consistent mass matrices has been proposed for vibration analyses by the finite element method. The procedure is based on the discrete Fourier analysis which enables one to compare the numerical approximations with the corresponding continuum characteristics. The procedure is applied to vibrations of bar, Euler-Bernoulli beam and plate bending elements. The results obtained by the present procedure clearly indicate that a judicious use of the improved mass matrices offered in the paper can lead to a significant accuracy improvement for intermediate frequencies that can play important roles in modeling of control-structure interaction systems, dynamic localizations and acoustic responses for space structures and underwater vehicles. Author

A89-30814*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

MODEL REDUCTION FOR FLEXIBLE SPACE STRUCTURES

WODEK GAWRONSKI and TREVOR WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1555-1565. refs

(AIAA PAPER 89-1339)

This paper presents the conditions under which modal truncation yields a near-optimal reduced-order model for a flexible structure. Next, a robust model reduction technique to cope with the damping uncertainties typical of flexible space structure is developed. Finally, a flexible truss and the COFS-1 structure are used to give realistic applications for the model reduction techniques studied in the paper. Author

A89-30815*# Lockheed Missiles and Space Co., Sunnyvale, CA.

DESIGN, ANALYSIS, AND TESTING OF A HYBRID SCALE STRUCTURAL DYNAMIC MODEL OF A SPACE STATION

MARC J. GRONET (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA), EDWARD F. CRAWLEY (MIT, Cambridge, MA), and BRADLEY R. ALLEN (CSA Engineering, Inc., Palo Alto, CA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1567-1575. Research supported by NASA. refs

(AIAA PAPER 89-1340)

The impracticality of testing the fully-assembled on-orbit configurations of future large erectable space platforms fosters an increased reliance on other means for verifying predicted structural dynamic performance. One option is scale modeling. This paper discusses the design of a hybrid scale dynamic test model of the Freedom Space Station and its associated suspension system. Hybrid scaling laws are reviewed, followed by scale factor trades, component design examples, and an analytical evaluation of the overall model fidelity. Component and subassembly test results from a six-bay hybrid scale model truss are presented. Potential interactions of gravity and the suspension system with the free-free dynamics of the scale model are investigated. Suspension system design parameters, such as the number, location, mass, and stiffness of the suspension devices are traded to minimize undesirable interactions and form the basis for an overall suspension system concept for the scale model. Author

A89-30816*# NASA Space Station Program Office, Reston, VA.
AN ASSESSMENT OF THE STRUCTURAL DYNAMIC EFFECTS ON THE MICROGRAVITY ENVIRONMENT OF A REFERENCE SPACE STATION
STEVE DEL BASSO (Grumman Corp., Space Station Program Support Div., Reston, VA) and ALAN J. LINDENMOYER (NASA, Space Station Freedom Program Office, Reston, VA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1576-1590. refs
(AIAA PAPER 89-1341)

An interim 'Permanently Manned Capability' Space Station configuration and one designated 'Assembly Complete' are modeled by FEM techniques in order to select forcing functions for modal transient response analysis and illustrate sample waveforms. In all, 114 applied-force cases have been executed to simulate such expected operational disturbances as crewmembers' treadmill exercises and EVAs. The present discussion of the results obtained give attention to the acceleration-response environment of the U.S. Laboratory's center grid-point. The magnitude of the acceleration responses obtained indicate that attenuation systems must be incorporated, or operational constraints must be instituted. O.C.

A89-30817*# NASA Space Station Program Office, Reston, VA.
AN AUTOMATED, INTEGRATED APPROACH TO SPACE STATION STRUCTURAL MODELING
ALAN J. LINDENMOYER (NASA, Space Station Freedom Program Office, Reston, VA) and JOHN A. HABERMEYER (Grumman Corp., Space Station Program Support Div., Reston, VA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1591-1597.
(AIAA PAPER 89-1342)

NASA and its contractors have developed an integrated, interdisciplinary CAD/analysis system designated IDEAS(double asterisk)2 in order to conduct evaluations of alternative Space Station concepts' performance over the projected course of the Station's evolution in orbit. Attention is presently given to the requirements associated with automated FEM-building methods applicable to Space Station system-level structural dynamic analysis, and the ways in which IDEAS(double asterisk)2 addresses these requirements. Advantage is taken of the interactive capabilities of the SUPERTAB FEM preprocessor system for Space Station model manipulation and modification. O.C.

A89-30838#
LARGE DEFLECTION STATIC AND DYNAMIC FINITE ELEMENT ANALYSES OF COMPOSITE BEAMS WITH ARBITRARY CROSS-SECTIONAL WARPING
ALAN D. STEMPLE and SUNG W. LEE (Maryland, University, College Park) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1788-1798. refs
(Contract DAAL03-88-C-002)
(AIAA PAPER 89-1363)

A beam finite-element formulation that properly takes into account the warping effects of composite beams undergoing large deflection has been developed. This formulation can be used for static and free vibration analysis of both rotating and nonrotating composite beams. A comparative study with a solid-element model is presented as well as correlation with experimental observations. The present approach allows the modeling of thin-walled composite beams with complicated cross-section, tapers, and arbitrary planforms. Correlation of numerical tests with a three-dimensional solid-element formulation and experimental results demonstrate the validity and effectiveness of the present approach. Author

A89-30853#
DIRECT TIME-DOMAIN, FINITE ELEMENT MODELING OF FREQUENCY-DEPENDENT MATERIAL DAMPING USING AUGMENTING THERMODYNAMIC FIELDS (ATF)
GEORGE A. LESIEUTRE (Sparta, Inc., Laguna Hills, CA) and D. LEWIS MINGORI (California, University, Los Angeles) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1925-1935. refs
(AIAA PAPER 89-1380)

A new method of modeling frequency-dependent material damping in structural dynamics analysis is reported. Motivated by results from materials science, augmenting thermodynamic fields (ATF) are introduced to interact with the usual mechanical displacement field. The methods of irreversible thermodynamics are used to develop coupled material constitutive relations and partial differential equations of evolution (PDE). The resulting PDE are implemented for numerical solution within the computational framework of the finite element method. The ATF modeling method is illustrated using several examples including longitudinal vibration of a rod, transverse vibration of a beam, and vibration of a large space truss structure. Author

A89-30854*# Massachusetts Inst. of Tech., Cambridge.
A FREQUENCY DOMAIN ANALYSIS FOR DAMPED SPACE STRUCTURES
NESBITT W. HAGOOD and EDWARD F. CRAWLEY (MIT, Cambridge, MA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1936-1946. refs
(Contract NAGW-21)
(AIAA PAPER 89-1381)

A method is presented for the analysis of damped structural systems in which the structural components are represented by impedance models and analyzed in the frequency domain. Methods are presented to assemble and condense system impedance matrices, and then to identify approximate mass, stiffness, and damping matrices for systems whose impedances are complicated functions of frequency. Formulas are derived for determination of approximate values for system natural frequencies and damping using frequency domain quantities. The sensitivities of these approximate values to system parameter changes are analyzed. The implementation of these analysis tools is discussed and applied to a simple mechanical system. Author

A89-30855#
MODEL CORRECTION USING A SYMMETRIC EIGENSTRUCTURE ASSIGNMENT TECHNIQUE
D. C. ZIMMERMANN (Florida, University, Gainesville) and M. WIDENGREN (Kungliga Tekniska Hogskolan, Stockholm, Sweden) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1947-1954.

refs
(AIAA PAPER 89-1382)

Improvement of structural models by incorporating measured structural modal parameters is approached from a controls aspect. The approach is developed for linear structures which exhibit nonproportional damping. Residual damping and stiffness matrices are determined such that the improved analytical model eigenstructure matches that obtained experimentally. The method is based on the development of a symmetric eigenstructure assignment algorithm. Examples will be presented which demonstrate the algorithm. Author

A89-30856#

DYNAMIC CONTINUUM MODELING OF BEAMLIKE SPACE STRUCTURES USING FINITE ELEMENT MATRICES

USIK LEE (Korea Institute of Aeronautical Technology, Seoul, Republic of Korea) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1955-1962. refs
(AIAA PAPER 89-1383)

A rational and straightforward method is introduced for developing equivalent continuum models of large beam-like periodic lattice structures based on energy equivalence. Extended Timoshenko beam model is chosen to take account of the effects due to couplings between extension, transverse shear and bending deformations. The procedure for developing continuum models involves utilizing well-defined existing finite element matrices directly in calculating strain and kinetic energies from which equivalent continuum structural and dynamic properties are induced. The numerical results of free vibration analysis show that the method developed in this paper gives very reliable dynamic characteristics compared to other methods. Author

A89-30893*# Virginia Polytechnic Inst. and State Univ., Blacksburg.

LOCATING DAMAGED MEMBERS IN A TRUSS STRUCTURE USING MODAL TEST DATA - A DEMONSTRATION EXPERIMENT

SUZANNE WEAVER SMITH (Virginia Polytechnic Institute and State University, Blacksburg) and PAUL E. MCGOWAN (NASA, Langley Research Center, Hampton, VA) AIAA, ASME, ASCE, AHS, and ASC, Srtuctures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989. 8 p. refs
(AIAA PAPER 89-1291)

An experiment is designed to demonstrate and verify the performance of the on-orbit assessment approach for large flexible space truss structures. The on-orbit assessment approach can be accomplished, in principle, with dynamic response information, structural identification methods, and model correlation techniques which produce an adjusted mathematical model. An optimal update of the structure model is formed using the response data, then examined to locate damaged members. The experiment uses a laboratory scale model truss structure which exhibits characteristics expected for large space truss structures. Vibration experiments are performed to generate response data for the damaged truss. The damage location approach is described, as well as analytical work performed in support of the vibration tests, the measured response of the test article, and some preliminary results. S.A.V.

A89-31029*# Honeywell, Inc., Glendale, AZ.

REACTION TORQUE MINIMIZATION TECHNIQUES FOR ARTICULATED PAYLOADS

KEVIN KRAL (Honeywell Sperry Space Systems, Glendale, AZ) and ROBERTO M. ALEMAN (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'88; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 17-20, 1988. Research Triangle Park, NC, Instrument Society of America, 1988, p. 419-429.

Articulated payloads on spacecraft, such as antenna telemetry systems and robotic elements, impart reaction torques back into the vehicle which can significantly affect the performance of other payloads. This paper discusses ways to minimize the reaction torques of articulated payloads through command-shaping algorithms and unique control implementations. The effects of reaction torques encountered on Landsat are presented and compared with simulated and measured data of prototype systems employing these improvements. Author

A89-31091#

CONTROL OF ARTICULATED AND DEFORMABLE SPACE STRUCTURES

HAROLD L. ALEXANDER (Stanford University, CA) IN: Machine intelligence and autonomy for aerospace systems. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 327-347. refs

The technology developed to date for dynamic control of deformable space structures and articulated space robots is discussed with a view to applications associated with future space industrialization. A freely-floating manipulator base, such as a satellite robot, has no conveniently constant relationship between joint angles and end-effector position, relative to a target object. Noncollocated tip-position control has demonstrated benefits for the dynamic control of manipulators. Operational-space control, based on a full, nonlinear, rigid-body dynamic and kinematic model of the manipulator being controlled, is an additional possible method. Attention is given to laboratory simulations of several control systems. O.C.

A89-31454#

NEW GENERALIZED STRUCTURAL FILTERING CONCEPT FOR ACTIVE VIBRATION CONTROL SYNTHESIS

BONG WIE and KUK-WHAN BYUN (Texas, University, Austin) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 147-154. Previously cited in issue 22, p. 3639, Accession no. A87-50502. refs

A89-31455#

CONTROL OF FLEXIBLE STRUCTURES WITH SPILLOVER USING AN AUGMENTED OBSERVER

YOSSI CHAIT and CLARK J. RADCLIFFE (Michigan State University, East Lansing) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 155-161. refs

Modern modal control methods for flexible structures have control and observation spillover that can degrade performance and reduce the stability margin of the closed-loop controlled structure. The sensor output is often filtered to reduce observation spillover; however, the filter introduces signal distortion and perturbs the closed-loop system eigenvalue locations. This perturbation can reduce the stability margin and jeopardize convergence of a deterministic observer. If the filter equations are not explicitly included in the observer design, then the separation principle between the controller and the observer states no longer holds when present in the unfiltered system. A new method is presented where the observer equations are augmented to include a first-order filter dynamics. The separation principle, controllability, and observability of the unfiltered system are invariant to the filter dynamics in this new method, resulting in no perturbation of controlled system eigenvalue locations. The filter cutoff frequency can be located even within the bandwidth of the system, thereby increasing the filter effectiveness in reducing observation spillover. Spillover-generated errors in closed-loop eigenvalues of these control methods are compared using a numerical example. Author

A89-31467#

MISSION FUNCTION CONTROL FOR DEPLOYMENT AND RETRIEVAL OF A SUBSATELLITE

HIRONORI FUJII and SHINTARO ISHIJIMA (Tokyo Metropolitan Institute of Technology, Japan) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 243-247. Previously cited in issue 22, p. 3550, Accession no. A87-50447. refs

A89-31469*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
CONTROL-STRUCTURE INTERACTION IN PRECISION POINTING SERVO LOOPS
JOHN T. SPANOS (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 256-263. refs

The control-structure interaction problem is addressed via stability analysis of a generic linear servo loop model. With the plant described by the rigid body mode and a single elastic mode, structural flexibility is categorized into one of three types: (1) appendage, (2) in-the-loop minimum phase, and (3) in-the-loop nonminimum phase. Closing the loop with proportional-derivative (PD) control action and introducing sensor roll-off dynamics in the feedback path, stability conditions are obtained. Trade studies are conducted with modal frequency, modal participation, modal damping, loop bandwidth, and sensor bandwidth treated as free parameters. Results indicate that appendage modes are most likely to produce instability if they are near the sensor rolloff, whereas in-the-loop modes are most dangerous near the loop bandwidth. The main goal of this paper is to provide a fundamental understanding of the control-structure interaction problem so that it may benefit the design of complex spacecraft and pointing system servo loops. In this framework, the JPL Pathfinder gimbal pointer is considered as an example. Author

A89-31470#
LOW-AUTHORITY CONTROL OF LARGE SPACE STRUCTURES BY USING A TENDON CONTROL SYSTEM
Y. MUROTSU, H. OKUBO, and F. TERUI (Osaka Prefecture, University, Osaka, Japan) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 264-272. Previously cited in issue 22, p. 3549, Accession no. A87-50413. refs

A89-32162
OPTIMIZATION OF THE TRAJECTORIES AND PARAMETERS OF INTERORBITAL TRANSPORT VEHICLES WITH LOW-THRUST ENGINES [OPTIMIZATSIIA TRAEKTORII I PARAMETROV MEZHORBITAL'NYKH TRANSPORTNYKH APPARATOV S DVIGATELIAMI MALOI TIAGI]
S. A. ISHKOV and V. V. SALMIN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 27, Jan.-Feb. 1989, p. 42-53. In Russian. refs

The problem of choosing optimal parameters and control programs for interorbital transport vehicles with low-thrust engines is examined. The spacecraft dynamics with respect to the center of mass and additional fuel expenditures for the purpose of control are taken into account in solving the dynamic and parameteric optimization problems. An iterative scheme is proposed for the joint optimization of the parameters and motion control laws. B.J.

N89-10264*# Alabama Univ., Huntsville. Dept. of Physics.
COMPACT IMAGING SPECTROMETER FOR INDUCED EMISSIONS Final Technical Report, 31 Mar. 1986 - 1 Feb. 1988
DOUGLAS G. TORR Sep. 1988 20 p
(Contract NAG8-060)
(NASA-CR-183187; NAS 1.26:183187) Avail: NTIS HC A03/MF A01 CSCL 14B

On the basis of spectral measurements made from the Space Shuttle and on models of the possible Space Station external environment, it appears likely that, even at the planned altitudes of Space Station, photon emissions will be induced. These emissions will occur to some degree throughout the ultraviolet-visible-infrared spectrum. The emissions arise from a combination of processes including gas phase collisions between relatively energetic ambient and surface emitted or re-emitted atoms or molecules, where the surface raises some species to excited energy states. At the present time it is not possible to model these processes or the anticipated intensity levels with any accuracy, as a number of fundamental parameters needed for such calculations are still poorly known or unknown. However, it is possible that certain spectral line and band features will exceed the desired goal that concomitant emissions not exceed the natural zodiacal background. Also, in the near infrared and infrared, it appears that this level will be exceeded to a significant degree. Therefore it will be necessary to monitor emission levels in the vicinity of Space Station, both in order to establish the levels and to better model the environment. A small spectrometer is briefly described which is suitable for monitoring the spectrum from 1200 A to less than or equal to 12,000 A. The instrument uses focal plane array detectors to image this full spectral range simultaneously. The spectral resolution is 4 to 12 A, depending on the portion of the wavelength range. Author

N89-10297*# North Carolina Agricultural and Technical State Univ., Greensboro. Dept. of Architectural Engineering.
DYNAMICS AND CONTROL OF THE ORBITING GRID STRUCTURES AND THE SYNCHRONOUSLY DEPLOYABLE BEAM Final Report
ELIAS G. ABU-SABA 28 Sep. 1988 62 p
(Contract NAG1-405)
(NASA-CR-183205; NAS 1.26:183205) Avail: NTIS HC A04/MF A01 CSCL 20K

Analytical models were provided for the orbiting grid structure and the joint dominated beam and computational procedures used in determining the eigen value characteristics. Author

N89-11250# Toronto Univ. (Ontario). Inst. for Aerospace Studies.
THE MINI-OSCILLATOR TECHNIQUE: A FINITE ELEMENT METHOD FOR THE MODELING OF LINEAR VISCOELASTIC STRUCTURES Thesis
DONALD J. MCTAVISH Mar. 1988 123 p
(UTIAS-323; ISSN-0082-5255) Avail: NTIS HC A06/MF A01

The use of finite elements to model complex structures has been traditionally effective with regard to mass properties and equilibrium elastic stiffness properties. A practical formulation is presented for the analysis of structures whose constituent materials may be classed as linear viscoelastic. Construction of viscoelastic finite element matrices fully compatible with the usual second order equations of motion is demonstrated, given a knowledge of material properties. The viscoelastic material properties are represented in the Laplace domain by the Golla-Hughes-McTavish (GHM) Analytic Model. The Mini-Oscillator Technique is introduced and developed through the consideration of a single modulus finite element for which the mass and elastic stiffness matrices are known. The simplest case of a single degree of freedom finite element is examined in detail to expose a mechanical analogy from which the mini oscillator technique derives its name. The procedure is then extended to the case of a general structural model with many elements. Each finite element may be of a different material with stiffness properties ranging between simple elastic and multi modulus viscoelastic. Author

N89-11253# Missouri Univ., Rolla. Dept.of Mechanical and Aerospace Engineering.
CONTINUUM MODELING OF LATTICED STRUCTURES
S. ABRATE *In* Vibration Inst., The Shock and Vibration Digest, Volume 20, No. 10 p 3-8 Oct. 1988
Avail: NTIS HC A05/MF A01

Articles concerned with modeling discrete structures by equivalent continua are reviewed. Applications to the dynamic analysis of large space structures or civil engineering structures are of particular interest. This paper is a continuation of an earlier review presented in the Shock and Vibration Digest. Author

N89-11262*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A COMPARATIVE OVERVIEW OF MODAL TESTING AND SYSTEM IDENTIFICATION FOR CONTROL OF STRUCTURES
J.-N. JUANG and R. S. PAPPA *In* Vibration Inst., The Shock

and Vibration Digest, Volume 20, No. 6 p 4-15 Jun. 1988
Avail: NTIS HC A05/MF A01

A comparative overview is presented of the disciplines of modal testing used in structural engineering and system identification used in control theory. A list of representative references from both areas is given, and the basic methods are described briefly. Recent progress on the interaction of modal testing and control disciplines is discussed. It is concluded that combined efforts of researchers in both disciplines are required for unification of modal testing and system identification methods for control of flexible structures. Author

N89-11270 Columbia Univ., New York, NY.
RESPONSE OF DISCRETELY STIFFENED STRUCTURES AND TRANSMISSION OF STRUCTURE-BORNE NOISE Ph.D. Thesis
CONSTANTINOS SOTIRIO LYRINTZIS 1987 81 p
Avail: Univ. Microfilms Order No. DA8809385

An analytical study is presented to predict the dynamic response and structure-borne noise generation and transmission of complex discretely stiffened and interconnected structures under random loads. The method is based on transfer matrices for the structural response and on modal decomposition for the interior acoustic field. The acoustic enclosure is taken to be rectangular in shape of which a portion of the boundaries is elastic while the remaining surface is acoustically rigid. This formulation can be used for the response and structure-borne noise generation studies in space station and aircraft structures. Numerical results are presented for a variety of acousto-structural problems. It is found that this approach permits easy parametric evaluation and that through proper selection of structural parameters, loading conditions and acoustic characteristics, the vibration response and noise transmission can be reduced. Dissert. Abstr.

N89-11791*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AN APPLICATION OF HIGH AUTHORITY/LOW AUTHORITY CONTROL AND POSITIVITY
S. M. SELTZER, D. IRWIN, D. TOLLISON (Control Dynamics Co., Huntsville, Ala.), and H. B. WAITES Aug. 1988 15 p
(NASA-TM-100338; NAS 1.15:100338) Avail: NTIS HC A03/MF A01 CSCL 22/2

Control Dynamics Company (CDy), in conjunction with NASA Marshall Space Flight Center (MSFC), has supported the U.S. Air Force Wright Aeronautical Laboratory (AFWAL) in conducting an investigation of the implementation of several DOD controls techniques. These techniques are to provide vibration suppression and precise attitude control for flexible space structures. AFWAL issued a contract to Control Dynamics to perform this work under the Active Control Technique Evaluation for Spacecraft (ACES) Program. The High Authority Control/Low Authority Control (HAC/LAC) and Positivity controls techniques, which were cultivated under the DARPA Active Control of Space Structures (ACOSS) Program, were applied to a structural model of the NASA/MSFC Ground Test Facility ACES configuration. The control systems design were accomplished and linear post-analyses of the closed-loop systems are provided. The control system designs take into account effects of sampling and delay in the control computer. Nonlinear simulation runs were used to verify the control system designs and implementations in the facility control computers. Finally, test results are given to verify operations of the control systems in the test facility. Author

N89-11793*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
CONTROL OF FLEXIBLE STRUCTURES-2 (COFS-2) FLIGHT CONTROL, STRUCTURE AND GIMBAL SYSTEM INTERACTION STUDY Final Report
STANLEY FAY, STEPHEN GATES, TIMOTHY HENDERSON, LESTER SACKETT, KIM KIRCHWEY, ISAAC STODDARD, and JOEL STORCH Sep. 1988 205 p
(Contract NAS9-17560)
(NASA-CR-172095; R-2088; NAS 1.26:172095) Avail: NTIS HC A10/MF A01 CSCL 22/2

The second Control Of Flexible Structures Flight Experiment (COFS-2) includes a long mast as in the first flight experiment, but with the Langley 15-m hoop column antenna attached via a gimbal system to the top of the mast. The mast is to be mounted in the Space Shuttle cargo bay. The servo-driven gimbal system could be used to point the antenna relative to the mast. The dynamic interaction of the Shuttle Orbiter/COFS-2 system with the Orbiter on-orbit Flight Control System (FCS) and the gimbal pointing control system has been studied using analysis and simulation. The Orbiter pointing requirements have been assessed for their impact on allowable free drift time for COFS experiments. Three fixed antenna configurations were investigated. Also simulated was Orbiter attitude control behavior with active vernier jets during antenna slewing. The effect of experiment mast dampers was included. Control system stability and performance and loads on various portions of the COFS-2 structure were investigated. The study indicates possible undesirable interaction between the Orbiter FCS and the flexible, articulated COFS-2 mast/antenna system, even when restricted to vernier reaction jets. Author

N89-11796# Interuniversity Micro-Electronics Center, Leuven (Belgium).
USE OF NONVOLATILE SEMICONDUCTOR CIRCUITS IN AUTONOMOUS SPACECRAFT CONTROL Final Report
H. E. MAES, J. WITTERS, and E. SCHENKELAERS Paris, France ESA 1988 46 p
(Contract ESTEC-6918/86-NL-IW(SC))
(ESA-CR(P)-2639; ETN-88-93170) Avail: NTIS HC A03/MF A01

The suitability of commercially available nonvolatile memory parts for very specific applications in spacecraft was studied. Potential products were identified and concrete proposals for their applications were developed. Design of a general purpose computing system with the ability of store data in nonvolatile RAM at power failure is shown. ESA

N89-11921*# SatCon Technology Corp., Cambridge, MA.
AN ADVANCED ACTUATOR FOR HIGH-PERFORMANCE SLEWING Final Report
JAMES DOWNER, DAVID EISENHAURE, and RICHARD HOCKNEY Washington NASA Sep. 1988 163 p
(Contract NAS1-18322)
(NASA-CR-4179; NAS 1.26:4179; R05-87) Avail: NTIS HC A08/MF A01 CSCL 13/9

A conceptual design for an advanced momentum exchange actuator for application to spacecraft slewing is described. The particular concept is a magnetically-suspended, magnetically gimballed Control Moment Gyro (CMG). A scissored pair of these devices is sized to provide the torque and angular momentum capacity required to reorient a large spacecraft through large angle maneuvers. The concept described utilizes a composite material rotor to achieve the high momentum and energy densities to minimize system mass, an advanced superconducting magnetic suspension system to minimize system weight and power consumption. The magnetic suspension system is also capable of allowing for large angle gimballing of the rotor, thus eliminating the mass and reliability penalties attendant to conventional gimbals. Descriptions of the various subelement designs are included along with the necessary system sizing formulation and material. Author

N89-12303# Lawrence Livermore National Lab., CA.
DECENTRALIZED ADAPTIVE CONTROL OF LARGE SCALE SYSTEMS, WITH APPLICATION TO ROBOTICS Ph.D. Thesis
DONALD T. GRAVEL, JR. Mar. 1988 117 p
(Contract W-7405-ENG-48)
(DE88-015409; UCRL-53866) Avail: NTIS HC A06/MF A01

Present day economic, technological, and environmental systems are large and complex. Gaining an understanding of large scale systems, that is, modeling their behavior and designing appropriate stabilizing controls, is a foremost challenge of modern system theory. One approach to large scale system modeling and control is decomposition of the large system into smaller, more manageable units. This is known as the decentralized approach. Decentralized control schemes have proven to be robust to a large range of uncertainties and nonlinearities in interconnections and subsystem dynamics. For the purpose of decentralized control, decompositions of large scale systems are typically formulated to isolate uncertainty about system behavior to the interaction between subsystems. Thereby the subsystems themselves are well modeled and decentralized controllers can be designed according to standard techniques. In this thesis, the theory of decentralized adaptive control for decentrally stabilizable systems has been developed. The new schemes depend upon local high gain feedback to stabilize local systems sufficiently to overcome interconnection disturbances. DOE

N89-12624*# Yale Univ., New Haven, CT. Center for Systems Science.
VIBRATION SUPPRESSION IN A LARGE SPACE STRUCTURE Final Report
KUMPATI S. NARENDRA Aug. 1988 12 p
(Contract NAS9-17395)
(NASA-CR-182831; NAS 1.26:182831) Avail: NTIS HC A03/MF A01 CSCL 22/2

The Yale University Center for Systems Science and the NASA Johnson Space Center collaborated in a study of vibration suppression in a large space structure during the period January 1985 to August 1987. The research proposal submitted by the Center to NASA concerned disturbance isolation in flexible space structures. The general objective of the proposal was to create within the Center a critical mass of expertise on problems related to the dynamics and control of large flexible space structures. A specific objective was to formulate both passive and active control strategies for the disturbance isolation problem. Both objectives were achieved during the period of the contract. While an extensive literature exists on the control of flexible space structures, it is generally acknowledged that many important questions remain open at even a fundamental level. Hence, instead of studying grossly simplified models of complex structural systems, it was decided as a first step to confine attention to detailed and thorough analyses of simple structures. Author

N89-12761# Cincinnati Univ., OH. Dept. of Aerospace Engineering.
PRELIMINARY APPLICATIONS OF DECENTRALIZED ESTIMATION TO LARGE FLEXIBLE SPACE STRUCTURES Final Report
SUSAN M. DUMBACHER *In* Universal Energy Systems, Inc., United States Air Force Graduate Student Summer Support Program, Volume 1 16 p Dec. 1987
Avail: NTIS HC A99/MF E03 CSCL 22/2

The advent of space travel requires the examination of Large Flexible Space Structures (LFSS) as a means to achieve it. Much experimentation is being done in the field of control and estimation of parameters on these structures, since adequate testing cannot be done on earth to determine exactly the damping, frequencies and mode shapes of these structures. To vibrationally suppress a LFSS, or maintain it at a state of equilibrium, actuators and sensors are placed at various locations along the structure which are then used to damp out selected modes. To determine modal positions and velocities of a LFSS, decentralized estimation/control is examined here as an alternative to a fully centralized system. Author

N89-13198*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCING AUTOMATION AND ROBOTICS TECHNOLOGY FOR THE SPACE STATION AND FOR THE US ECONOMY Progress Report No. 6, Oct. 1987 - Mar. 1988
ROBERT NUNAMAKER 15 Jun. 1988 54 p Prepared in cooperation with NASA, Lyndon B. Johnson Space Center, Houston, Tex.
(NASA-TM-100989; NAS 1.15:100989) Avail: NTIS HC A04/MF A01 CSCL 09/2

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. This material was documented in the initial report (NASA Technical Memo 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 sixth in a series of progress updates and covers the period between October 1, 1987 and March 1, 1988. NASA has accepted the basic recommendations of ATAC for its Space Station 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 progress report identifies the work of NASA and the Space Station study contractors, research in progress, and issues connected with the advancement of automation and robotics technology on the Space Station. Author

N89-13462*# Pennsylvania State Univ., University Park. Dept. of Electrical Engineering.
INFINITE-DIMENSIONAL APPROACH TO SYSTEM IDENTIFICATION OF SPACE CONTROL LABORATORY EXPERIMENT (SCOLE)
S. A. HOSSAIN and K. Y. LEE *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 17-53 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The identification of a unique set of system parameters in large space structures poses a significant new problem in control technology. Presented is an infinite-dimensional identification scheme to determine system parameters in large flexible structures in space. The method retains the distributed nature of the structure throughout the development of the algorithm and a finite-element approximation is used only to implement the algorithm. This approach eliminates many problems associated with model truncation used in other methods of identification. The identification is formulated in Hilbert space and an optimal control technique is used to minimize weighted least squares of error between the actual and the model data. A variational approach is used to solve the problem. A costate equation, gradients of parameter variations and conditions for optimal estimates are obtained. Computer simulation studies are conducted using a shuttle-attached antenna configuration, more popularly known as the Space Control Laboratory Experiment (SCOLE) as an example. Numerical results show a close match between the estimated and true values of the parameters. Author

N89-13463*# California Univ., Los Angeles. Dept. of Electrical Engineering.
SOME NONLINEAR DAMPING MODELS IN FLEXIBLE STRUCTURES
A. V. BALAKRISHNAN *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 54-66 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

A class of nonlinear damping models is introduced with application to flexible flight structures characterized by low damping. Approximate solutions of engineering interest are obtained for the model using the classical averaging technique of Krylov and Bogoliubov. The results should be considered preliminary pending further investigation. Author

N89-13464*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NONLINEARITIES IN SPACECRAFT STRUCTURAL DYNAMICS
LARRY TAYLOR and KELLY LATIMER (Department of the Air Force, Washington, D.C.) *In its* Proceedings of the 4th Annual SCOLE Workshop p 67-101 Oct. 1988 Prepared in cooperation with George Washington Univ., Washington, D.C.
Avail: NTIS HC A17/MF A01 CSCL 22/2

In considering nonlinearities in spacecraft structural dynamics, the following are examined: (1) SCOLE Configuration-Equations of Motion; (2) Modeling Error Sources; (3) Approximate Solutions; (4) Comparison of Model Accuracy; (5) Linear and Nonlinear Damping; (6) Experimental Results; and, (7) Future Work. Author

N89-13465*# Ohio State Univ., Columbus.
CONTROL DESIGN APPROACHES FOR LARC EXPERIMENTS
STEVE YURKOVICH and UMIT OZGUNER *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 103-122 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

Control design approaches for SCOLE experimentation at Langley Research Center are considered; the following future topics are discussed: (1) Effects of Actuator Dynamics; (2) Refinement of STAC; (3) System Identification; and (4) Experimentation. Author

N89-13466*# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
STABILITY ANALYSIS OF LARGE SPACE STRUCTURE CONTROL SYSTEMS WITH DELAYED INPUT
A. S. S. R. REDDY and PETER M. BAINUM *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 123-132 Oct. 1988 Presented at the 6th VPI and SU/AIAA Symposium on Dynamics and Control of Large Structures
Avail: NTIS HC A17/MF A01 CSCL 22/2

Large space structural systems, due to their inherent flexibility and low mass to area ratio, are represented by large dimensional mathematical models. For implementation of the control laws for such systems a finite amount of time is required to evaluate the control signals; and this time delay may cause instability in the closed loop control system that was previously designed without taking the input delay into consideration. The stability analysis of a simple harmonic oscillator representing the equation of a single mode as a function of delay time is treated analytically and verified numerically. The effect of inherent damping on the delay is also analyzed. The control problem with delayed input is also formulated in the discrete time domain. Author

N89-13467*# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
THE DYNAMICS AND CONTROL OF THE IN-ORBIT SCOLE CONFIGURATION
PETER M. BAINUM, A. S. S. R. REDDY, CHEICK MODIBO DIARRA, and FEIYUE LI *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 145-180 Oct. 1988
(Contract NSG-1414)
Avail: NTIS HC A17/MF A01 CSCL 22/2

The study of the dynamics of the Spacecraft Control Laboratory Experiment (SCOLE) is extended to emphasize the synthesis of control laws for both the linearized system as well as the large amplitude slewing maneuvers required to rapidly reorient the antenna line of sight. For control of the system through small amplitude displacements from the nominal equilibrium position LQR techniques are used to develop the control laws. Pontryagin's maximum principle is applied to minimize the time required for the slewing of a general rigid spacecraft system. The minimum slewing time is calculated based on a quasi-linearization algorithm for the resulting two point boundary value problem. The effect of delay in the control input on the stability of a continuously acting controller (designed without considering the delay) is studied analytically for a second order plant. System instability can result even for delays which are only a small fraction of the natural period of motion. Author

N89-13468*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INITIAL TEST RESULTS ON STATE ESTIMATION ON THE SCOLE MAST
D. SPARKS, JR. *In its* Proceedings of the 4th Annual SCOLE Workshop p 181-191 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

Modal state estimation tests are performed on the SCOLE mast for the fixed Shuttle platform case. Kalman filter state estimation results from a five mode computer model of the SCOLE mast, developed from a finite element analysis, are compared with those state estimates obtained from laboratory tests. Two comparison runs are presented, one an excitation of the first two bending modes, another, an excitation of the first torsional mode of the mast. Results from both runs show poor agreement in modal estimation between the computer model simulations and the laboratory test data. At present, the reason(s) for this poor performance is unknown. Both the laboratory hardware and software and the computer model are being checked for possible sources of errors. Further computer simulations as well as laboratory testing will be performed. Author

N89-13469*# Control Research Corp., Lexington, MA.
SLEWING AND VIBRATION CONTROL OF THE SCOLE
JIGUAN GENE LIN *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 193-215 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

A discussion of Slewing and Vibration Control makes the following conclusions: (1) A 2-stage approach is feasible and promising for rapid slewing and precision pointing of SCOLE; (2) Not all bang-bang type of time-minimized slew maneuvers will excite large structural vibrations in SCOLE; and (3) Modal dashpots can be a concentrated high-power vibration control, as well as the usual diffuse (broadband, low-power (low-authority) control. The following recommendations are made: (1) Limit the magnitude of applied forces on reflector to either the 25-lb limit of vernier thrusters on the real Space Shuttle or the 150-lb level equivalent to the cold-gas jets of laboratory SCOLE; (2) to complete stage 2, add an integrated design of LQF/LTR (Linear-Quadratic-Gaussian/Loop-Transfer Recovery) and Modal Dashpots; and, (3) Validate the 2-stage approach using the SCOLE laboratory facility with a comprehensive sequence of integrated designs and experiments coupling nonlinear rigid-body motions with flexible-body dynamics. Author

N89-13470*# Purdue Univ., West Lafayette, IN.
PLACING DYNAMIC SENSORS AND ACTUATORS ON FLEXIBLE SPACE STRUCTURES
GREGORY A. NORRIS and ROBERT E. SKELTON *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 217-257 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

Input/Output Cost Analysis involves decompositions of the quadratic cost function into contributions from each stochastic input and each weighted output. In the past, these suboptimal cost decomposition methods of sensor and actuator selection (SAS) have been used to locate perfect (infinite bandwidth) sensor and actuators on large scale systems. This paper extends these ideas to the more practical case of imperfect actuators and sensors with dynamics of their own. NASA's SCOLE examples demonstrate that sensor and actuator dynamics affect the optimal selection and placement of sensors and actuators. Author

N89-13471*# California Univ., Berkeley. Dept. of Electrical Engineering and Computer Sciences.
OPTIMIZATION-BASED DESIGN OF CONTROL SYSTEMS FOR FLEXIBLE STRUCTURES
E. POLAK, T. E. BAKER, T-L. WUU, and Y-P. HARN *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 259-290 Oct. 1988
(Contract N00014-86-K-0295; AF-AFOSR-0116-86; NSF ECS-85-17362)
Avail: NTIS HC A17/MF A01 CSCL 22/2

The purpose of this presentation is to show that it is possible to use nonsmooth optimization algorithms to design both closed-loop finite dimensional compensators and open-loop optimal controls for flexible structures modeled by partial differential equations. An important feature of our approach is that it does not require modal decomposition and hence is immune to instabilities caused by spillover effects. Furthermore, it can be used to design control systems for structures that are modeled by mixed systems of coupled ordinary and partial differential equations. Author

N89-13472*# Naval Research Lab., Washington, DC.
EFFECT OF ACTUATOR DYNAMICS ON CONTROL OF BEAM FLEXURE DURING NONLINEAR SLEW OF SCOLE MODEL
SHALOM FISHER *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 291-307 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The effect of actuator dynamics on the control of beam flexure during nonlinear slewing of the SCOLE model is discussed. Two aspects of physical limitations on the regulation of beam flexure are similated, i.e., (1) a one foot travel limitation of displacement of proof-mass actuators; and (2) a time delay of 0.1 secs. in application of controls. The goal was to assess the magnitude of induced errors and, comparing the results to the ideal, and to determine how much flexure there is during slew and settling. Author

N89-13473*# North Carolina Univ., Charlotte. Dept. of Electrical Engineering.
COMBINED PROBLEM OF SLEW MANEUVER CONTROL AND VIBRATION SUPPRESSION
Y. P. KAKAD *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 309-320 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The combined problem of slew maneuver control and vibration suppression of NASA Spacecraft Control Laboratory Experiment (SCOLE) is considered. The coupling between the rigid body modes and flexible modes together with the effect of the control forces on the flexible antenna is discussed. The nonlinearities in the equations are studied in terms of slew maneuver angular velocities. Author

N89-13474*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST MODEL-BASED CONTROLLER SYNTHESIS FOR THE SCOLE CONFIGURATION
E. S. ARMSTRONG, S. M. JOSHI, and E. J. STEWART (George Washington Univ., Hampton, Va.) *In its* Proceedings of the 4th Annual SCOLE Workshop p 321-327 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The design of a robust compensator is considered for the SCOLE configuration using a frequency-response shaping technique based on the LQG/LTR algorithm. Results indicate that a tenth-order compensator can be used to meet stability-performance-robustness conditions for a 26th-order SCOLE model without destabilizing spillover effects. Since the SCOLE configuration is representative of many proposed spaceflight experiments, the results and design techniques employed potentially should be applicable to a wide range of large space structure control problems. Author

N89-14472*# Lockheed Missiles and Space Co., Palo Alto, CA. Research and Development Div.
THE COMPUTATIONAL STRUCTURAL MECHANICS TESTBED ARCHITECTURE. VOLUME 1: THE LANGUAGE
CARLOS A. FELIPPA Dec. 1988 95 p
(Contract NAS1-18444)
(NASA-CR-178384; NAS 1.26:178384; LMSC/D878511-VOL-1)
Avail: NTIS HC A05/MF A01 CSCL 20/11

This is the first set of five volumes which describe the software architecture for the Computational Structural Mechanics Testbed. Derived from NICE, an integrated software system developed at Lockheed Palo Alto Research Laboratory, the architecture is composed of the command language CLAMP, the command language interpreter CLIP, and the data manager GAL. Volumes 1, 2, and 3 (NASA CR's 178384, 178385, and 178386, respectively) describe CLAMP and CLIP, and the CLIP-processor interface. Volumes 4 and 5 (NASA CR's 178387 and 178388, respectively) describe GAL and its low-level I/O. CLAMP, an acronym for Command Language for Applied Mechanics Processors, is designed to control the flow of execution of processors written for NICE. Volume 1 presents the basic elements of the CLAMP language and is intended for all users. Author

N89-14902*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace Engineering.
CONTROL OF THE FLEXIBLE MODES OF AN ADVANCED TECHNOLOGY GEOSTATIONARY PLATFORM Abstract Only
DIANE V. DEWALT *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 50 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

A controls analysis is conducted on an advanced technology geostationary platform. This spacecraft is a large flexible structure with a payload of Earth-sensing instruments which will collect data from Earth's oceans, land, and atmosphere as a part of the bold initiative mission to Planet Earth proposed by NASA. This program will provide a collection of data from a family of spacecraft in both low-Earth orbit and geostationary orbit, which will afford a global definition of the Earth as a system with the capability to predict future events resulting from human and natural forces. The platform concept studied here is a large flexible structure with a payload of eighteen instruments. Because the platform is in geostationary orbit, these instruments have sensitive pointing accuracy requirements, in the range of 0.1 to 0.0001 degrees, which must be satisfied. The structure housing the instruments is large and flexible with characteristic low natural frequencies, so active control is necessary for vibration suppression. Author

N89-14925*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
EXTENSION AND VALIDATION OF A METHOD FOR LOCATING DAMAGED MEMBERS IN LARGE SPACE TRUSSES Abstract Only
SUZANNE WEAVER SMITH *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 97-98 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

The damage location approach employs the control system capabilities for the structure to test the structure and measure the dynamic response. The measurements are then used in a system identification algorithm to produce a model of the damaged structure. The model is compared to one for the undamaged structure to find regions of reduced stiffness which indicate the location of damage. Kabe's 3,4 stiffness matrix adjustment method was the central identification algorithm. The strength of his method is that, with minimal data, it preserves the representation of the physical connectivity of the structure in the resulting model of the damaged truss. However, extensive storage and computational effort were required as a result. Extension of the damage location method to overcome these problems is the first part of the current work. The central system identification algorithm is replaced with the MSMT method of stiffness matrix adjustment which was previously derived by generalizing an optimal-update secant method form quasi-Newton approaches for nonlinear optimization. Validation of the extended damage location method is the second goal. Author

N89-14932*# Ohio State Univ., Columbus. Dept. of Engineering Mechanics.
THE INFLUENCE OF AND THE IDENTIFICATION OF NONLINEARITY IN FLEXIBLE STRUCTURES Abstract Only
LAWRENCE D. ZAVODNEY *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 108-109 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 20/11

Several models were built at NASA Langley and used to demonstrate the following nonlinear behavior: internal resonance in a free response, principal parametric resonance and subcritical instability in a cantilever beam-lumped mass structure, combination resonance in a parametrically excited flexible beam, autoparametric interaction in a two-degree-of-freedom system, instability of the linear solution, saturation of the excited mode, subharmonic bifurcation, and chaotic responses. A video tape documenting these phenomena was made. An attempt to identify a simple structure consisting of two light-weight beams and two lumped masses using the Eigensystem Realization Algorithm showed the inherent difficulty of using a linear based theory to identify a particular nonlinearity. Preliminary results show the technique requires novel interpretation, and hence may not be useful for structural modes that are coupled by a guadratic nonlinearity. A literature survey was also completed on recent work in parametrically excited nonlinear system. In summary, nonlinear systems may possess unique behaviors that require nonlinear identification techniques based on an understanding of how nonlinearity affects the dynamic response of structures. In this was, the unique behaviors of nonlinear systems may be properly identified. Moreover, more accutate quantifiable estimates can be made once the qualitative model has been determined. Author

N89-15111*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RESULTS OF AN INTEGRATED STRUCTURE-CONTROL LAW DESIGN SENSITIVITY ANALYSIS
MICHAEL G. GILBERT Dec. 1988 21 p Presented at the 2nd NASA/Air Force Symposium on Recent Experiences in Multidisciplinary Analysis and Optimization, Hampton, VA, Sep. 1988
(NASA-TM-101517; NAS 1.15:101517) Avail: NTIS HC A03/MF A01 CSCL 01/3

Next generation air and space vehicle designs are driven by increased performance requirements, demanding a high level of design integration between traditionally separate design disciplines. Interdisciplinary analysis capabilities have been developed, for aeroservoelastic aircraft and large flexible spacecraft control for instance, but the requisite integrated design methods are only beginning to be developed. One integrated design method which has received attention is based on hierarchal problem decompositions, optimization, and design sensitivity analyses. This paper highlights a design sensitivity analysis method for Linear Quadratic Cost, Gaussian (LQG) optimal control laws, which predicts change in the optimal control law due to changes in fixed problem parameters using analytical sensitivity equations. Numerical results of a design sensitivity analysis for a realistic aeroservoelastic aircraft example are presented. In this example, the sensitivity of the optimally controlled aircraft's response to various problem formulation and physical aircraft parameters is determined. These results are used to predict the aircraft's new optimally controlled response if the parameter was to have some other nominal value during the control law design process. The sensitivity results are validated by recomputing the optimal control law for discrete variations in parameters, computing the new actual aircraft response, and comparing with the predicted response. These results show an improvement in sensitivity accuracy for integrated design purposes over methods which do not include changess in the optimal control law. Use of the analytical LQG sensitivity expressions is also shown to be more efficient that finite difference methods for the computation of the equivalent sensitivity information. Author

N89-15155*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIENCES IN APPLYING OPTIMIZATION TECHNIQUES TO CONFIGURATIONS FOR THE CONTROL OF FLEXIBLE STRUCTURES (COFS) PROGRAM
JOANNE L. WALSH Oct. 1988 31 p Presented at the 2nd NASA/Air Force Symposium on Recent Advances in Multidisciplinary Analysis and Optimization, Hampton, VA, 28-30 Sep. 1988
(NASA-TM-101511; NAS 1.15:101511) Avail: NTIS HC A03/MF A01 CSCL 22/2

Optimization procedures are developed to systematically provide closely-spaced vibration frequencies. A general-purpose finite-element program for eigenvalue and sensitivity analyses is combined with formal mathematical programming techniques. Results are presented for three studies. The first study uses a simple model to obtain a design with two pairs of closely-spaced frequencies. Two formulations are developed: an objective function-based formulation and constraint-based formulation for the frequency spacing. It is found that conflicting goals are handled better by a constraint-based formulation. The second study uses a detailed model to obtain a design with one pair of closely-spaced frequencies while satisfying requirements on local member frequencies and manufacturing tolerances. Two formulations are developed. Both the constraint-based and the objective function-based formulations perform reasonably well and converge to the same results. However, no feasible design solution exists which satisfies all design requirements for the choices of design variables and the upper and lower design variable values used. More design freedom is needed to achieve a fully satisfactory design. The third study is part of a redesign activity in which a detailed model is used. The use of optimization in this activity allows investigation of numerous options (such as number of bays, material, minimum diagonal wall thicknesses) in a relatively short time. The procedure provides data for judgments on the effects of different options on the design. Author

N89-15156# General Analytic Corp., Athens, GA.
A NEW APPROACH TO THE ANALYSIS AND CONTROL OF LARGE SPACE STRUCTURES, PHASE 1 Final Report, 15 Oct. 1987 - 14 Mar. 1988
GEORGE ADOMIAN 12 Mar. 1988 129 p
(Contract F49620-87-C-0098)
(AD-A198143; GAC-881; AFOSR-88-0702TR) Avail: NTIS HC A07/MF A01 CSCL 22/5

The large structures contemplated would be constructed in space. Because of the limitations on launching massive payloads, it is clear that these structures will be made of lightweight material and will necessarily be flexible and easily excited into vibrations. Analytical problems will arise in designing large space structures in which physically realistic and accurate solutions will be critical. Such designs must consider weight, sizes, stiffness, thermal and mechanical distortions, stresses due to gravity and positioning thrusts. Some specific analytical problems will involve vibration, heating and cooling, multidimensional control, and structural problems arising from random support motion and random fluctuations of the system dynamic properties. GRA

N89-15161 Missouri Univ., Rolla.
MODELING AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES Ph.D. Thesis
JAYANT V. RAMAKRISHNAN 1988 230 p
Avail: Univ. Microfilms Order No. DA8816024

Simulation of space structures forms a critical part of the space station design process. The distributed parameter system is discretized by the finite element technique and represented by a finite set of ordinary differential equations. However, from the viewpoint of control computations, the dimensions of the finite element matrices are too large. A lower order model based on some criteria is derived via the process of aggregation and is used for simulation purposes. The thesis investigates the merits and demerits of some model reduction techniques as addressed to this specific problem. A simple and intuitively appealing degree-of-controllability definition is derived that enhances the approach to the actuator/sensor placement problem. Controller synthesis for a realistic space station, the associated spillover, bounds of suboptimality and the performance degradation are investigated. The balanced realization technique and the Routh approximation method are used in the synthesis of lower order models. The simulations include vibration suppression and minimization of line-of-sight errors. Results indicate that controllers derived using reduced order models perform very well.
Dissert. Abstr.

N89-15163*# California Univ., Los Angeles.
A MATHEMATICAL FORMULATION OF THE SCOLE CONTROL PROBLEM. PART 2: OPTIMAL COMPENSATOR DESIGN Final Report
A. V. BALAKRISHNAN Dec. 1988 24 p
(Contract NAG1-464)
(NASA-CR-181720; NAS 1.26:181720) Avail: NTIS HC A03/MF A01 CSCL 22/2

The study initiated in Part 1 of this report is concluded and optimal feedback control (compensator) design for stability augmentation is considered, following the mathematical formulation developed in Part 1. Co-located (rate) sensors and (force and moment) actuators are assumed, and allowing for both sensor and actuator noise, stabilization is formulated as a stochastic regulator problem. Specializing the general theory developed by the author, a complete, closed form solution (believed to be new with this report) is obtained, taking advantage of the fact that the inherent structural damping is light. In particular, it is possible to solve in closed form the associated infinite-dimensional steady-state Riccati equations. The SCOLE model involves associated partial differential equations in a single space variable, but the compensator design theory developed is far more general since it is given in the abstract wave equation formulation. The results thus hold for any multibody system so long as the basic model is linear. Author

N89-15429# Research Inst. of National Defence, Stockholm (Sweden).
DOUBLE CURVED SHELLS: BENDING GEOMETRY, LOAD CARRYING PROPERTIES, AND TECHNICAL APPLICATIONS Status Report, 1986-1987
STURE O. LUNDIN Jun. 1988 29 p In SWEDISH; ENGLISH summary
(FOA-C-20724-2.6; ISSN-0347-3694; ETN-89-93543) Avail: NTIS HC A03/MF A01

Thin shells of compound curvature show properties of being bendable between compact rolled-up configurations and spacious load-carrying conditions. The use of these properties makes it possible to construct elements that are compact for storage and transportation and being voluminous and load-carrying while in use, for example bridges, masts, and space applications. The bending characteristics of actual shells are described, including their mathematical treatment, manufacture of prototypes, aspects of materials, and a summary of potential applications. ESA

N89-15433*# Catholic Univ. of America, Washington, DC. Dept. of Mechanical Engineering.
ACTIVE CONTROL OF BUCKLING OF FLEXIBLE BEAMS Final Report
A. BAZ and L. TAMPE 19 Jan. 1989 35 p
(Contract NAG5-520)
(NASA-CR-183333; NAS 1.26:183333) Avail: NTIS HC A03/MF A01 CSCL 20/11

The feasibility of using the rapidly growing technology of the shape memory alloys actuators in actively controlling the buckling of large flexible structures is investigated. The need for such buckling control systems is becoming inevitable as the design trends of large space structures have resulted in the use of structural members that are long, slender, and very flexible. In addition, as these truss members are subjected mainly to longitudinal loading they become susceptible to structural instabilities due to buckling. Proper control of such instabilities is essential to the effective performance of the structures as stable platforms for communication and observation. Mathematical models are presented that simulate the dynamic characteristics of the shape memory actuator, the compressive structural members, and the associated active control system. A closed-loop computer-controlled system is designed, based on the developed mathematical models, and 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 obtained results emphasize the importance of buckling control and suggest the potential of the shape memory actuators as attractive means for controlling structural deformation in a simple and reliable way. Author

N89-15438*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FREE-VIBRATION CHARACTERISTICS AND CORRELATION OF A SPACE STATION SPLIT-BLANKET SOLAR ARRAY
KELLY S. CARNEY and FRANCIS J. SHAKER 1989 15 p
Prepared for presentation at the 30th Structures, Structural Dynamics and Materials Conference, Mobile, AL, 3-5 Apr. 1989; sponsored in part by AIAA, ASME, ASCE, AHS and ACS
(NASA-TM-101452; E-4563; NAS 1.15:101452) Avail: NTIS HC A03/MF A01 CSCL 20/11

Two methods for studying the free-vibration characteristics of a large split-blanket solar array in a zero-g cantilevered configuration are presented. The zero-g configuration corrresponds to an on-orbit configuration of the Space Station solar array. The first method applies the equations of continuum mechanics to determine the natural frequencies of the array; the second uses the finite element method program, MSC/NASTRAN. The stiffness matrix from the NASTRAN solution was found to be erroneously grounded. The results from the two methods are compared. It is concluded that the grounding does not seriously compromise the solution to the elastic modes of the solar array. However, the correct rigid body modes need to be included to obtain the correct dynamic model. Author

N89-15927*# Old Dominion Univ., Norfolk, VA. Dept. of Electrical and Computer Engineering.
GUIDANCE AND CONTROL STRATEGIES FOR AEROSPACE VEHICLES Progress Report, 1 Jul. - 31 Dec. 1988
DESINENI S. NAIDU and JOSEPH L. HIBEY Jan. 1989 41 p
(Contract NAG1-736)
(NASA-CR-182339; NAS 1.26:182339) Avail: NTIS HC A03/MF A01 CSCL 01/3

The optimal control problem arising in coplanar orbital transfer employing aeroassist technology and the fuel-optimal control problem arising in orbital transfer vehicles employing aeroassist technology are addressed. B.G.

N89-15971# Business and Technological Systems, Inc., Laurel, MD.
ALGORITHMS FOR ROBUST IDENTIFICATION AND CONTROL OF LARGE SPACE STRUCTURES, PHASE 1 Final Report, Aug. 1987 - Mar. 1988
JAMES V. CARROLL 14 May 1988 85 p Sponsored in part by SDIO/Innovative Science and Technology Office, Washington, DC
(Contract F49620-87-C-0099)
(AD-A198130; BTS63-88-34/AB; J1131; AFOSR-88-0755TR) Avail: NTIS HC A05/MF A01 CSCL 22/1

A new method of providing robust attitude control for tracking and slewing maneuvers for large flexible space structures in orbit is developed, and preliminary analyses and performance studies are conducted. The key elements of the method are system identification in real time, based on canonical variate analysis, and adaptive robust control using Model Predictive Control. The Canonical Variate Analysis method also possesses the built-in capability for performing statistically optimal model order reduction. Computational algorithms are developed using several low order flexible models. The results of this feasibility effort demonstrate that the new method is subject to careful design to reduce computer core size problems, but that its overall performance offers encouraging potential for more complete development. GRA

N89-15973# SatCon Technology Corp., Cambridge, MA.
DISTRIBUTED MAGNETIC ACTUATORS FOR FINE SHAPE CONTROL Final Report, Jul. 1987 - Jan. 1988
GEORGE ANASTAS, DAVID EISENHAURE, RICHARD HOCKNEY, BRUCE JOHNSON, and KATHLEEN MISOVEC Jun. 1988 91 p
(Contract F04611-87-C-0047)
(AD-A199287; R01-88; AFAL-TR-88-026) Avail: NTIS HC A05/MF A01 CSCL 22/2

New spacecraft designs feature large structures characterized by low natural frequencies and stringent pointing and vibration requirements. These large space structures pose unique and difficult control problems. These problems include system bandwidths greater than structural natural frequencies; lack of accurate information about the dynamic characteristic of the structure being controlled; complicated high-order dynamics, including non-linear behavior; and stringent requirements for distributed shape control. An important part of the solution to these control problems is the development of actuators capable of applying force or torque to the structures. Conventionally these actuators have been reaction mass actuators or distributed piezoelectric materials. The objective of this research program was to investigate other innovative actuator designs for use in flexible spacecraft structure control. In particular, actuators based on the direct use of electromagnetic forces were developed.

GRA

N89-15975*# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.

THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES, PART 11

PETER M. BAINUM, A. S. S. R REDDY, CHEICK M. DIARRA, and FEIYUE LI Aug. 1988 69 p

(Contract NSG-1414)

(NASA-CR-184770; NAS 1.26:184770) Avail: NTIS HC A04/MF A01 CSCL 22/2

A mathematical model is developed to predict the dynamics of the proposed Spacecraft Control Laboratory Experiment during the stationkeeping phase. The Shuttle and reflector are assumed to be rigid, while the mass connecting the Shuttle to the reflector is assumed to be flexible with elastic deformations small as compared with its length. It is seen that in the presence of gravity-gradient torques, the system assumes a new equilibrium position primarily due to the offset in the mass attachment point to the reflector from the reflector's mass center. Control is assumed to be provided through the Shuttle's three torquers and throught six actuators located by painrs at two points on the mass and at the reflector mass center. Numerical results confirm the robustness of an LQR derived control strategy during stationkeeping with maximum control efforts significantly below saturation levels. The linear regulator theory is also used to derive control laws for the linearized model of the rigidized SCOLE configuration where the mast flexibility is not included. It is seen that this same type of control strategy can be applied for the rapid single axis slewing of the SCOLE through amplitudes as large as 20 degrees. These results provide a definite trade-off between the slightly larger slewing times with the considerable reduction in over-all control effort as compared with the results of the two point boundary value problem application of Pontryagin's Maximum Principle.

Author

N89-16901# Integrated Systems, Inc., Santa Clara, CA.

ADAPTIVE CONTROL TECHNIQUES FOR LARGE SPACE STRUCTURES Annual Technical Report, 1 Jun. 1986 - 31 May 1987

ROBERT L. KOSUT 23 Dec. 1987 91 p

(Contract F49620-85-C-0094)

(AD-A200208; ISI-110; AFOSR-88-0848TR) Avail: NTIS HC A05/MF A01 CSCL 22/2

This report summarizes the research performed on adaptive control techniques for Large Space Structures (LSS). The research effort concentrated on two areas: (1) on-line robust design from identified models - what is referred to here as adaptive calibration; and (2) an analysis of slow-adaptation for adaptive control of LSS. The report summarizes the results obtained in these areas and also includes Appendices which contain technical articles: (1) Adaptive Control of Large Space Structures; (2) Adaptive Control Via Finite Modeling and Robust Control; (3) On the use of the Method of Averaging for the Stability analysis of Adaptive Linear Control Systems; and (4) Conditions for the Convergence and Divergence of Parameter Adaptive Linear Systems. GRA

N89-16902 Virginia Polytechnic Inst. and State Univ., Blacksburg.

SPILLOVER STABILIZATION IN THE CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES Ph.D. Thesis

EVA A. CZAJKOWSKI 1988 285 p

Avail: Univ. Microfilms Order No. DA8817403

Active control of large flexible space structures is typically implemented to control only a few known elastic modes. Linear Quadratic Regulators (LQR) and Kalman-Bucy Filter (KBF) observers are usually designed to control the desired modes of vibration. Higher modes, referred to as residual modes, are generally ignored in the analysis and may be excited by the controller to cause a net destablizing effect on the system. This is referred to as spillover phenomenon. The stabilization of the neglected dynamics of the higher modes of vibration are considered. Modal controllers are designed with improved spillover stability properties. The proposed method calls for designing the observer so as to improve spillover stability with minimum loss in performance. Two formulations are pursued. The first is based on optimizing the noise statistics used in the design of the KBF. The second optimizies directly the gain matrix of the observer.

Dissert. Abstr.

N89-17444*# Catholic Univ. of America, Washington, DC. Dept. of Electrical Engineering.

DEVELOPMENT OF KINEMATIC EQUATIONS AND DETERMINATION OF WORKSPACE OF A 6 DOF END-EFFECTOR WITH CLOSED-KINEMATIC CHAIN MECHANISM Interim Report, 1 Jul. 1988 - 1 Jan. 1989

CHARLES C. NGUYEN and FARHAD J. POORAN Feb. 1989 17 p

(Contract NAG5-780)

(NASA-CR-183241; NAS 1.26:183241) Avail: NTIS HC A03/MF A01 CSCL 12/1

This report presents results from the research grant entitled Active Control of Robot Manipulators, funded by the Goddard Space Flight Center, under Grant NAG5-780, for the period July 1, 1988 to January 1, 1989. An analysis is presented of a 6 degree-of-freedom robot end-effector built to study telerobotic assembly of NASA hardware in space. Since the end-effector is required to perform high precision motion in a limited workspace, closed-kinematic mechanisms are chosen for its design. A closed-form solution is obtained for the inverse kinematic problem and an iterative procedure employing Newton-Raphson method is proposed to solve the forward kinematic problem. A study of the end-effector workspace results in a general procedure for the workspace determination based on link constraints. Computer simulation results are presented. Author

N89-17901# Technische Hochschule, Darmstadt (Germany, F.R.). Fachbereich Mechanik.

DESIGN OF CONTROLLERS FOR ACTIVE VIBRATION DAMPING IN FLEXIBLE MECHANICAL STRUCTURES Ph.D. Thesis [ENTWURF VON REGLERN ZUR AKTIVEN SCHWINGUNGSDAEMPFUNG AN FLEXIBLEN MECHANISCHEN STRUKTUREN]

JOHANNES SCHMIDT 1987 133 p In GERMAN

(ETN-89-93499) Avail: NTIS HC A07/MF A01

The design of controllers for the active damping of vibrations in structural components which can be modelled as one-dimensional continua, described by partial differential equations, of the hyperbolic type was investigated. The basic control element produces, in a point of the component, regulating variables which maximize the energy flow to the actuator. The control laws result from the analysis of the energy flow to the actuator. The control laws were tested in numerical simulations. The advantages of the control concept are based on the fact that the regulating variables in the control laws of the structure occur only in the neighborhood of the actuator. The representation of the hyperbolic equations of motion in the normal form is not only efficient for the treatment of control problems, but also for the investigation of the dispersion. ESA

N89-18039*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

INTERACTIVE ORBITAL PROXIMITY OPERATIONS PLANNING SYSTEM

ARTHUR J. GRUNWALD and STEPHEN R. ELLIS Nov. 1988 48 p

(NASA-TP-2839; A-88091; NAS 1.60:2839) Avail: NTIS HC A03/MF A01 CSCL 05/8

An interactive graphical proximity operations planning system was developed, which allows on-site design of efficient, complex, multiburn maneuvers in a dynamic multispacecraft environment. Maneuvering takes place in and out of the orbital plane. The difficulty in planning such missions results from the unusual and counterintuitive character of orbital dynamics and complex time-varying operational constraints. This difficulty is greatly overcome by visualizing the relative trajectories and the relevant constraints in an easily interpretable graphical format, which provides the operator with immediate feedback on design actions. The display shows a perspective bird's-eye view of a Space Station and co-orbiting spacecraft on the background of the Station's orbital plane. The operator has control over the two modes of operation: a viewing system mode, which enables the exporation of the spatial situation about the Space Station and thus the ability to choose and zoom in on areas of interest; and a trajectory design mode, which allows the interactive editing of a series of way points and maneuvering burns to obtain a trajectory that complies with all operational constraints. A first version of this display was completed. An experimental program is planned in which operators will carry out a series of design missions which vary in complexity and constraints. Author

N89-18402*# National Aeronautics and Space Administration, Washington, DC.

CONTROLS AND GUIDANCE: SPACE

JOHN D. DIBATTISTA *In its* NASA Information Sciences and Human Factors Program p 105-125 Sep. 1988

Avail: NTIS HC A10/MF A01 CSCL 22/2

The Space Controls and Guidance Research and Technology Program is directed toward enabling the next generation of space transportation systems, large future spacecraft, and space systems such as the Space Station to have large communication antennas and high precision segmented reflector astrophysical telescopes. The new generation of transportation vehicles has demanding requirements to provide for an order of magnitude reduction in cost as well as an increase in capability. The future orbital facilities have demanding control requirements for pointing and stabilization, momentum management, build-up and growth accommodation, and disturbance management. To address these advanced requirements, the research and development program is designed to provide the generic technology base to support the implementation of advanced guidance, navigation, and control. The area of computational controls will be stressed in order to develop cost effective, high speed, high fidelity control system simulation and analysis and synthesis tools. The trust of this work will be to develop methods and software to enable analysis and real-time hardware-in-the-loop simulation of complex spacecraft for control design certification. To address future orbital facilities requirements, an advanced technology program is underway in system identification, distributed control, integrated controls/structures design methods, and advanced sensors and actuators. Because the behavior of large, light weight per unit area deployable/assembled spacecraft is greatly influenced by the ground environment, the testing and verification activity is both ground- and space-based. Author

N89-19334# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.

MODELING OF FLEXIBLE SPACECRAFT ACCOUNTING FOR ORBITAL EFFECTS

PETER M. BAINUM *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 3-8 11 Dec. 1987

Avail: NTIS HC A05/MF A01 CSCL 22/5

Many current investigations of the shape and orientation control of proposed flexible orbiting large space structures (LSS) do not incorporate the effects of the gravity-gradient and orbital dynamic coupling into the plant models. This means that for the corresponding linearized unforced, open-loop systems, the poles of the rigid rotational modes are at the origin. The manner in which the orbitally induced coupling effects, due to gravity-gradient and gyroscopic effects, are introduced is clearly indicated in the continuum formulation of Santini for predicting the motion of a general orbiting flexible body in orbit. These coupling terms reflect both coupling between the rigid and flexible motions and also intra-modal coupling effects. Elastic deformations are considered small as compared with characteristic body dimensions. Equations are developed for both the rigid and elastic (generic) motions, based on an a prior knowledge of the frequencies and shape functions of all modes included within the truncated system model. The orbitally induced coupling terms are seen to depend on volume integrals whose integrands are functions of the various components of the different modal shape functions together with the coordinates of the differential mass elements. Author

N89-19335# Massachusetts Inst. of Tech., Cambridge. Dept. of Mechanical Engineering.

WAVE PROPAGATION IN LARGE SPACE STRUCTURES

JAMES H. WILLIAMS, JR. and RAYMOND J. NAGEM *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 9-11 11 Dec. 1987

Avail: NTIS HC A05/MF A01 CSCL 22/5

The first step in the mathematical analysis of any physical system is the selection of a mathematical model to represent the system. This selection is extremely important, since it not only determines in advance the scope of possible results of the analysis, but also heavily influences the design of auxiliary devices and systems, such as control systems. In the dynamic analysis of large space structures, mathematical models have consisted primarily of a set of vibration modes. The popularity of the modal vibration model of large space structures is due partly to the well-developed analytical techniques which can be applied to such a model, and partly to the success with which modal vibration models have been used to describe structures on earth. However, in view of the unprecedented size of large space structures and their potential technological importance, it is worthwhile to examine the limitations of modal vibration models and to consider the usefulness of other models. A particular concern here is with models which view large space structures as media in which wave propagation provides an accurate dynamic description. Author

N89-19336# Iowa Univ., Iowa City. Center for Computer Aided Design.

A RECURSIVE METHOD FOR PARALLEL PROCESSOR MULTIFLEXIBLE BODY DYNAMIC SIMULATION

EDWARD J. HAUG *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 13-17 11 Dec. 1987

Avail: NTIS HC A05/MF A01 CSCL 22/5

The purpose of this note is to outline a recently developed method for formulating and solving equations of motion of multibody dynamic systems that is well suited for high speed dynamic simulation using parallel processors. An outline of the approach is given here, with references to papers that develop the mathematical foundations. Examples involving a rigid body vehicle system real-time simulation, a geometrically nonlinear rotating blade, and a space manipulator are used to illustrate application of the method and to indicate computational efficiency that can be gained. Author

N89-19338# Jet Propulsion Lab., California Inst. of Tech., Pasadena. Applied Technologies Section.

CONCEPT OF ADAPTIVE STRUCTURES

MICHAIL ZAK *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 23-24 11 Dec. 1987

Avail: NTIS HC A05/MF A01 CSCL 22/5

The concept of adaptive structures is brought up in connection with the need in ultra lightweight structural systems to maintain desired properties and configurations without human intervention when subjected to dynamic, thermal, and other environmental forces. Examples are large antenna structures and flexible robotic structures. In the both cases such adaptivity would allow less massive structural members to be employed under normal loading conditions. During special circumstances when unusually large loads are encountered, temporary stiffening would allow the use

of less sturdy structures, resulting in large savings in their cost, and in increasing their mobility and efficiency. Within the framework of a finite-dimensional representation of structural dynamics, the adaptivity can be implemented by the dependence of the stiffness matrix (k) upon the expected load (Q), or expected (programmed) changes in configurations, i.e., (k) = (k(t)) where the dependence upon time is programmed in advance. In order to sustain unexpected loads the adaptive structure can be provided by feedback force control, or by a parametrical stiffness control.
Author

N89-19339# State Univ. of New York, Buffalo. Dept. of Mechanical and Aerospace Engineering.
COMMENTS ON ELECTROMECHANICAL ACTUATORS FOR CONTROLLING FLEXIBLE STRUCTURES
D. J. INMAN, R. W. MAYNE, and D. C. ZIMMERMAN (Florida Univ., Gainesville.) *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 25-27 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Two types of specific electromechanical actuators are described and discussed. A proof mass actuator and an electric motor are examined in terms of the amount of damping each produces in a specific structural control experiment. Theoretical and experimental values of actuator produced damping are examined. The effects of actuator dynamics on control law implementation are noted. In addition, a theoretical parameter study of the dynamic response of a dc motor controlling a flexible model of a beam are summarized.
Author

N89-19340# Virginia Univ., Charlottesville. Dept. of Mechanical and Aerospace Engineering.
SYSTEM IDENTIFICATION OF SUBOPTIMAL FEEDBACK CONTROL PARAMETERS BASED ON LIMITING-PERFORMANCE/MINIMUM-TIME CHARACTERISTICS
WALTER D. PILKEY *In its* Proceedings of the Fifth AFOSR Forum on Space Structures p 29-32 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Most active controllers developed to control large structures are subject to constraints. For instance, control characteristics of proof-mass actuators are dominated by the nature of the constraints. To find the optimal or suboptimal control laws for such controllers can be a formidable task. Intuition of a designer plays an important role and the design method may vary dramatically in accordance with the constraints of the system. Therefore, one may wish to have a systematic methodology to solve the control problems subject to control force and state variable constraints. Limiting-performance/minimum-time (LP/MT) control calculates the optimal control force as a function of time for a known system with initial conditions, subject to certain constraints and external excitations while minimizing a given performance index. Although the LP/MT control gives optimal open loop control for the system, it is desirable to develop a closed loop control which has more practical value. Perhaps a system identification technique can be used to establish a suboptimal feedback control law based on the LP/MT control characteristics.
Author

N89-19341# Aerospace Corp., Los Angeles, CA.
INTEGRATED STRUCTURAL ANALYSIS AND CONTROL (ISAAC): ISSUES AND PROGRESS
M. ASWANI, D. S. FLAMM, C. L. GUSTAFSON, A. B. JENKIN, J. D. KAWAMOTO, and G. T. TSENG *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 43-47 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The ISAAC program at the Aerospace Corporation has been pursuing issues which arise in the simultaneous design of structures and control systems for large space structures using a mathematical programming code. There are many practical advantages to such integrated design, such as tuning the structure to directly improve the closed loop performance measure. Here, the focus is on key elements in the work, and in particular those elements which distinguish our emphasis from that of other workers in the field. There is obviously more to gain by simultaneously tuning structural and controller designs. Closed loop performance criteria which directly measure desired characteristics are available. The big issues are parametrization of controller and structure, and computational techniques for evaluation of criteria, constraints, and their derivatives.
Author

N89-19342# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.
ACTIVE CONTROL OF ELASTIC WAVE MOTION IN STRUCTURAL NETWORKS
DAVID W. MILLER and ANDREAS H. VONFLOTOW *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 49-51 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Recent work performed at the M.I.T. Space Systems Laboratory 1 has dealt with control design based on wave propagation models of flexible structures. Reflection and transmission properties of performance critical locations are actively altered in order to meet mission requirements regarding dynamic isolation, energy shunting, and vibration suppression. Using an input/output relation, the wave scattering characteristics of the location, or structural junction, can be actively altered in order to vary the path of power transmission or reduce power emanating from the junction. Such a technique has several advantages. Wave control approaches the problem as feedforward disturbance rejection of incoming waves. In some applications, this can eliminate resonant behavior by creating matched terminations. Local models are insensitive to all but local modelling errors. Since a wave model is a local description, a guarantee of control stability is not based upon knowledge of global structural behavior. Instead, stability is judged based on the frequency dependent power generation/dissipation properties of the active junction. Global control performance is dependent upon significance of the disturbance path containing the active junction. The control energy expended is of the order of the disturbance energy and only a few actuators and sensors are required to carry out most tasks.
Author

N89-19343# Integrated Systems, Inc., Santa Clara, CA.
ADAPTIVE CONTROL OF LARGE SPACE STRUCTURES
ROBERT L. KOSUT *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 51-55 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Some of the research issues involved in the design and analysis of adaptive control systems for large space structures (LSS) are described. The need for adaptive control arises from many envisioned future LSS missions which impose stringent performance demands on tracking accuracy and structural vibration attenuation. Both active feedback control and passive damping will be a practical necessity, and moreover, their design will require a model of the LSS system whose accuracy is compatible with the performance demands. Structural variations from many sources, such as deployment, material fatigue, and even random variations in materials and manufacturing tolerances, will significantly degrade closed-loop performance. Thus, the on-orbit dynamics of LSS will not be sufficiently like those obtained from either ground-testing or even from sophisticated computer generated modeling techniques, such as finite element modeling. Current structural modeling techniques are just not sufficiently accurate or able to account for all the possible sources of parameter variations. Therefore, under these conditions, it will be necessary to identify the LSS dynamics directly from on-orbit measurements, and simultaneously, tune or redesign the control. Hence, the control design cycle will be an adaptive process.
Author

N89-19344# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
MAJORANT ANALYSIS OF PERFORMANCE DEGRADATION DUE TO UNCERTAINTY
DAVID C. HYLAND *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 57-64 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The problem addressed here is the determination of bounds on the degradation of system performance due to uncertainties and/or unforeseen and imperfectly modelled subsystem interactions. Such bounding techniques represent a fundamental systems analysis tool that is indispensable for further elucidation of decentralized controller architectures and robust design.
Author

N89-19345# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
THE OPTIMAL PROJECTION EQUATIONS FOR FIXED-ORDER DYNAMIC COMPENSATION: EXISTENCE, CONVERGENCE AND GLOBAL OPTIMALITY
DAVID C. HYLAND *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 65-72 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Regardless of how appealing the optimal projection formulation may appear to be, its contribution is vacuous unless certain serious questions can be resolved. These include: (1) Under what conditions can the optimal projection equations be guaranteed a priori to possess a solution. (2) Given problem data, exactly how many solutions do the equations possess. (3) Of the possible solutions, what are their stability properties, what is their performance, and which is the global optimum. (4) How can numerical algorithms be constructed which can be guaranteed to converge to any desired solution especially the global minimum. It seems clear that any attempt to address the above issues must utilize mathematical methods which are global in nature. To this end we have applied degree theory and associated homotopic continuation methods to analyze the solutions to the optimal projection equations and to construct convergent, implementable algorithms for their computation. The purpose of this presentation is to report significant recent results in this regard. Author

N89-19346# Ohio State Univ., Columbus. Dept. of Electrical Engineering.
DECENTRALIZED/RELEGATED CONTROL FOR LARGE SPACE STRUCTURES
UMIT OZGUNER and STEVE YURKOVICH *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 73-75 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The complexity of present and envisaged space structures dictates the inevitable need for emphasis on control and structure interaction. Moreover, in view of present methodologies, stringent control requirements such as precise pointing and slewing, vibration suppression, and shape control indicate that much work remains to be done in this important area. Recent results in the decentralized, relegated control of large space structures, with concentration on topics of decentralization, relegation, servomechanism design, and multiple mirror system examples are given.
Author

N89-19347# Illinois Univ., Urbana. Coordinated Science Lab.
FROBENIUS-HANKEL NORM FRAMEWORK FOR DISTURBANCE REJECTION AND LOW ORDER DECENTRALIZED CONTROLLER DESIGN
J. MEDANIC and W. R. PERKINS *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 77-79 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

There is a desire to design low-order controllers for high order plants. Procedures to solve the low-order controller design problem can broadly be divided into two classes. Direct methods, in which the parameters defining a low order controller are computed by some optimization or other procedure, and indirect methods, in which a high order controller is found first, and then a procedure is used to simplify it. Examples of direct methods are the parametric linear-quadratic (LQ) design and the projective controls procedure developed by the authors. In the case of indirect methods, the linear-quadratic-Gaussian (LQG), the frequency weighted LQG, and the H (infinity)-norm minimization approaches provide the high order controller and, each in its own right, captures many relevant performance/robustness design goals. However, procedures for reducing high order controllers to low order controllers are less well developed. Author

N89-19348# Lawrence Livermore National Lab., CA.
A CONTROLLED COMPONENT SYNTHESIS METHOD FOR TRUSS STRUCTURE VIBRATION CONTROL
K. DAVID YOUNG *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 81-83 11 Dec. 1987
(Contract W-7405-ENG-48)
Avail: NTIS HC A05/MF A01 CSCL 22/5

A new framework for the design of controllers for truss structure vibration control which is closely related to that of the Subsystem Decomposition Approach is introduced. The method developed herein deviates from conventional control system design practice in which a dynamic model of the open loop plant is often the initial data given to the control system designer. Instead, the controlled plant is assembled from the controlled components in the control design process. The development of this controlled component synthesis method is motivated on one hand by the well developed component mode synthesis methods (8 to 10) - a collection of structural analysis methods which has been demonstrated to be effective for solving large complex structural analysis problems for almost three decades, and on the other, stimulated by the subsystem decomposition viewpoint in large scale system theory. Connections between controlled component synthesis and existing large scale system decomposition techniques are established herein to build a control theoretic foundation for the developed method. A simple truss vibration control problem has been employed to illustrate the design procedures, as well as demonstrating the potentials of the developed method for controlling very large dimensional repetitive truss structures.
Author

N89-19349*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST EIGENSTRUCTURE ASSIGNMENT BY A PROJECTION METHOD: APPLICATION USING MULTIPLE OPTIMIZATION CRITERIA
J. L. JUNKINS, D. W. REW, and J. N. JUANG *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 85-88 11 Dec. 1987 Sponsored by NASA
Avail: NTIS HC A05/MF A01 CSCL 22/5

New ideas which lead to feedback control laws for large flexible structures which are insensitive to model uncertainty are presented. A pole placement method is presented which leads to near-unitary closed loop eigenvectors, and a new method is introduced to design the control while simultaneously considering three competing measures of optimality. Robustness versus Integral algorithms are applicable to at least moderately high-dimensioned systems. In the present discussion, controls for two coupled flexible bodies are considered. A 6x24 gain matrix is designed to control a 12 modes system using 6 actuators. Researchers also developed control laws for the R2P2 simulator at Martin Marietta; in this case 3 actuators are used to control a 12th order system. Simulation studies indicate that researchers indeed achieved robust designs without significant difficulties associated with spillover into the uncontrolled modes. Here, several key ideas and numerical results are given. In the references, details of the formulation, discussions of salient features, and connection to the availiable literature are given.
Author

N89-19356 Virginia Polytechnic Inst. and State Univ., Blacksburg.
NONLINEAR OPTIMAL CONTROL AND NEAR-OPTIMAL GUIDANCE STRATEGIES IN SPACECRAFT GENERAL ATTITUDE MANEUVERS Ph.D. Thesis
YIING-YUH LIN 1988 94 p
Avail: Univ. Microfilms Order No. DA8825331

Solving the optimal open-loop control problems for spacecraft large-angle attitude maneuvers generally requires the use of numerical techniques whose reliability is strongly case dependent. The primary goal of this dissertation is to increase the solution reliability of the associated nonlinear two-point boundary-value problems as derived from Pontryagin's Principle. Major emphasis is placed upon the formulation of the best possible starting or nominal solution. Constraint relationships among the state and costate variables are utilized. A hybrid approach which begins with the direct gradient method and ends with the indirect method of particular solutions is proposed. Test case results which indicate improved reliability are presented. The nonlinear optimal control law derived from iterative procedures cannot adjust itself in accordance with state deviations measured during the control period. A real-time near-optimal guidance scheme which takes the perturbed states to the desired manifold by tracking a given optimal trajectory is also presented. Numerical simulations are presented which show that highly accurate tracking results can be achieved. Dissert. Abstr.

N89-19357# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
EXPERIMENTAL VERIFICATION OF AN INNOVATIVE PERFORMANCE-VALIDATION METHODOLOGY FOR LARGE SPACE SYSTEMS Annual Report, Aug. 1987 - Aug. 1988
DAVID C. HYLAND Sep. 1988 53 p
(Contract F49620-87-C-0108)
(AD-A202243; AFOSR-88-1192TR) Avail: NTIS HC A04/MF A01 CSCL 22/2

A technology gap exists in verifying performance of large space systems. To fill that gap the proposed program seeks to develop and validate an efficient pre-flight performance verification methodology. The approach involves selective component testing along with analysis of subsystem interactions. The method exploits MEOP (Maximum Entropy/Optimal Projection) Control-System Design and Majorant Robustness Analysis. The approach will be formulated for several representative large space systems and experimentally verified on a 3-meter diameter multi-hex panel ground-based active controls testbed. GRA

N89-19358# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
MAXIMUM ENTROPY/OPTIMAL PROJECTION DESIGN SYNTHESIS FOR DECENTRALIZED CONTROL OF LARGE SPACE STRUCTURES Final Report, Oct. 1986 - May 1988
DAVID C. HYLAND, DENNIS S. BERNSTEIN, and EMMANUEL G. COLLINS, JR. May 1988 281 p
(Contract F49620-86-C-0038)
(AD-A202375; AFOSR-88-1203TR) Avail: NTIS HC A13/MF A01 CSCL 22/2

The Maximum Entropy/Optimal Projection (MEOP) Methodology is a novel approach to designing implementable vibration-suppression controllers for large space systems. Two issues, in particular, have been addressed, namely, controller order (i.e., complexity) and system robustness (i.e., sensitivity to plant variations). Extensions developed herein include generalizations to decentralized controller architectures and a new robustness analysis technique known as Majorant Robustness Analysis. This final report also encompasses extensions to hierarchical control as well as the development of numerical algorithms for solving the control design equations. GRA

N89-19362# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Space Flight Dynamics Section.
INVESTIGATION OF FLIGHT SENSORS AND ACTUATORS FOR THE VIBRATION DAMPING AUGMENTATION OF LARGE FLEXIBLE SPACE STRUCTURES Final Report
TH. LANGE, comp. Paris, France ESA May 1988 237 p
(Contract ESTEC-6902/86-NL-MAC(SC))
(ESA-CR(P)-2670; ETN-89-93926) Avail: NTIS HC A11/MF A01

Sensor and actuator hardware was analyzed with respect to a two-dimensional generic structural model representing a material processing platform on a large space structure. Two devices based on inertial control for vibration damping are presented. The Rotating Resonance InTegrating Accelerometer (RITA) is based upon a rotating pendulum to be applied for inertial acceleration measurement without any bias or stiction effect associated with ordinary servoed proof-mass accelerometers. The RITA features the suspension of the rotating proof-mass by a spring assembly tuned in resonance with the rotor spin frequency. Thus high measurement sensitivity and a high axial stiffness can be realized. The Linear Stepper Motor Actuator (LISA) is proposed as an alternative with respect to the pivoted proof-mass actuators. In LISA the proof-mass incorporates the motor coils, which are attached to a lightweight carriage by a spring/damper assembly. Thus high stepping rates with low switching times can be realized with relatively low motor power. This kind of proof-mass suspension damps out the high frequency noise level to a large extent. Semiactive hydraulic control methods utilizing the energy dissipation property of viscous fluids flowing through special surface treated pipes to increase the frictional effect are also presented. Due to the high weight penalty they are not suitable for structures represented by the box truss model but could be applied for structures extending over several hundred meters. This is due to the expected high damping forces requiring a smaller number of actuators and reducing the relative weight penalty. ESA

N89-19596# Texas A&M Univ., College Station. Dept. of Aerospace Engineering.
CONTROL OF FLEXIBLE STRUCTURES: MODEL ERRORS, ROBUSTNESS MEASURES, AND OPTIMIZATION OF FEEDBACK CONTROLLERS Final Report, 1 Jun. 1986 - 31 Aug. 1988
JOHN L. JUNKINS and S. R. VADALI 31 Oct. 1988 300 p
(Contract F49620-86-K-0014)
(AD-A202234; AFOSR-88-1252TR) Avail: NTIS HC A13/MF A01 CSCL 22/2

This report summarizes new methods for flexible structures' dynamic analysis, system identification, and maneuver controls. New control design methods are introduced for considering several competing performance measures simultaneously. A new attitude control method using single gimbal control moment gyros is introduced. New results and insights on singularity avoidance are presented. A method is given for simultaneous optimization of structural design parameters and feedback controller. GRA

N89-19999# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
RCS/PIEZOELECTRIC DISTRIBUTED ACTUATOR STUDY Final Report, Aug. 1985 - Mar. 1988
THOMAS BAILEY, ALEXANDER GRUZEN, and PAUL MADDEN Aug. 1988 113 p
(Contract F04611-85-K-0050)
(AD-A201276; CSDL-R-2076; AFAL-TR-88-038) Avail: NTIS HC A06/MF A01 CSCL 22/2

The objective of the program was to develop the technology of piezoelectric distributed actuators, and to test the effectiveness and performance of the actuators when used to augment the damping of a simulated large flexible space structure. The CSDL/AFAL experimental test facility located at CSDL, Inc. was used to test and demonstrate the technology. GRA

N89-20081*# Southern Univ., Baton Rouge, LA. Dept. of Electronics Engineering Technology.
FEASIBILITY OF USING HIGH TEMPERATURE SUPERCONDUCTING MAGNETS AND CONVENTIONAL MAGNETIC LOOP ANTENNAS TO ATTRACT OR REPEL OBJECTS AT THE SPACE STATION Final Report
MANJIT S. RANDHAWA *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 2 14 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 20/14

A study was undertaken to see if magnetic forces can be used at the Space Station to attract or repel spacecrafts such as the Orbital Manuevering Vehicle (OMV) or the Orbiter. A large magnet, in the form of a current loop, is assumed to be placed at the Space Station and another one on the spacecraft. The expression for the force between the two dipoles (loops) is obtained. Using a force of 15 Newtons (3.4 pounds) in order to move the spacecraft, the number of ampere-turn needed in the current loops was calculated at various distances between them. The expression for the force of attraction between a current loop and a soft magnetic material was also examined and the number of amp-turn needed to provide a force of one-tenth of a pound at various distances is also calculated. This one tenth of a pound force would be used in a life line system for the retrieval of an adrift crewman or tool at the Space Station. The feasibility of using conventional antenna on the Station and the incoming vehicle for attraction or repulsion was also examined. Author

06

ELECTRONICS

Includes techniques for power and data distribution, antenna RF performance analysis, communications systems, and spacecraft charging effects.

A89-11122#
HIGH-VOLTAGE SOLAR CELL MODULES IN SIMULATED LOW-EARTH-ORBIT PLASMA
HEINZ THIEMANN (Physikalisch Technische Studien GmbH, Freiburg im Breisgau, Federal Republic of Germany) and KLAUS-PETER BOGUS (ESA, Technical Directorate, Noordwijk, Netherlands) *Journal of Spacecraft and Rockets* (ISSN 0022-4650), vol. 25, July-Aug. 1988, p. 278-285. refs

The behavior of solar cell modules at high voltages in a surrounding simulated LEO plasma has been characterized over an applied voltage range from -700 to +500 V. Measurements were obtained in a large chamber under high vacuum using argon ions from a Kaufman source to generate a high-density plasma of up to 10 to the 6th/cu cm. The results suggest that secondary electrons contribute to the anomalous current increase noted at positive module voltages above 300 V. The surface potential on the coverglasses of the solar cells was shown to increase to high values only in the vicinity of the interconnectors. R.R.

A89-12573
ON THE EXPLOITATION OF GEOMETRICAL SYMMETRY IN STRUCTURAL COMPUTATIONS OF SPACE POWER STATIONS
ALAIN BOSSAVIT (Electricite de France, Clamart) Space Power (ISSN 0951-5089), vol. 7, no. 2, 1988, p. 199-210. refs

An account is given of the principles of computational structural analysis. Means of exploiting the geometrical symmetry of space structures to save on the computational cost of their mechanical characteristics are discussed. Bilateral symmetry is considered as well as the assembly of elements. K.K.

A89-12872
INTERBOARD ENERGY SUPPLY AND TRANSFER
K. B. SERAFIMOV (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia po Vissha Geodeziia, Sofia, Bulgaria) Bolgarskaia Akademiia Nauk, Doklady (ISSN 0366-8681), vol. 41, no. 8, 1988, p. 61-64.

Transfer of electrical power by SHF transmission between satellites is discussed. It is pointed out that such a technique could decrease satellite mass and complexity and greatly increase satellite useful lifetimes, since battery lifetime would no longer be a limiting factor. Fixed antennas could be used for (1) transfer between GEO satellites (from sunlit satellite to eclipsed satellite), (2) transfer from GEO to satellites at higher orbits, and (3) transfer from solar power satellites to communications or remote-sensing satellites; mobile antennas would be required for transmission to or among LEO satellites. T.K.

A89-14136
EARTH-TO-SATELLITE MICROWAVE BEAMS - INNOVATIVE APPROACH TO SPACE POWER
M. I. HOFFERT, G. MILLER, B. HEILWEIL, W. ZIEGLER, and M. KADIRAMANGALAM (New York University, NY) IN: Microwave and particle beam sources and propagation; Proceedings of the Meeting, Los Angeles, CA, Jan. 13-15, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 148-169. SDIO-sponsored research. refs
(Contract DAAL02-86-K-0116)

A new space power concept incorporating earth-to-satellite microwave power beams coupled to onboard-regeneration electrochemical energy storage is proposed for energizing defensive satellite constellations. The system addresses housekeeping, orbital maneuvering, and burst-mode power requirements, and offers an attractive alternative to the nuclear and solar space power systems currently envisioned for this application. Component and overall system considerations of this scheme are discussed and compared with alternatives. Outstanding research problems are defined and preliminary analyses pertaining to orbital mechanics and satellite ground tracks, accessibility of orbits to microwave beams, transmission efficiencies, electronic and mechanical designs for the transmitter and rectenna, regenerative fuel cell energy storage, power conditioning, and thermal management are addressed. C.D.

A89-14739
DESIGN OF ONBOARD ANTENNAS WITH A LOW SIDELOBE LEVEL [PROEKTIROVANIE BORTOVYKH ANTENN S NIZKIM UROVNEM BOKOVOGO IZLUCHENIIA]
I. A. STRUKOV, D. P. SKULACHEV, and A. N. TKACHEV IN: Scientific instrumentation for space studies. Moscow, Izdatel'stvo Nauka, 1987, p. 94-104. In Russian. refs

The radiation characteristics of millimeter-wave horn antennas with a low sidelobe level are examined, and it is shown that corrugated radiators are superior to the conventional smooth ones. An analysis is made of the radiation characteristics of parabolic horn antennas with corrugated radiators. As an example, attention is given to the design and engineering characteristics of the antenna system for the 8-mm-band radiometer in the spaceborne Relikt-1 experiment, designed to measure the relic radiation. B.J.

A89-14967
PHASE I SPACE STATION POWER SYSTEM DEVELOPMENT
ROBERT O. PRICE Aerospace Engineering (ISSN 0736-2536), vol. 8, Oct. 1988, p. 19-23.

The development of the electric power system (EPS) for the Space Station is discussed. The EPS requirements related to station size, operational lifetime, operational autonomy, and technology evolution are considered. It is suggested that environmental control and life support will require 55 kWe of power. The possible use of solar photovoltaic, solar thermal dynamic, or a hybrid combination of the two are examined. R.B.

A89-15207
HIGH POWER INFLATABLE RADIATOR FOR THERMAL REJECTION FROM SPACE POWER SYSTEMS
D. CHITTENDEN, G. GROSSMAN, E. ROSSEL, P. VAN ETTEN, and G. WILLIAMS (L'Garde, Inc., Tustin, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 353-358. refs
(Contract F33615-87-C-2752)

The present study has investigated a novel concept of an inflatable radiator which captures burst heat from space-based defense systems during its short generation period and radiates it to space later over a longer period. During the operation phase, the radiator is extended out of the spacecraft and filled with steam generated by the waste heat. As the spacecraft continues orbiting the earth, the steam is condensed gradually. The radiator is retracted during condensation so as to maintain a constant saturation pressure, and is folded neatly into the spacecraft, ready for the next mission. A preliminary design of the inflatable radiator has been performed during which various aspects of its operation were studied. The paper discusses the results of these studies including the choice and evaluation of candidate materials, design of the bag with the retraction, folding and drive mechanisms, the thermal, dynamic stability and survivability analyses. Author

A89-15211
ROTATING FILM RADIATOR FOR HEAT REJECTION IN SPACE
JEAN F. LOUIS (MIT, Cambridge, MA) and SEUNG JIN SONG IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 385-390. Research supported by Sundstrand Corp. refs

After a review of advanced radiator concepts, a rotating film radiator concept is analyzed to reduce the radiator mass in solar dynamic power systems. The concept envisions a rotating disk with a thin film of radiator liquid flowing radially outward while radiating directly to space. The radiator concept only utilizes currently existing technologies and overcomes containment problems faced by another concept, the rotating bubble membrane radiator, which is also analyzed. A preliminary design suggests that the rotating film radiator can achieve a specific mass of 5.5 kg/kWt or 3.5 kg/m-squared. Author

A89-15247
THERMAL ANALYSIS AND FUNDAMENTAL TESTS ON HEAT PIPE RECEIVER FOR SOLAR DYNAMIC SPACE POWER SYSTEM
MAKOTO FUJIWARA, TAMOTSU SANO (Mitsubishi Heavy Industries, Ltd., Takasago Research and Development Center, Japan), KIYOSHI SUZUKI, and SHINYA WATANABE (Mitsubishi Heavy Industries, Ltd., Kobe Shipyard and Machinery Works, Japan) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 195-200.

A performance analysis was conducted on a heat pipe receiver structure using potassium as the working fluid. The thermal storage capability of the phase change material (LiF-CaF2) was examined, and the effect of the volume change of the thermal storage material during phase changes was investigated. Finally, a trial production of the heat pipe receiver element was carried out, and its performance was studied by test simulating the insolation cycle using an electric heater. B.J.

A89-15291
SPACE POWER TECHNOLOGY FOR THE 21ST CENTURY (SPT21)
WILLIAM U. BORGER and LOWELL D. MASSIE (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 1-7. refs

A brief overview is given of planning studies for military space power technology development, undertaken under USAF sponsorship during 1987. Consideration is given to the planning process itself, the planning drivers, and the primary options identified, which include hardened solar photovoltaic systems, hardened compact space nuclear reactors, hardened solar thermal-dynamic systems, and very lightweight minimally hard solar or nuclear systems. Also discussed are critical electrical and thermal support technologies and advanced concepts. The major aspects addressed are listed in extensive charts and graphs. T.K.

A89-15292* National Aeronautics and Space Administration, Washington, DC.
SPACE POWER TECHNOLOGY TO MEET CIVIL SPACE REQUIREMENTS
EARL VANLANDINGHAM (NASA, Propulsion, Power, and Energy Div., Washington, DC) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 9-16.

The current status of NASA R&D programs for space power systems is reviewed and illustrated with drawings and diagrams. Topics addressed include photovoltaic systems, energy-storage technology, solar-dynamic systems, the SP-100 Advanced Technology Program, Stirling engine technology, and thermal management. Consideration is given to power management and distribution, power-system autonomy, high-Tc superconductor technology, space power materials, and environmental interactions. T.K.

A89-15295* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE STATION POWER SYSTEM REQUIREMENTS
JOHN W. DUNNING, JR. (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 29-36. Previously announced in STAR as N88-21245.

Presented is an overview of the requirements on which the Space Station Electric Power System is based as well as a summary of the design itself. The current design, which is based on silicon photovoltaic arrays, NiH2 batteries, and 20 kHz distribution technology, meets all of the requirements. Author

A89-15297
SOLAR CELL REVERSE BIASING AND POWER SYSTEM DESIGN
CRAIG BECKER-IRVIN (Aerospace Corp., Electronics and Optics Div., El Segundo, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 43-47.

This paper reviews the solar-cell reverse-biasing phenomenon and explores the parameters that affect reverse biasing of shadowed solar cells. Power-system design features which can minimize the detrimental effects of shadowing are also examined. Author

A89-15305* TRW, Inc., Redondo Beach, CA.
STATUS OF ADVANCED PHOTOVOLTAIC SOLAR ARRAY PROGRAM
RICHARD KURLAND (TRW, Inc., Space and Technology Group, Redondo Beach, CA) and PAUL STELLA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 91-95.
(Contract JPL-957990; NAS7-918)

The current development status of ultralightweight flexible-blanket foldout solar arrays being designed and fabricated under the NASA Advanced Photovoltaic Solar Array (APSA) program is surveyed. The goal of APSA is the construction of a 25-kW array with specific power 300 W/kg (BOL) by the year 2000. Topics discussed here include array configurations, blanket deployment systems, prototype wing-hardware fabrication, component-level test results, solar-cell technologies, and array performance estimates. Diagrams, drawings, graphs, and tables of numerical data are provided. T.K.

A89-15309
LIGHTWEIGHT SOLAR ARRAYS FOR HIGH RADIATION ENVIRONMENTS
THEODORE G. STERN (General Dynamics Corp., Space Systems Div., San Diego, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering

Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 127-129.

Results are reported from design studies of Si or GaAs solar cells for the high-radiation environments encountered in space missions such as LEO-GEO transfer. Optimum shielding levels for planar and concentrator arrays are calculated, and the results are presented in graphs. It is found that concentrators offer potential weight savings because they require less shielding per W of output power. T.K.

A89-15321

SPACE REACTOR SHIELD TECHNOLOGY

VAHE KESHISHIAN, RICHARD L. GAY, and RODNEY D. MEYER (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 219-223.

Lithium hydride was selected for the neutron shield material due to its excellent properties. It has to be canned and may be compartmentalized to reduce the probability of complete shielding effectiveness loss due to meteoroid puncture of the can. Fabrication of the shield by casting techniques is recommended to maintain shield integrity during vibration and to accommodate complex penetrations. A method for casting full-scale shields is described. Author

A89-15323

URANIUM-ZIRCONIUM HYDRIDE FUEL PERFORMANCE IN THE SNAP-DYN SPACE POWER REACTOR

ANDREW G. STADNIK and JOHN P. PAGE (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 233-238. refs

This paper describes the performance characteristics of the uranium-zirconium-hydride (UZrH) fuel system designed for the SNAP-DYN (Systems for Nuclear Auxiliary Power Dynamic) reactor considered for use in space power applications. Results on swelling, hydrogen loss, burnup, and other properties indicate that the UZrH fuel can support the lifetime requirement for the SNAP-DYN design without an extensive test program. Diagrams of the SNAP-DYN reactor and its fuel element are presented. I.S.

A89-15324

SNAP REACTOR REFLECTOR CONTROL SYSTEMS DEVELOPMENT

DONALD F. OWEN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 239-244. refs

The development of the Systems for Nuclear Auxiliary Power (SNAP) reactor reflector control systems (designed for a severe launch and operational environment) is discussed together with their application for near-term use. The design and the operation of each of the SNAP reactor control systems and of their components are described, and the results of major component testing are presented. It is concluded that the SNAP reactor reflector control systems technology is directly applicaple to the most recent uranium-zirconium-hydride space reactor design, the SMAP-DYN reactor. Design diagrams are included. I.S.

A89-15333

REAL-TIME EXPERT SYSTEMS FOR ADVANCED POWER CONTROL

R. J. SPIER and M. E. LIFFRING (Boeing Aerospace Co., Seattle, WA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 293-298. refs

The Autonomous Power System testbed's high-level control algorithm integration for fault-detection, fault-isolation, and fault restoration in a real-time execution environment is presently discussed with a view to the benefits obtained by furnishing dynamically varying levels of control for expert systems. Attention is given to methods for the maximization of the usefulness of a degraded electrical power system. It is found that fast-response autonomy is applicable to available electrical power system hardware controls. O.C.

A89-15335* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

STARR - AN EXPERT SYSTEM FOR FAILURE DIAGNOSIS IN A SPACE BASED POWER SYSTEM

BRYAN WALLS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 303-306.

Starr, a prototype expert system, is designed to monitor and model a space power system, recognize problem states, identify the failure, and recommend the proper action to be taken. The system was modeled on the autonomously managed power system (AMPS) breadboard at NASA-Marshall. An object-oriented approach was used for the Starr model. K.K.

A89-15336* Martin Marietta Corp., Denver, CO.

CONCURRENT DEVELOPMENT OF FAULT MANAGEMENT HARDWARE AND SOFTWARE IN THE SSM/PMAD

KENNETH A. FREEMAN, RICK WALSH (Martin Marietta Corp., Astronautics Group, Denver, CO), and DAVID J. WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 307-312.

Space Station issues in fault management are discussed. The system background is described with attention given to design guidelines and power hardware. A contractually developed fault management system, FRAMES, is integrated with the energy management functions, the control switchgear, and the scheduling and operations management functions. The constraints that shaped the FRAMES system and its implementation are considered. K.K.

A89-15342

SOLAR CONCENTRATOR ADVANCED DEVELOPMENT PROGRAM UPDATE

F. H. VALADE (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 351-356. refs

The power generation system under development for the Space Station, which is a hybrid of solar dynamic and photovoltaic systems, is examined. The Solar Concentrator Advanced Development program is discussed, including the optical and environmental performance requirements, the initial design trade offs, and the design selected for fabrication. R.B.

A89-15343* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

ADVANCED SPACE SOLAR DYNAMIC RECEIVERS

HAL J. STRUMPF, MURRAY G. COOMBS (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., Torrance, CA), and DOVIE E. LACY (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 357-365.

A study has been conducted to generate and evaluate advanced solar heat receiver concepts suitable for orbital application with Brayton and Stirling engine cycles in the 7-kW size range. The generated receiver designs have thermal storage capability (to enable power production during the substantial eclipse period which accompanies typical orbits) and are lighter and smaller than state-of-the-art systems, such as the Brayton solar receiver being designed and developed by AiResearch for the NASA Space Station. Two receiver concepts have been developed in detail: a packed bed receiver and a heat pipe receiver. The packed bed receiver is appropriate for a Brayton engine; the heat pipe receiver is applicable for either a Brayton or Stirling engine. The thermal storage for both concepts is provided by the melting and freezing of a salt. Both receiver concepts offer substantial improvements in size and weight compared to baseline receivers. Author

A89-15345* Tennessee Univ. Space Inst., Tullahoma.
DEVELOPMENT OF A COMPONENT CENTERED FAULT MONITORING AND DIAGNOSIS KNOWLEDGE BASED SYSTEM FOR SPACE POWER SYSTEM
S. C. LEE (Tennessee, University, Tullahoma) and LOUIS F. LOLLAR (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 377-382. refs

The overall approach currently being taken in the development of AMPERES (Autonomously Managed Power System Extendable Real-time Expert System), a knowledge-based expert system for fault monitoring and diagnosis of space power systems, is discussed. The system architecture, knowledge representation, and fault monitoring and diagnosis strategy are examined. A 'component-centered' approach developed in this project is described. Critical issues requiring further study are identified. C.D.

A89-15348* Martin Marietta Aerospace, Denver, CO.
AUTOMATED POWER MANAGEMENT WITHIN A SPACE STATION MODULE
WILLIAM D. MILLER and ELLEN F. JONES (Martin Marietta Corp., Astronautics Group, Denver, CO) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 395-399. NASA-supported research.

An effort to advance and develop techniques and approaches for automation and autonomy in power management and distribution with a Space Station module is described. The applicable breadboard architecture is discussed, summarizing the function partitioning. The breadboard software is briefly addressed, and the breadboard automated operation is described in detail. C.D.

A89-15349
A DIAGNOSTIC EXPERT SYSTEM FOR SPACE-BASED ELECTRICAL POWER NETWORKS
EDWARD W. GHOLDSTON, DON F. JANIK, and GARTH LANE (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 401-406. refs

This paper focuses on the development of a prototype expert system which could be utilized to analyze the Space Station electrical power system. The diagnostic requirements of such a system are summarized, and the hierarchy of the expert system development is reviewed. The system hardware and software are described, and the program structure and rule base are examined. C.D.

A89-15350* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
COOPERATING EXPERT SYSTEMS FOR SPACE STATION - POWER/THERMAL SUBSYSTEM TESTBEDS
CARLA M. WONG (NASA, Ames Research Center, Moffett Field, CA), DAVID J. WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL), GALE R. SUNDBERG (NASA, Lewis Research Center, Cleveland, OH), KATHLEEN L. HEALEY, and JEFFREY S. DOMINICK (NASA, Johnson Space Center, Houston, TX) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 407-414. refs

The Systems Autonomy Demonstration Project (SADP) is a NASA-sponsored series of increasingly complex demonstrations to show the benefits of integrating knowledge-based systems with conventional process control in real-time, real-world problem domains that can facilitate the operations and availability of major Space Station distributed systems. This paper describes the system design, objectives, approaches, and status of each of the testbed knowledge-based systems. Simplified schematics of the systems are shown. C.D.

A89-15354* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AN AUTOMATED DYNAMIC LOAD FOR POWER SYSTEM DEVELOPMENT
NORMA DUGAL WHITEHEAD and ROBERT E. KAPUSTKA (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 437-440.

This paper describes a dynamic load which is computer-controlled and has an increased bandwidth of more than 10 times that commercially available at the time the development of the project began. The load is 3 kW with a bandwidth of 35 kHz. The hardware and software are described, and the control circuitry is shown. C.D.

A89-15369 Purdue Univ., West Lafayette, IN.
SIMULATION OF A DC INDUCTOR RESONANT INVERTER FOR SPACECRAFT POWER SYSTEMS
O. WASYNCZUK and P. C. KRAUSE (Purdue University, West Lafayette, IN) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 523-528. Research supported by P. C. Krause and Associates, Inc. and NASA.

A detailed simulation of a dc inductor, resonant inverter is described. Computer traces are given and compared with test results for various modes of operation including start-up. A power system including a Lundell alternator, 6-pulse rectifier, dc inductor resonant inverter, Litz cable, and resistive load are simulated to illustrate the performance of the dc inductor resonant inverter in a system environment. Author

A89-15376
SPACE STATION PHOTOVOLTAIC POWER MODULE DESIGN
S. T. VOGT and R. A. PROESCHEL (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 567-572.

The Space Station photovoltaic power module is designed to provide 18.75 kW of electrical power. Four such modules will supply the 75 kW of electrical power used on the Phase I station. The function of each module is to generate photovoltaic dc power, store a portion of it for use during eclipse, and convert the net dc output to ac for distribution to users throughout the station by the power management and distribution system. Power is generated by planar solar array assemblies with silicon solar cells. Energy storage is provided by multiple individual pressure vessel Ni-H2 batteries contained in the energy storage assemblies. Provisions for thermal control, pointing and tracking, and dc-to-ac power conversion are also included in the modlue design. Author

A89-15378* Ford Aerospace and Communications Corp., Palo Alto, CA.

SPACE STATION BATTERY SYSTEM DESIGN AND DEVELOPMENT

R. J. HAAS, A. K. CHAWATHE, and G. VAN OMMERING (Ford Aerospace Corp., Space Systems Div., Palo Alto, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 577-582.
(Contract NAS3-24666)

The Space Station Electric Power System will rely on nickel-hydrogen batteries in its photovoltaic power subsystem for energy storage to support eclipse and contingency operations. These 81-Ah batteries will be designed for a 5-year life capability and are configured as orbital replaceable units (ORUs), permitting replacement of worn-out batteries over the anticipated 30-year Station life. This paper describes the baseline design and the development plans for the battery assemblies, the battery ORUs and the battery system. Key elements reviewed are the cells, mechanical and thermal design of the assembly, the ORU approach and interfaces, and the electrical design of the battery system. The anticipated operational approach is discussed, covering expected performance as well as the processor-controlled charge management and discharge load allocation techniques. Development plans cover verification of materials, cells, assemblies and ORUs, as well as system-level test and analyses. Author

A89-15379

PHOTOVOLTAIC POWER SUBSYSTEM DESIGN FOR SPACE STATION

J. E. MCNAMARA, H. C. KOHLWES, R. L. MISIN, D. HOSICK (Ford Aerospace Corp., Space Systems Div., Palo Alto, CA), and W. H. ALLEN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 583-588. refs

The photovoltaic (PV) power subsystem within the Space Station Electrical Power System produces 75 kW of baseload power to support payloads, housekeeping, and Power System operations. It is comprised of four PV modules, each with two solar array wings for primary power generation and five batteries for energy storage. The subsystem main bus is regulated to a nominal 160 Vdc level, with setpoint flexibility, using a pulse-width-modulated, switching sequential shunt approach. Batteries are managed with individual charge/discharge regulators, permitting controlled load sharing and low-stress charging. These power sources interface with the main dc bus via a dc switching unit, the output of which is provided to main inverters that produce 20 kHz, 440 Vac distribution power. The paper describes the subsystem, major features of the components, and the control and management aspects of the design. Control functions are allocated between hardware and software loops, the latter resident in a dedicated controller in each module. Rationale for design selection as well as hardware development plans are discussed. Author

A89-15380

SPACE STATION SOLAR ARRAY DESIGN AND DEVELOPMENT

R. V. ELMS, K. MIYAGI, and C. A. WINSLOW (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 589-594.

The Space Station solar arrays are required to support a 75 kW bus with eight array wings over a four-year period in low earth orbit. This paper describes the design requirements, the baseline design, and the development test program. B.J.

A89-15388* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

MULTI-HUNDRED KILOWATT ROLL RING ASSEMBLY EVALUATION RESULTS

DAVID D. RENZ (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 643-648. Previously announced in STAR as N88-21375.

NASA Lewis Research Center has been evaluating low loss multi-hundred-kilowatt Roll Ring assemblies (an 8 circuit and a 4 circuit) for use on Space Station as the rotating joint power transfer device. In this device ac or dc power is transferred across the rotating joint through compressed rotating flexures. Results and conclusions of the evaluation program are presented. Author

A89-15396

SPACE POWER REACTOR AMTEC CONCEPT

J. W. H. CHI, R. K. SIEVERS (Westinghouse Electric Corp., Advanced Energy Systems Div., Madison, PA), and T. K. HUNT (Ford Motor Research Laboratory, Dearborn, MI) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 691-693. refs

Recent progress in the development of Alkali Metal Thermo Electric Converter (AMTEC) technology include stable high power density electrodes, the demonstration of a vapor-fed cell, the consideration of capillary-pumped AMTEC, and the conceptual design of an AMTEC module for space power applications. The characteristics of AMTEC and its operating temperatures are such that it is ideally suited for integration with the SP-100 nuclear reactor for higher performance, second generation space power systems. This paper presents a study of space power systems in the multikilowatt range (less than 50 kWe) that integrates a down-scaled SP-100 reactor with AMTEC modules. The results for 10 kWe and 30 kWe systems were compared with corresponding systems that use thermoelectric converters. They show that significant reductions in radiator area and system mass can be achieved when using AMTEC. Author

A89-15403* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

POWER TRANSMISSION STUDIES FOR TETHERED SP-100

DAVID J. BENTS (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 733-741. Previously announced in STAR as N88-21251. refs

The tether and/or transmission line connecting the SP-100 to Space Station presents some unorthodox challenges in high voltage engineering, power transmission, and distribution. The line, which doubles as a structural element of this unusual spacecraft, will convey HVDC from SP-100 to the platform in low Earth orbit, and environment where the local plasma is sufficient to cause breakdown of exposed conductors at potentials of only a few hundred volts. Its anticipated several years operation, and continuously accumulating exposure to meteoroids and debris, raises an increasing likelihood that mechanical damage, including perforation, will be sustained in service. The present concept employs an array of gas insulated solid wall aluminum coaxial tubes; a conceptual design which showed basic feasibility of the SP-100 powered Space Station. Practical considerations of launch, deployment and assembly have led to investigation of reel deployable, dielectric insulated coaxial cables. To be competitive, the dielectric would have to operate reliably in a radiation environment under electrical stresses exceeding 50 kV/cm. The SP-100 transmission line high voltage interfaces are also considered. Author

A89-15405
HIGH VOLTAGE BREAKDOWN IN THE SPACE ENVIRONMENT
L. B. GORDON (Auburn University, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 749-754. SDIO-supported research.
(Contract DNA001-85-C-0183)

Recent results and the direction of current research at the Space Power Institute at Auburn University concerning some of the high-voltage insulation issues in the space environment are discussed. A high-vacuum space simulation chamber with capability for rapid pumpdown is described, as is a high-vacuum space simulation chamber for measuring the Paschen curve breakdown characteristics of gas mixtures. The rapid outgassing characteristics of a number of materials have been measured, leading to the conclusion that outgassing dominates the local region for materials newly exposed to a vacuum environment. C.D.

A89-15408
THE BREAKDOWN CHARACTERISTICS OF OUTGASSING DOMINATED VACUUM REGIONS
S. A. MERRYMAN, A. J. BANDY, and L. B. GORDON (Auburn University, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 763-765. SDIO-supported research.
(Contract DNA001-85-C-0183)

The prospect of using the space vacuum as an electrical insulator for high power/high voltage applications makes it necessary to determine the electrical breakdown characteristics of this region. A dominating factor in the breakdown characterization is the effect of material outgassing on the insulating properties of a vacuum region. Outgassing properties are studied here for commonly used insulating materials such as G-10 fiberglass laminates, Teflon, and polyethylene. Preliminary measurements of the outgassing species, the effect of temperature on the rate of outgassing, and the electrical breakdown voltage as a result of outgassing are presented. C.D.

A89-15411
SPACECRAFT ELECTRICAL POWER SYSTEMS LESSONS LEARNED
AMY C. REISS GERSON (Boeing Aerospace Co., Seattle, WA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 785-788. refs

This paper presents results of a survey of space power systems experts from industry, government, and academia concerning solutions to power systems problems. The topics addressed include systems engineering, solar arrays, arcing and corona discharge, plasma interaction, solar array deployment, power electronics, batteries, and power distribution wiring. Problems and concerns are reviewed for program phases starting with design, through development, testing, and flight operations. C.D.

A89-15416* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
RAY TRACING OPTICAL ANALYSIS OF OFFSET SOLAR COLLECTOR FOR SPACE STATION SOLAR DYNAMIC SYSTEM
KENT S. JEFFERIES (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 4. New York, American Society of Mechanical Engineers, 1988, p. 225-232. Previously announced in STAR as N88-22080.

OFFSET, a detailed ray tracing computer code, was developed at NASA Lewis Research Center to model the offset solar collector for the Space Station solar dynamic electric power system. This model traces rays from 50 points on the face of the sun to 10 points on each of the 456 collector facets. The triangular facets are modeled with spherical, parabolic, or toroidal reflective surface contour and surface slope errors. The rays are then traced through the receiver aperture to the walls of the receiver. Images of the collector and of the sun within the receiver produced by this code provide insight into the collector receiver interface. Flux distribution on the receiver walls, plotted by this code, is improved by a combination of changes to aperture location and receiver tilt angle. Power loss by spillage at the receiver aperture is computed and is considerably reduced by using toroidal facets. Author

A89-15418
SOLAR THERMODYNAMIC POWER GENERATION EXPERIMENT ON SPACE FLYER UNIT
NOBUHIRO TANATSUGU (Tokyo, University, Sagamihara, Japan) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 4. New York, American Society of Mechanical Engineers, 1988, p. 239-242.

An account is given of the orbital experiment planned for the solar thermodynamic power system of the Japanese Space Flyer Unit (SFU). The power system encompasses a solar radiation collector, a thermal storage system, and a space radiator; attention is given to their reliability and durability. An examination is made of the ways in which vibration and inertia due to the moving parts of the system affect the SFU's payload. O.C.

A89-15827* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
GAAS MMIC ELEMENTS IN PHASED-ARRAY ANTENNAS
REGIS F. LEONARD (NASA, Lewis Research Center, Cleveland, OH) IN: Optoelectronic signal processing for phased-array antennas; Proceedings of the Meeting, Los Angeles, CA, Jan. 12, 13, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 72-79. refs

Over the last six years NASA Lewis Research Center has carried out a program aimed at the development of advanced monolithic microwave integrated circuit technology, principally for use in phased-array antenna applications. Arising out of the Advanced Communications Technology Satellite (ACTS) program, the initial targets of the program were chips which operated at 30 and 20 GHz. Included in this group of activities were monolithic power modules with an output of 2 watts at GHz, variable phase shifters at both 20 and 30 GHz, low noise technology at 30 GHz, and a fully integrated (phase shifter, variable gain amplifier, power amplifier) transmit module at 20 GHz. Subsequent developments are centered on NASA mission requirements, particularly Space Station communications systems and deep space data communications. Author

A89-17674*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE INDUCED ENVIRONMENT AROUND SPACE STATION
MARSHA R. TORR (NASA, Marshall Space Flight Center, Huntsville, AL) and D. G. TORR (Science and Engineering Associates, Inc., Huntsville, AL) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 23 p. refs
(IAF PAPER 88-095)

The potential impact of the International Space Station on its immediate environment is discussed, summarizing the results of recent investigations by NASA working groups. Consideration is given to the neutral-gas environment, the induced photon emission, particulate contamination, the ionized environment, the Induced-environment Monitoring Package proposed for inclusion in the Space Station equipment, and recommendations for further research. Diagrams, drawings, graphs, and tables of numerical data are provided. T.K.

A89-17727#
COMPARISON OF A CASSEGRAIN MIRROR CONFIGURATION TO A STANDARD PARABOLIC DISH CONCENTRATOR CONFIGURATION FOR A SOLAR-DYNAMIC POWER SYSTEM
JUERGEN BLUMENBERG and WILFRIED ZOERNER (Muenchen,

Technische Universitaet, Munich, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p.
(IAF PAPER 88-209)

Two possible insolation-collector configurations have been analyzed and optimized for application to a solar-dynamic large spacecraft power system: a 'standard' collector, and a Cassegrain collector. The standard configuration is defined by the paraboloid's rim angle only, while the Cassegrain is described by both the primary mirror's paraboloid rim angle and the secondary mirror's hyperboloid position. An optimization of maximum concentration, optical efficiency, and thermal efficiency, has established that collector performance is virtually independent of concentration for values of 1000-2000. O.C.

A89-17728#
A SYSTEM FOR SPACECRAFT ENERGY TRANSFER
K. SERAFIMOV (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia po Vissha Geodeziia, Sofia, Bulgaria) and I. BOGOMILOV (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia za Kosmicheski Izsledvaniia, Sofia, Bulgaria) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 4 p.
(IAF PAPER 88-216)

This paper discusses principles of an energy transfer system, in which a spacecraft situated in the lighted section of the orbit can transfer energy to a spacecraft situated in the darkened section of an orbit. The transfer is facilitated by microwave power transmission. The losses of energy transfer between spacecrafts in geostationary orbits are analyzed. Possible designs of an energy transfer system equipped with appropriate facilities for scanning and transferring of energy from a geostationary object to spacecrafts on other orbits are discussed. I.S.

A89-17729#
EXPERIMENTAL SYSTEM FOR MICROWAVE POWER TRANSMISSION FROM SPACE TO EARTH
R. AKIBA (Tokyo, University, Japan), M. SHIGEHARA, and Y. TORIYAMA (Toshiba Corp., Space Div., Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p.
(IAF PAPER 88-218)

A simplified version of the Energy Storable Orbital Power Station (ESOPS) will be available for the experimental transmission of energy by microwaves from orbital space to the earth surface. In order to maximize ESOPS orbital mass (up to 10 tons), a 500-km orbital altitude has been chosen. The ESOPS will transmit microwave power during a visible period of 5-10 min. The rectennas receiving the microwave power from ESOPS are distributed in a circle of approximately 16 percent diameter; 90-percent power collection is anticipated. O.C.

A89-17730*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PHOTOVOLTAICS FOR HIGH CAPACITY SPACE POWER SYSTEMS
DENNIS J. FLOOD (NASA, Lewis Research Center, Cleveland, OH) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. Previously announced in STAR as N89-10122. refs
(IAF PAPER 88-221)

The anticipated energy requirements of future space missions will grow by factors approaching 100 or more, particularly as a permanent manned presence is established in space. The advances that can be expected in solar array performance and lifetime, when coupled with advanced, high energy density storage batteries and/or fuel cells, will continue to make photovoltaic energy conversion a viable power generating option for the large systems of the future. The specific technologies required to satisfy any particular set of power requirements will vary from mission to mission. Nonetheless, in almost all cases the technology push will be toward lighter weight and higher efficiency, whether of solar arrays of storage devices. This paper will describe the content and direction of the current NASA program in space photovoltaic technology. The paper will also discuss projected system level capabilities of photovoltaic power systems in the context of some of the new mission opportunities under study by NASA, such as a manned lunar base, and a manned visit to Mars. Author

A89-17752#
SOLAR ARRAY PADDLE WITH LIGHTWEIGHT LATTICE PANEL
H. HASHIMOTO (National Space Development Agency of Japan, Ibaraki), T. AKAEDA, M. IWAKAMI, K. MATSUMURA, and Y. KAWAI (Toshiba Corp., Kawasaki, Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p.
(IAF PAPER 88-271)

A very efficient solar array paddle has been developed for large scale satellites in communication and/or direct-broadcasting missions using higher electrical power up to ten kilowatt range with lighter weight requirements. A power-to-mass ratio of the paddle was improved by employing an ultrathin silicon solar cell of 50-micron thickness and the Lightweight Lattice Panel (LLP)>. This paper describes the concept of the paddle configuration, details the constituent parts, and summarizes development test results. Author

A89-18170*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN INNOVATIVE APPROACH TO SUPPLYING AN ENVIRONMENT FOR THE INTEGRATION AND TEST OF THE SPACE STATION DISTRIBUTED AVIONICS SYSTEMS
THOMAS BARRY (NASA, Johnson Space Center, Houston, TX), TERRANCE SCHEFFER (McDonnell Douglas Astronautics Co., Saint Louis, MO), and L. R. SMALL (IBM, Armonk, NY) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 788-791.
(AIAA PAPER 88-3978)

This paper describes an innovative approach to supplying an environment for the integration and testing of the Space Station distributed avionics systems. The environment's relationship to the process flow of the Space Station verification from systems development to on-orbit verification is presented. This paper also describes the uses of the environment's hardware implementation called Data Management System (DMS) kits. The way in which this environment allows system developers to independently verify their system's performance, fault detection, and recovery capability is explained. Author

A89-18449
INVESTIGATION OF THE EFFECTS OF A JET AND THERMAL RADIATION FROM AN ELECTROROCKET ENGINE ON A SPACECRAFT SOLAR ARRAY [ISSLEDOVANIE VOZDEISTVIIA STRUI I TEPLOVOGO IZLUCHENIIA ELEKTRORAKETNOGO DVIGATELIA NA SOLNECHNYE BATAREI KOSMICHESKOGO APPARATA]
S. N. ASKHABOV, D. P. GRDLICHKO, A. I. KOZLOV, V. A. KOLOSKOV, A. B. PETROV et al. Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 796-798. In Russian.

The paper presents an investigation of the stability of a solar array under the prolonged effect of a jet and thermal radiation from an electrojet engine, simulated by two models of a stationary plasma engine. It is concluded that the results obtained reflect with sufficient accuracy the atomization of the protective coatings of solar cells and solar-array structural elements under the effect of an ion beam under conditions of sun-synchronous and lower orbits. B.J.

A89-19678* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN ENVIRONMENT FOR THE INTEGRATION AND TEST OF THE SPACE STATION DISTRIBUTED AVIONICS SYSTEMS
THOMAS BARRY (NASA, Johnson Space Center, Houston, TX),

TERRANCE SCHEFFER (McDonnell Douglas Astronautics Co., Saint Louis, MO), and L. R. SMALL (IBM Corp., System Integration Div., Houston, TX) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 3, Nov. 1988, p. 16-20.

An approach to supplying an environment for the integration and test of the Space Station distributed avionics systems is described. Background is included on the development of this concept including the lessons learned from Space Shuttle experience. The environment's relationship to the process flow of the Space-Station verification, from systems development to on-orbit verification, is presented. The uses of the environment's hardware implementation, called Data Management System (DMS) kits, are covered. It is explained how these DMS kits provide a development version of the space-station operational environment and how this environment allows system developers to verify their systems performance, fault detection, and recovery capability. Conclusions on how the use of the DMS kits, in support of this concept, will ensure adequate on-orbit test capability are included. I.E.

A89-19916*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

SPACE VEHICLE GLOW AND ITS IMPACT ON SPACECRAFT SYSTEMS

H. B. GARRETT, A. CHUTJIAN, and S. GABRIEL (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Sept.-Oct. 1988, p. 321-340. refs

Spacecraft glow poses a contamination threat to low orbital altitude optical sensor systems. The complexity of the phenomena entails a multifaceted approach to system design for vehicle glow minimization. In the case of Space Shuttle cloud glow, which involves line and band emission, filtering and careful optical sensor wavelength selection may also prove useful; Space Shuttle thruster glow mitigation entails the limitation of thruster firings during sensor operations. Careful selection of instrument baffle materials and coatings, as well as control of surface temperatures, are recommended as ways of limiting glow impact for instruments directed in the direction of vehicle movement. O.C.

A89-20016* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

A NEW SPACE STATION POWER SYSTEM

GEOFFREY A. LANDIS (NASA, Lewis Research Center, Cleveland, OH; Brown University, Providence, RI) Acta Astronautica (ISSN 0094-5765), vol. 17, Sept. 1988, p. 975-977. refs

A new concept for a Space Station power system is proposed which reduces the drag effect of the solar panels and eliminates eclipsing by the Earth. The solar generator is physically separated from the Space Station, and power transmitted to the station by a microwave beam. The power station can thus be placed high enough that drag is not a significant factor. For a resonant orbit where the ratio of periods s:p is a ratio of odd integers, and the orbital planes nearly perpendicular, an orbit can be chosen such that the line of sight is never blocked if the lower orbit has an altitude greater than calculatable mininum. For the 1:3 resonance, this minimum altitude is 0.5 r(e). Finally, by placing the power station into a sun-synchronous orbit, it can be made to avoid shadowing by the Earth, thus providing continuous power. Author

A89-20197* Drexel Univ., Philadelphia, PA.

OPTICALLY RECONFIGURED ACTIVE PHASED ARRAY ANTENNAS

A. S. DARYOUSH and B. CHOE (Drexel University, Philadelphia, PA) Microwave and Optical Technology Letters (ISSN 0895-2477), vol. 1, Nov. 1988, p. 344-348. Research supported by Du Pont de Nemours and Co., AEL, and NASA. refs

Future generations of phased array antennas for space-based and airborne platforms are designed based on a large number of active T/R modules. The constructed radiating beam is degraded in the event of modules failure. Simulation results indicate that the control of frequency, interelement spacing, and the individual radiating element pattern alongside the more conventional technique of amplitude and phase can be used to reconfigure the desired radiating beam in the event of the active T/R module failure. Author

A89-22172* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

INTELLIGENT, AUTONOMOUS SYSTEMS IN SPACE

H. LUM and E. HEER (NASA, Ames Research Center, Moffett Field, CA) Acta Astronautica (ISSN 0094-5765), vol. 17, Oct. 1988, p. 1081-1091. refs

The Space Station is expected to be equipped with intelligent, autonomous capabilities; to achieve and incorporate these capabilities, the required technologies need to be identitifed, developed and validated within realistic application scenarios. The critical technologies for the development of intelligent, autonomous systems are discussed in the context of a generalized functional architecture. The present state of this technology implies that it be introduced and applied in an evolutionary process which must start during the Space Station design phase. An approach is proposed to accomplish design information acquisition and management for knowledge-base development. Author

A89-23281* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

STATUS OF THE SPACE STATION POWER SYSTEM

COSMO R. BARAONA and DEAN W. SHEIBLEY (NASA, Lewis Research Center, Cleveland, OH) (NASA, Space Electrochemical Research and Technology Conference, Cleveland, OH, Apr. 14-16, 1987) Journal of Power Sources (ISSN 0378-7753), vol. 22, March-Apr. 1988, p. 195-203. Previously announced in STAR as N87-29915.

The major requirements and guidelines that affect the manned Space Station configuration and the power systems are explained. The evolution of the Space Station power system from the NASA program development feasibility phase through the current preliminary design phase is described. Several early station concepts are described and linked to the present concept. The recently completed phase B tradeoff study selections of photovoltaic system technologies are described. The present solar dynamic and power management and distribution systems are also summarized for completeness. Author

A89-23540

MOTION STEREO AND EGO-MOTION COMPLEX LOGARITHMIC MAPPING (ECLM)

SANDRA L. BARTLETT and RAMESH JAIN (Michigan, University, Ann Arbor) IN: Digital and optical shape representation and pattern recognition; Proceedings of the Meeting, Orlando, FL, Apr. 4-6, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 138-145. refs

(Contract NSF MCS-82-19739; F49620-82-C-0089)

Ego-motion Complex Logarithmic Mapping (ECLM) employs approximate ego-motion information obtainable in such applications (which require object-recognition, depth-determination, and dynamic scene-segmentation) as autonomous-navigation vehicles, space station construction, and robot arm control, to choose the origin of the mapping. This choice facilitates the use of important characteristics of optical flow without the onerous requirement to calculate the flow. An evaluation is made of the performance of point-, line-, and region algorithms in ECLM space, as well as of the ways in which they can be used for depth determination. O.C.

A89-23721

NONSTATIONARY POTENTIAL OF A SPACECRAFT EMITTING ELECTRONS INTO FREE SPACE [NESTATSIONARNYI POTENTSIAL KOSMICHESKOGO APPARATA, EMITTIRUIUSHCHEGO ELEKTRONY V SVOBODNOE PROSTRANSTVO]

A. IU. BESSARABSKII and E. G. SHUSTIN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Nov.-Dec. 1988, p. 953-956. In Russian.

The problem of the potential of an isolated body emitting an electron beam into a rarefied gas is investigated by the method of qualitative analytical estimates and by a model experiment in a vacuum chamber with a limiting pressure of 1.6 x 10 to the -5th torr. Both theoretical and experimental results indicate that the electron-emitting body can be charged to a potential exceeding the accelerating voltage. B.J.

A89-24293* New Hampshire Univ., Durham.
HEAVY ION BEAM-IONOSPHERE INTERACTIONS - CHARGING AND NEUTRALIZING THE PAYLOAD
R. L. KAUFMANN, R. L. ARNOLDY (New Hampshire, University, Durham), D. N. WALKER, J. C. HOLMES (U.S. Navy, Naval Research Laboratory, Washington, DC), C. J. POLLOCK (NASA, Marshall Space Flight Center, Huntsville, AL) et al. Journal of Geophysical Research (ISSN 0148-0227), vol. 94, Jan. 1, 1989, p. 453-471. refs
(Contract NSF ATM-85-21819; NSF ATM-88-02271; NAG6-12; NAG6-11; NAG5-601)
Three different electrical charging and neutralization processes were experienced during gun operation in the Argon Release Controlled Studies rocket flights, which carried ion generators to 400-500 km in the nighttime auroral ionosphere: DC charging of the vehicle, brief charging at gun turn-on, and extended oscillatory sequences. The present analysis of these phenomena has determined that, during oscillatory events, the entire environment of a payload could alternate between hot electron and cold electron configurations at rates which may have been in excess of 10 kHz. O.C.

A89-25204#
SOLID-SOLID PHASE CHANGE THERMAL STORAGE APPLICATION TO SPACE-SUIT BATTERY PACK
CHANG H. SON and JEFFREY H. MOREHOUSE (South Carolina, University, Columbia) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p. refs
(AIAA PAPER 89-0240)
High cell temperatures are seen as the primary safety problem in the Li-BCX space battery. The exothermic heat from the chemical reactions could raise the temperature of the lithium electrode above the melting temperature. Also, high temperature causes the cell efficiency to decrease. Solid-solid phase-change materials were used as a thermal storage medium to lower this battery cell temperature by utilizing their phase-change (latent heat storage) characteristics. Solid-solid phase-change materials focused on in this study are neopentyl glycol and pentaglycerine. Because of their favorable phase-change characteristics, these materials appear appropriate for space-suit battery pack use. The results of testing various materials are reported as thermophysical property values, and the space-suit battery operating temperature is discussed in terms of these property results. Author

A89-25405*# TRW, Inc., Redondo Beach, CA.
LARGE STRUCTURE CURRENT COLLECTION IN PLASMA ENVIRONMENTS
N. JOHN STEVENS (TRW Power and Systems Integration Laboratory, Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(Contract NAS3-24659)
(AIAA PAPER 89-0496)
The floating potential, relative to the space plasma, of large satellites proposed for future missions is an important factor in the current balance between the plasma particle collection of biased surfaces and exposed conductors. To solve this balance, a knowledge of the plasma current collection processes is required. One of the unknowns in these relationships is the current collection of large areas of conducting surfaces. Only limited experimental data is available on this collection process. Data from one of the few available tests is used herein to verify the applicability of a plasma collection model for large surfaces. The model is then applied to determine the floating potential of the NASA Space Station. Author

A89-25488#
OBSERVATION OF SURFACE CHARGING ON ENGINEERING TEST SATELLITE V OF JAPAN
HIRONOBU NISHIMOTO (National Space Development Agency of Japan, Tsukuba), HARUHISA FUJII (Mitsubishi Electric Corp., Manufacturing Development Laboratory, Amagasaki, Japan), and TOSHIO ABE (Mitsubishi Electric Corp., Kamakura, Japan) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0613)
A potential monitor (POM) was developed and was installed on geostationary Engineering Test Satellite V of Japan launched on August 27, 1987. The POM can measure the surface potentials of insulating material samples which get charged in the space environment. Three kinds of thermal control materials were used as the samples. The following observational results were obtained: (1) the charging potentials increased negatively in the shadow of antenna or shunt of solar array paddle, (2) the potentials gradually increased for one year, and (3) the potentials changed periodically with the temperature of the sensing part of the POM. Author

A89-25489#
INVESTIGATION OF ESD HAZARD FOR LARGE SPACE SOLAR ARRAYS CONFIGURED WITH GFRP/KAPTON SUBSTRATE
JOHN S. ARCHER, HANS S. RAUSCHENBACH, and N. JOHN STEVENS (TRW, Inc., Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0617)
The in-orbit failures of thin Kapton dielectric sheets in solar arrays were reviewed. From the data reported in the literature, supplemented by tests simulating high voltage breakdowns on substrate materials, design recommendations for future lightweight solar arrays were drawn. System configurations are identified which will minimize the hazard and improve the robustness of solar arrays with respect to electrostatic-discharge-induced substrate shorts. It is suggested that, for a 10-year-life spacecraft in geosynchronous orbit, the maximum dc voltage stress for 0.001-in-thick Kapton dielectrics be kept below 25 V. For 0.002-in-thick Kapton dielectrics, a maximum dc stress level of 40 V is estimated, and for 0.003 in, 50 V. Author

A89-25537*# Colorado State Univ., Fort Collins.
PLASMA CONTACTING - AN ENABLING TECHNOLOGY
JOHN D. WILLIAMS and PAUL J. WILBUR (Colorado State University, Fort Collins) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(Contract NAG3-776)
(AIAA PAPER 89-0677)
An experimental study of plasma contacting with an emphasis on the electron collection mode of this process is described. Results illustrating variations in plasma property profiles and potential differences that develop at hollow cathode plasma contactors are presented. A model of the electron collection plasma contacting process that is consistent with experimentally measured results is reviewed. The shortcomings of laboratory results as direct predictors of contactor performance in space and their usefulness in validating numerical models of the contacting process, that can be used to predict such performance, are discussed. Author

A89-27897* Ergenics, Inc., Wyckoff, NJ.
A FUEL CELL ENERGY STORAGE SYSTEM FOR SPACE STATION EXTRAVEHICULAR ACTIVITY
MATTHEW J. ROSSO, JR., OTTO J. ADLHART (Ergenics Power Systems, Inc., Wyckoff, NJ), and JOSE A. MARMOLEJO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p.
(SAE PAPER 881105)
The development of a fuel cell energy storage system for the Space Station Extravehicular Mobility Unit (EMU) is discussed. The ion-exchange membrane fuel cell uses hydrogen stored as a metal hydride. Several features of the hydrogen-oxygen fuel cell

are examined, including its construction, hydrogen storage, hydride recharge, water heat, water removal, and operational parameters. R.B.

A89-28440#
AN ANALYSIS OF GPS ELECTROSTATIC DISCHARGE RATES
J. W. HAFFNER (Rockwell International Corp., Seal Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0616)

Solar wind statistics and energy density considerations were used to calculate the probability of hot plasma reaching the orbit of GPS spacecraft. The results of these calculations were that the spacecraft should experience hot plasma 0.3 percent of the time (1 day/year). However, scaling from several laboratory and on-orbit (at GEO) measurements showed that, when hot plasma is present, the GPS spacecraft would be expected to experience several hundred discharges per hour. Of the various techniques considered for reducing or eliminating these discharges, conductive coatings (such as indium/tin oxide) and astroquartz appears to be the most promising. Author

A89-29115#
SPACE DEPLOYABLE MEMBRANE CONCENTRATORS FOR SOLAR DYNAMIC POWER SYSTEMS
K. J. BENINGA and B. L. BUTLER (Science Applications International Corp., San Diego, CA) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 335-342. refs

The use of membrane concentrators as an alternative to more rigid segmented concentrators for solar dynamic power applications in space is examined. A quasi-isotropic preformed parabolic dish composite membrane which can be folded or rolled up for transport to space for subsequent deployment is described. Two structural support systems have been developed for the deployment and support of the membranes in space. The materials selection and membrane fabrication are discussed. C.D.

A89-29116*# Garrett Corp., Torrance, CA.
ADVANCED SOLAR RECEIVERS FOR SPACE POWER
H. J. STRUMPF, M. G. COOMBS (Garrett Corp., Garrett AiResearch Div., Torrance, CA), and D. E. LACY (NASA, Lewis Research Center, Cleveland, OH) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 343-352.

A study has been conducted to generate and evaluate advanced solar heat receiver concepts suitable for orbital application with Brayton and Stirling engine cycles in the 7-kW size range. The generated receiver designs have thermal storage capability and, when implemented, will be lighter, smaller, and/or more efficient than baseline systems such as the configuration used for the Brayton solar receiver under development by Garrett AiResearch for the NASA Space Station. In addition to the baseline designs, four other receiver concepts were designed and evaluated with respect to Brayton and Stirling engines. These concepts include a higher temperature version of the baseline receiver, a packed bed receiver, a plate-fin receiver, and a heat pipe receiver. The thermal storage for all designs is provided by the melting and freezing of a salt. Author

A89-29117*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE DEVELOPMENT OF AN ADVANCED GENERIC SOLAR DYNAMIC HEAT RECEIVER THERMAL MODEL
Y. C. WU, E. J. ROSCHKE, and L. KOHOUT (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 353-360. refs

An advanced generic solar dynamic heat receiver thermal model under development which can analyze both orbital transient and orbital average conditions is discussed. This model can be used to study advanced receiver concepts, evaluate receiver concepts under development, analyze receiver thermal characteristics under various operational conditions, and evaluate solar dynamic system thermal performances in various orbit conditions. The model and the basic considerations that led to its creation are described, and results based on a set of baseline orbit, configuration, and operational conditions are presented to demonstrate the working of the receiver model. C.D.

A89-29119#
SPACE STATION SOLAR CONCENTRATOR DEVELOPMENT
F. H. VALADE (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 369-374. refs

Solar dynamic concentrator technology for use aboard the Space Station is discussed. The design requirements are reviewed and the Space Station environment is described. The materials evaluation of candidate substrates and coatings is addressed, and the design details of a Space Station concentrator are examined. Developmental testing now being done is described. C.D.

A89-29122*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PHOTOVOLTAIC POWER MODULES FOR NASA'S MANNED SPACE STATION
C. A. TATRO (NASA, Lewis Research Center, Cleveland, OH) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 489-497. Previously announced in STAR as N88-11745. refs

The capability and the safety of manned spacecraft are largely dependent upon reliable electric power systems. Two similar space power systems able to survive the low earth orbit environment, are being considered for NASA's Manned Space Station (SS), scheduled to begin operation in the mid 1990's. The Space Station Electric Power System (EPS) is composed of Photovoltaic (PV) Power Modules, Solar Dynamic (SD) Power Modules, and the Power Management and Distribution (PMAD) System. One EPS configuration will deliver 37.5 kW of PV based, utility grade, ac power to SS users. A second 75 kWe PV based EPS option is also being considered for SS deployment. The two EPS options utilize common modules and differ only in the total number of PV Power Modules used. Each PV Power Module supplies 18.75 kWe of ac power and incorporates its own energy storage and thermal control. The general requirements and the current preliminary design configuration of the Space Station PV Power Modules are examined. Author

A89-29123*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LOW EARTH ORBIT ENVIRONMENTAL EFFECTS ON THE SPACE STATION PHOTOVOLTAIC POWER GENERATION SYSTEMS
H. K. NAHRA (NASA, Lewis Research Center, Cleveland, OH) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 499-507. Previously announced in STAR as N88-12429. refs

A summary of the low earth orbital environment, its impact on the photovoltaic power systems of the Space Station and the solutions implemented to resolve the environmental concerns or issues are described. Low earth orbital environment (LEO) presents several concerns to the photovoltaic power systems of the Space Station. These concerns include atomic oxygen interaction with the polymeric substrate of the solar arrays, ionized environment effects on the array operating voltage, the effects of the meteoroids and debris impacts and penetration through the different layers of the solar cells and their circuits, and the high energy particle and radiation effects on the overall solar array performance. Potential solutions to some of the degrading environmental interactions that will provide the photovoltaic power system of the Space Station with the desired life are also summarized. Author

A89-29753
SPACECRAFT CHARGING AND ELECTROMAGNETIC EFFECTS ON GEOSTATIONARY SATELLITES [DECHARGES DIELECTRIQUES ET PERTURBATIONS ELECTROMAGNETIQUES SUR SATELLITES GEOSTATIONNAIRES]
JEAN-PIERRE MARQUE, JEAN GRANDO, ALAIN DELANNOY, and GERARD LABAUNE (ONERA, Chatillon-sous-Bagneux, France) Annales des Telecommunications (ISSN 0003-4347), vol. 43, Nov.-Dec. 1988, p. 615-624. In French. Research supported by DRET and CNES. refs

Various operational anomalies on satellites in geosynchronous orbit, chiefly occurring during magnetic storms, are attributed to spacecraft charging. The buildup of static charges on the surfaces of the spacecraft leads to various breakdown processes. Self-sustained discharges, characterized by strong electron emission out of the material, may occur on negatively charged films of polymer used, for example, as thermal blankets. The so-called blowoff emission occurs through a complex interaction of the electromagnetic field with the spacecraft. Author

A89-29928
MICROWAVE POWER BEAMING FROM EARTH-TO-SPACE
WALT S. GREGORWICH (Lockheed Research Laboratories, Palo Alto, CA) IN: 1988 IEEE Aerospace Applications Conference, Park City, UT, Feb. 7-12, 1988, Digest. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, 9 p. refs

The author presents an overview of the potential and limitations of microwave power transfer. In addition, state-of-the-art technology is reviewed as well as required hardware to implement such a system. Tradeoffs among frequency selection, atmospheric effects, orbital geometry and energy storage are discussed. Present hardware capabilities of ground station antennas, microwave power sources, and spacecraft receiving antennas such as large unfurlable and space erectable dishes, deployable rectennas, and tethered systems are also reviewed. It is concluded that on the basis of present technology, the efficient transfer of microwave power from earth to a low-orbiting satellite is feasible. I.E.

A89-30100
THE HALO AROUND SPACECRAFT [OREOL VOKRUG KOSMICHESKIKH APPARATOV]
A. I. LAZAREV, S. V. AVAKIAN (Gosudarstvennyi Opticheskii Institut, Leningrad, USSR), and V. I. SEVAST'IANOV Priroda (ISSN 0032-874X), Feb. 1989, p. 100-102. In Russian.

Astronauts aboard various spacecraft (e.g., Soyuz 10 and 23, and the Space Shuttle Columbia in March 1982) have observed an intense glow or halo around the spacecraft. The most likely hypothesis is that this glow is caused by the excitation of the rarefied atmosphere surrounding the spaceraft by fluxes of molecules and ions of the upper layers of the earth's atmosphere. It is noted that this glow phenomenon can be counteracted by the proper choice of materials (e.g., polyethylene) to cover the spacecraft surface. B.J.

A89-30737*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FREE-VIBRATION CHARACTERISTICS AND CORRELATION OF A SPACE STATION SPLIT-BLANKET SOLAR ARRAY
KELLY S. CARNEY and FRANCIS J. SHAKER (NASA, Lewis Research Center, Cleveland, OH) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 813-819. Previously announced in STAR as N89-15438. refs
(AIAA PAPER 89-1252)

Two methods for studying the free-vibration characteristics of a large split-blanket solar array in a zero-g cantilevered configuration are presented. The zero-g configuration corresponds to an on-orbit configuration of the Space Station solar array. The first method applies the equations of continuum mechanics to determine the natural frequencies of the array; the second uses the finite element method program, MSC/NASTRAN. The stiffness matrix from the NASTRAN solution was found to be erroneously grounded. The results from the two methods are compared. It is concluded that the grounding does not seriously compromise the solution to the elastic modes of the solar array. However, the correct rigid body modes need to be icluded to obtain the correct dynamic model. Author

A89-30866*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFICIENT EIGENVALUE ASSIGNMENT FOR LARGE SPACE STRUCTURES
PEIMAN G. MAGHAMI and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 2037-2045. refs
(AIAA PAPER 89-1393)

A novel and efficient approach for the eigenvalue assignment of large first-order time-invariant systems is developed using full-state feedback and output feedback. First, a Schur decomposition is applied to triangularize the state matrix. Second, a series of coordinate rotations (Givens rotations) are used to move the eigenvalue to be reassigned to the end of the diagonal of its Schur form. Third, the eigenvalue is moved to the desired location by a full-state feedback, without affecting the remaining eigenvalues. The second and third step can be repeated until all the assignable eigenvalues are moved to the desired locations. Given the freedom of multiple inputs, the feedback gain matrix is calculated to minimize an objective function composed of a gain matrix norm and/or a robustness index of the closed-loop system. Numerical examples are given to demonstrate the feasibility of the proposed approach. Author

A89-31882*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PARTICLE ADHESION TO SURFACES UNDER VACUUM
JACK B. BARENGOLTZ (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Mar.-Apr. 1989, p. 103-108. Previously cited in issue 17, p. 2823, Accession no. A88-43765. refs

A89-31915*# Massachusetts Inst. of Tech., Cambridge.
INDUCED EMISSION OF RADIATION FROM A LARGE SPACE-STATION-LIKE STRUCTURE IN THE IONOSPHERE
D. E. HASTINGS and J. WANG (MIT, Cambridge, MA) AIAA Journal (ISSN 0001-1452), vol. 27, April 1989, p. 438-445. refs
(Contract NAG3-695)

Large conducting structures in the ionosphere may have currents flowing through them which close in the ionospheric plasma. These currents can arise either from current leakage from an onboard power distribution system or by being induced by the motional electric field. Associated with these currents will be broadband electromagnetic radiation in the Alfven and lower hybrid bands. The radiation impedance of this electromagnetic radiation is explored for a structure of space-station-like dimensions as a function of the geometry of the structure and the composition of the ionic environment. It is shown that modification of the collecting area of the structure and environment can be used to minimize the radiation impedance. For a space station, the radiated power will at most be of the order of watts, which does not represent a significant power loss. However, the radiation field will give rise to a substantial pollution of the electromagnetic spectrum in the vicinity of the space station. Design choices to minimize this interference are suggested. Author

N89-10122*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

PHOTOVOLTAICS FOR HIGH CAPACITY SPACE POWER SYSTEMS

DENNIS J. FLOOD Oct. 1988 16 p Presented at the 39th Annual Astronautical Congress of the International Astronautical Federation, Bangalore, India, 8-15 Oct. 1988

(NASA-TM-101341; E-4360; NAS 1.15:101341) Avail: NTIS HC A03/MF A01 CSCL 10B

The anticipated energy requirements of future space missions will grow by factors approaching 100 or more, particularly as a permanent manned presence is established in space. The advances that can be expected in solar array performance and lifetime, when coupled with advanced, high energy density storage batteries and/or fuel cells, will continue to make photovoltaic energy conversion a viable power generating option for the large systems of the future. The specific technologies required to satisfy any particular set of power requirements will vary from mission to mission. Nonetheless, in almost all cases the technology push will be toward lighter weight and higher efficiency, whether of solar arrays or storage devices. This paper will describe the content and direction of the current NASA program in space photovoltaic technology. The paper will also discuss projected system level capabilities of photovoltaic power systems in the context of some of the new mission opportunities under study by NASA, such as a manned lunar base, and a manned visit to Mars. Author

N89-11315*# Lockheed Missiles and Space Co., Sunnyvale, CA.

PV MODULES FOR GROUND TESTING Final Report

10 Sep. 1986 132 p

(Contract NAS3-24657)

(NASA-CR-179476; NAS 1.26:179476; LMSC/D973480) Avail: NTIS HC A07/MF A01 CSCL 10/1

The main objective was to design and build a minimum of three photovoltaic test panels for plasma interaction experiments. These experiments are intended to provide data on the interactions between high-voltage solar arrays and the space plasma environment. Data gathered will significantly contribute to the development of design criteria for the space station solar arrays. Electrical isolation between the solar cell strings and the module mounting plate is required for high-voltage bias. Author

N89-11504# Los Alamos National Lab., NM. Chemistry and Laser Sciences Div.

HIGH ENERGY-INTENSITY ATOMIC OXYGEN BEAM SOURCE FOR LOW EARTH ORBIT MATERIALS DEGRADATION STUDIES

J. B. CROSS and N. C. BLAIS 1988 14 p Presented at the 16th International Symposium on Rarefied Gas Dynamics, Pasadena, Calif., 11 Jul. 1988

(Contract W-7405-ENG-36)

(DE88-014316; LA-UR-88-2188; CONF-880781-1) Avail: NTIS HC A03/MF A01

A high intensity (10 to the 19th O-atoms/s-sr) high energy (5 eV) source of oxygen atoms has been developed that produces a total fluence of 10 to the 22d O-atoms/sq cm in less than 100 hours of continuous operation at a distance of 15 cm from the source. The source employs a CW CO2 laser sustained discharge to form a high temperature (15,000 K) plasma in the throat of a 0.3-mm diameter nozzle using 3 to 8 atmospheres of rare gas/O2 mixtures. Visible and infrared photon flux levels of 1 watt/sq cm have been measured 15 cm downstream of the source while vacuum UV (VUV) fluxes are comparable to that measured in low earth orbit. The reactions of atomic oxygen with kapton, Teflon, silver, and various coatings have been studied. The oxidation of kapton (reaction efficiency = 3x10 to the -24 cm + or - 50 percent) has an activation energy of 0.8 Kcal/mole over the temperature range of 25 to 100 C at a beam energy of 1.5 eV and produces low molecular weight gas phase reaction products (H2O, NO, CO2). Teflon reacts with approx 0.1 to 0.2 efficiency to that of kapton at 25 C and both surfaces show a ruglike texture after exposure to the O-atom beam. Angular scattering distribution measurements of O-atoms show a near cosine distribution from reactive surfaces indicating complete accommodation of the translational energy with the surface while a nonreactive surface (nickel oxide) shows specular-like scattering with 50 percent accommodation of the translational energy with the surface. A technique for simple on orbit chemical experiments using resistance measurements of coated silver strips is described. DOE

N89-11802*# Arinc Research Corp., Annapolis, MD.

SPACE STATION ELECTRICAL POWER SYSTEM AVAILABILITY STUDY Final Contractor Report

SCOTT R. TURNQUIST and MARK A. TWOMBLY Nov. 1988 192 p

(Contract NASA ORDER C-31003-J)

(NASA-CR-182198; NAS 1.26:182198; ARINC-RP-5149-11-01-4744) Avail: NTIS HC A09/MF A01 CSCL 22/2

ARINC Research Corporation performed a preliminary reliability, and maintainability (RAM) anlaysis of the NASA space station Electric Power Station (EPS). The analysis was performed using the ARINC Research developed UNIRAM RAM assessment methodology and software program. The analysis was performed in two phases: EPS modeling and EPS RAM assessment. The EPS was modeled in four parts: the insolar power generation system, the eclipse power generation system, the power management and distribution system (both ring and radial power distribution control unit (PDCU) architectures), and the power distribution to the inner keel PDCUs. The EPS RAM assessment was conducted in five steps: the use of UNIRAM to perform baseline EPS model analyses and to determine the orbital replacement unit (ORU) criticalities; the determination of EPS sensitivity to on-orbit spared of ORUs and the provision of an indication of which ORUs may need to be spared on-orbit; the determination of EPS sensitivity to changes in ORU reliability; the determination of the expected annual number of ORU failures; and the integration of the power generator system model results with the distribution system model results to assess the full EPS. Conclusions were drawn and recommendations were made. Author

N89-11807*# Arizona State Univ., Tempe. Dept. of Electronics and Computer Technology.

IDENTIFICATION OF HIGH PERFORMANCE AND COMPONENT TECHNOLOGY FOR SPACE ELECTRICAL POWER SYSTEMS FOR USE BEYOND THE YEAR 2000 Final Technical Report, 16 May 1986 - 15 Dec. 1988

JAMES E. MAISEL 5 Dec. 1988 227 p

(Contract NAG3-714)

(NASA-CR-183003; NAS 1.26:183003) Avail: NTIS HC A11/MF A01 CSCL 10/2

Addressed are some of the space electrical power system technologies that should be developed for the U.S. space program to remain competitive in the 21st century. A brief historical overview of some U.S. manned/unmanned spacecraft power systems is discussed to establish the fact that electrical systems are and will continue to become more sophisticated as the power levels appoach those on the ground. Adaptive/Expert power systems that can function in an extraterrestrial environment will be required to take an appropriate action during electrical faults so that the impact is minimal. Manhours can be reduced significantly by relinquishing tedious routine system component maintenance to the adaptive/expert system. By cataloging component signatures over time this system can set a flag for a premature component failure and thus possibly avoid a major fault. High frequency operation is important if the electrical power system mass is to be cut significantly. High power semiconductor or vacuum switching components will be required to meet future power demands. System mass tradeoffs have been investigated in terms of operating at high temperature, efficiency, voltage regulation, and system reliability. High temperature semiconductors will be required. Silicon carbide materials will operate at a temperature around 1000 K and the diamond material up to 1300 K. The driver for elevated temperature operation is that radiator mass is reduced significantly because of inverse temperature to the fourth power. Author

N89-12399# TRW Space Technology Labs., Redondo Beach, CA. Applied Technology Div.

SPACE POWER MHD (MAGNETOHYDRODYNAMIC) SYSTEM Quarterly Technical Progress Report No. 3, 1 Nov. 1987 - 31 Jan. 1988

15 Mar. 1988 28 p

(Contract DE-AC22-87PC-79662)

(DE88-013085; DOE/PC-79662/T3; K535.88.RH-071) Avail: NTIS HC A03/MF A01

This progress report of the Space Power MHD System project presents the accomplishments during 1 November 1987 through 31 January 1988. The scope of work covered encompasses the definition of an MHD power system conceptual design and development plan (Task 1). Progress included the following: Subcontracts were issued to the MIT Plasma Fusion Center and the Westinghouse R and D Center. The performance of the 100 MW 500 sec. power system was optimized and the design concept finalized, including mass and energy balances. Mass and cost estimates were prepared. A design review was held at DOE/PETC. This also included the review of the technical issues definition and of the R and D Plan. Following the review, a final iteration on the conceptual design was initiated. Formulation of the R and D Plan was continued. Preparation of the Task 1 R and D Report was initiated. DOE

N89-12662# Ebasco Services, Inc., New York, NY.

A MULTIMEGAWATT SPACE POWER SOURCE RADIATOR DESIGN

JACEK JEDRUCH 28 Jan. 1988 19 p Presented at the 5th Symposium on Space Nuclear Power Systems, Albuquerque, N. Mex., 11 Jan. 1988

(Contract DE-AC07-76ID-01570)

(DE88-015185; EGG-M-38487; CONF-880122-17) Avail: NTIS HC A03/MF A01

The multimegawatt space power sources (MMSPS) proposed for deployment in the late 1990s to meet mission burst power requirements, require an increase by four orders of magnitude in the power rating of equipment currently used in space. Prenger and Sullivan (1982) describe various radiator concepts proposed for such applications. They range from the innovative liquid droplet radiator (Mattick and Hertzberg 1981) to the more conventional heat pipe concept (Girrens 1982). The present paper deals with the design of the radiator for one such system, characterized by both high temperature and high pressure. It provides an estimate of the size, mass, and problems of orbiting such a radiator, based on the assumption that the next generation of heavy launch vehicle with 120-tonne carrying capacity, and 4000-cu m cargo volume, will be available for putting hardware into orbit. DOE

N89-12842*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

IMPROVED DOCKING ALIGNMENT SYSTEM Patent Application

LEO G. MONFORD, inventor (to NASA) 15 Sep. 1988 19 p

(NASA-CASE-MSC-21372-1; NAS 1.71:MSC-21372-1; US-PATENT-APPL-SN-246595) Avail: NTIS HC A03/MF A01 CSCL 14/2

Improved techniques are provided for the alignment of two objects. The present invention is particularly suited for 3-D translation and 3-D rotational alignment of objects in outer space. A camera is affixed to one object, such as a remote manipulator arm of the spacecraft, while the planar reflective surface is affixed to the other object, such as a grapple fixture. A monitor displays in real-time images from the camera such that the monitor displays both the reflected image of the camera and visible marking on the planar reflective surface when the objects are in proper alignment. The monitor may thus be viewed by the operator and the arm manipulated so that the reflective surface is perpendicular to the optical axis of the camera, the roll of the reflective surface is at a selected angle with respect to the camera, and the camera is spaced a pre-selected distance from the reflective surface. NASA

N89-13485# Aerospace Corp., El Segundo, CA. Space Sciences Lab.

SPACECRAFT ENVIRONMENTAL ANOMALIES EXPERT SYSTEM Status Report

H. C. KOONS and D. J. GORNEY 1 Dec. 1988 115 p

(AEROSPACE-ATR-88(9562)-1) Avail: NTIS HC A06/MF A01

A microcomputer based expert system is being developed to assist 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, and total radiation dose. 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 Instrument Personal Consultant Plus expert system shell. The completed expert system knowledge base will include 150 to 200 rules, as well as a spacecraft attributes database, a historical spacecraft anomalies database, and a space environment database which is updated in near real time. Currently, the expert system is undergoing development and testing. The status of the expert system development completed in FY88 is reviewed. Author

N89-13492*# 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 1987 15 p Presented at Case for Mars 3, Boulder, Colo., 18-22 Jul. 1987; sponsored by American Aeronautical Society, JPL, Los Alamos National Lab., Ames Research Center, Lyndon B. Johnson Space Center, George C. Marshall Space Flight Center, Planetary Society

(NASA-TM-101436; E-4472; NAS 1.15:101436) Avail: NTIS HC A03/MF A01 CSCL 10/2

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

N89-13764*# National Aeronautics and Space Administration. Pasadena Office, CA.

REMOTE OBJECT CONFIGURATION/ORIENTATION DETERMINATION Patent Application

LARRY L. SCHUMACHER, inventor (to NASA) (Jet Propulsion Lab., California Inst. of Tech., Pasadena.) 29 Aug. 1988 12 p

(Contract NAS7-918)

(NASA-CASE-NPO-17436-1-CU; NAS 1.71:NPO-17436-1-CU; US-PATENT-APPL-SN-237035) Avail: NTIS HC A03/MF A01 CSCL 14/2

This invention relates to object detection and location systems and, more particularly, to a method for determining the configuration and location of an object with respect to an X, Y, X coordinate frame. In space applications in particular, there is a need to be able to passively determine the orientation of an object at a distance, for example, in the control of large, flexible space structures. At present, there is no available method or apparatus which will allow the operator to make such a determination. A similar problem and need exists in robotic application. It is the primary object of this invention to provide a system for remotely defining an object's configuration in a manner compatible with a computer's analytical capability. NASA

N89-15158# Air Force Geophysics Lab., Hanscom AFB, MA.
A CHARGE CONTROL SYSTEM FOR SPACECRAFT PROTECTION
B. M. SHUMAN, H. A. COHEN, J. HYMAN, R. R. ROBSON, and W. S. WILLIAMSON (Hughes Research Labs., Malibu, CA.) 26 Sep. 1988 16 p
(Contract AF PROJ. 2823)
(AD-A199904; AFGL-TR-88-0246) Avail: NTIS HC A03/MF A01 CSCL 22/1

An autonomous system to detect both absolute and differential spacecraft charging aboard high altitude satellites, and to reduce those potentials before hazardous arcing levels are reached, is now being developed. Operation of the system is based on the empirical results of the Space Test Program SCATHA (p78-2) and NASA ATS-6 satellites, both of which successfully demonstrated the principle of safely reducing spacecraft charging levels by the emission of a low energy neutral plasma--effectively shorting the spacecraft and charged dielectric surfaces to the ambient space plasma. The Charge Control System will utilize a xenon-based plasma source capable of igniting within one second, and capable of emitting a quasi-neutral plasma containing more than 1 MA of ions. Satellite frame potential (relative to the ambient space plasma) will be determined by an electrostatic analyzer capable of detecting both ions and electrons in the energy range 50 eV to 20 keV. Automatic operation of the system will accomplished by microprocessor controller which will interpret the sensor data and activate the plasma source when predetermined threshold levels are exceeded. With a gas supply for more than 2000 hours of operation in space, the system may be expected to provide on-orbit spacecraft protection for up to 10 years. GRA

N89-15171*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ISSUES AND OPPORTUNITIES IN SPACE PHOTOVOLTAICS
ROBERT W. FRANCIS, W. A. SOMERVILLE (Aerospace Corp., El Segundo, CA.), and DENNIS J. FLOOD 1988 14 p Presented at the 20th Photovoltaic Specialists Conference, Las Vegas, NV, 26-30 Sep. 1988; sponsored by the Institute of Electrical and Electronics Engineers
(NASA-TM-101425; E-4526; NAS 1.15:101425) Avail: NTIS HC A03/MF A01 CSCL 10/2

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

N89-15567*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AUTOMATIC DETECTION OF ELECTRIC POWER TROUBLES (ADEPT)
CAROLINE WANG, HUGH ZEANAH, AUDIE ANDERSON, CLINT PATRICK, MIKE BRADY, and DONNIE FORD (Alabama Univ., Huntsville.) *In its* Fourth Conference on Artificial Intelligence for Space Applications p 125-130 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

ADEPT is an expert system that integrates knowledge from three different suppliers to offer an advanced fault-detection system, and is designed for two modes of operation: real-time fault isolation and simulated modeling. Real time fault isolation of components is accomplished on a power system breadboard through the Fault Isolation Expert System (FIES II) interface with a rule system developed in-house. Faults are quickly detected and displayed and the rules and chain of reasoning optionally provided on a Laser printer. This system consists of a simulated Space Station power module using direct-current power supplies for Solar arrays on three power busses. For tests of the system's ability to locate faults inserted via switches, loads are configured by an INTEL microcomputer and the Symbolics artificial intelligence development system. As these loads are resistive in nature, Ohm's Law is used as the basis for rules by which faults are located. The three-bus system can correct faults automatically where there is a surplus of power available on any of the three busses. Techniques developed and used can be applied readily to other control systems requiring rapid intelligent decisions. Simulated modelling, used for theoretical studies, is implemented using a modified version of Kennedy Space Center's KATE (Knowledge-Based Automatic Test Equipment), FIES II windowing, and an ADEPT knowledge base. A load scheduler and a fault recovery system are currently under development to support both modes of operation. Author

N89-15586*# Sydney Univ. (Australia). Dept. of Computer Science.
DYNAMIC REASONING IN A KNOWLEDGE-BASED SYSTEM
ANAND S. RAO and NORMAN Y. FOO *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 261-270 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

Any space based system, whether it is a robot arm assembling parts in space or an onboard system monitoring the space station, has to react to changes which cannot be foreseen. As a result, apart from having domain-specific knowledge as in current expert systems, a space based AI system should also have general principles of change. This paper presents a modal logic which can not only represent change but also reason with it. Three primitive operations, expansion, contraction and revision are introduced and axioms which specify how the knowledge base should change when the external world changes are also specified. Accordingly the notion of dynamic reasoning is introduced, which unlike the existing forms of reasoning, provide general principles of change. Dynamic reasoning is based on two main principles, namely minimize change and maximize coherence. A possible-world semantics which incorporates the above two principles is also discussed. The paper concludes by discussing how the dynamic reasoning system can be used to specify actions and hence form an integral part of an autonomous reasoning and planning system. Author

N89-15587*# Missouri Univ., Rolla. Graduate Engineering Center.
STRATEGIES FOR ADDING ADAPTIVE LEARNING MECHANISMS TO RULE-BASED DIAGNOSTIC EXPERT SYSTEMS
D. C. STCLAIR, C. L. SABHARWAL, W. E. BOND, and KEITH HACKE (McDonnell-Douglas Research Labs., St. Louis, MO.) *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 271-279 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

Rule-based diagnostic expert systems can be used to perform many of the diagnostic chores necessary in today's complex space systems. These expert systems typically take a set of symptoms as input and produce diagnostic advice as output. The primary objective of such expert systems is to provide accurate and comprehensive advice which can be used to help return the space system in question to nominal operation. The development and maintenance of diagnostic expert systems is time and labor intensive since the services of both knowledge engineer(s) and domain expert(s) are required. The use of adaptive learning mechanisms to increment evaluate and refine rules promises to reduce both time and labor costs associated with such systems. This paper describes the basic adaptive learning mechanisms of strengthening, weakening, generalization, discrimination, and discovery. Next basic strategies are discussed for adding these learning mechanisms to rule-based diagnostic expert systems. These strategies support the incremental evaluation and refinement of rules in the knowledge base by comparing the set of advice given by the expert system (A) with the correct diagnosis (C). Techniques are described for selecting those rules in the in the knowledge base which should participate in adaptive learning. The strategies presented may be used with a wide variety of learning algorithms. Further, these strategies are applicable to a large number of rule-based diagnostic expert systems. They may be used to provide either immediate or deferred updating of the knowledge base. Author

N89-15794*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PLASMA INTERACTIONS MONITORING SYSTEM
WILLIAM T. ROBERTS *In its* Space Station Induced Monitoring p 19-25 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

The plasma environment around the space station is expected to be different from that environment which occurs naturally at these altitudes because of the unprecedented size of the space station, its orbital motion, and its high power distribution system. Although there are models which predict the environment around the station, they do not take into account changes in configuration, changes in the natural and induced environments, nor interactions between the different environments. There will be unique perturbations associated with the space station, which will vary as the space station is being developed. Even after the developed space station has been completed environmental conditions will change as the payloads are changed and as the station systems and materials undergo degradation and modification. Because the space station will be a point of many varied activities the environment will continually undergo perturbations from effluents resulting from operations of the reboost module, EVA, airlock operations, and vacuum venting. The use of the Mobile Service Center will cause disturbances which cannot, at this time, be predicted. Also, the natural environment will be affected by solar flares. In addition, the operations of attached payloads, (e.g., ASTROMAG) themselves will undoubtedly cause perturbations to the ambient environment. Finally, the natural environment will change as a result of natural perturbations such as solar flares and geomagnetic storms. Author

N89-15795*# Michigan Univ., Ann Arbor. Dept. of Atmospheric and Oceanic Science.
THE SPACE STATION NEUTRAL GAS ENVIRONMENT AND THE CONCOMITANT REQUIREMENTS FOR MONITORING
GEORGE CARIGNAN *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 27-28 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

At 340 km, for typical conditions, the neutral atmospheric density is several times 10E8/cc and is thus more abundant than the ionized component by several factors of 10. At that altitude, the principal series is atomic oxygen with 10 percent N2, and 1 percent He, and trace amounts of O2, H, N, NO, and Ar. The constituent densities are highly variable with local time, latitude, and geophysical indices. The physical interaction with surfaces at orbital velocity leads to large buildup of density on forward faces and great depletions in the wakes of objects. Chemical reactions lead to major modifications in constituent densities as in the case of the conversion of most colliding oxygen atoms to oxygen bearing molecules. The neutral environment about an orbiting body is thus a complex product of many variables even without a source of neutral contaminants. The addition of fluxes of gases emanating from the orbiting vehicle, as will be the case for the Space Station, with the associated physical and chemical interactions adds another level of complexity to the character of the environment and mandates a sophisticated measurement capability if the neutral environment is to be quantitatively characterized. Author

N89-15796*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
A COMPACT IMAGING SPECTROMETER FOR STUDIES OF SPACE VEHICLE INDUCED ENVIRONMENT EMISSIONS
MARSHA R. TORR, ed. and D. G. TORR (Alabama Univ., Huntsville.) *In its* Space Station Induced Monitoring p 31-38 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

On the basis of spectral measurements made from the Space Shuttle and on models of the possible Space Station external environment, it appears likely that, even at the planned altitudes of Space Station, photon emissions will be induced. These emissions will occur to some degree throughout the UV-visible-IR spectrum. The emissions arise from a combination of processes including gas phase collisions between relatively energetic ambient and surface emitted or re-emitted atoms or molecules, where the surface raises some species to excited energy states. At present it is not possible to model these processes or the anticipated intensity levels with accuracy, as a number of fundamental parameters needed for such calculations are still poorly known or unknown. However, it is possible that certain spectral line and band features will exceed the desired goal that contaminant emissions not exceed the natural zodiacal background. However, in the near infrared and infrared, it appears that this level will be exceeded to a significant degree. Therefore it will be necessary to monitor emission levels in the vicinity of Space Station, both in order to establish the levels and to better model the environment. In this note, we briefly describe a small spectrometer that is suitable for monitoring the spectrum from 1200A to less than or approximately 12,000A. This instrument uses focal plane array detectors to image this full spectral range simultaneously. The spectral resolution is 4 to 12A, depending on the portion of the wavelength range. Author

N89-15797*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
INFRARED MONITORING OF THE SPACE STATION ENVIRONMENT
THEODOR KOSTIUK, DONALD E. JENNINGS, and MICHAEL J. MUMMA *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 39-46 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

The measurement and monitoring of infrared emission in the environment of the Space Station has a twofold importance - for the study of the phenomena itself and as an aid in planning and interpreting Station based infrared experiments. Spectral measurements of the infrared component of the spacecraft glow will, along with measurements in other spectral regions, provide data necessary to fully understand and model the physical and chemical processes producing these emissions. The monitoring of the intensity of these emissions will provide background limits for Space Station based infrared experiments and permit the determination of optimum instrument placement and pointing direction. Continuous monitoring of temporal changes in the background radiation (glow) will also permit better interpretation of Station-based infrared earth sensing and astronomical observations. The primary processes producing infrared emissions in the Space Station environment are: (1) Gas phase excitations of Station generated molecules (e.g., CO2, H2O, organics...) by collisions with the ambient flux of mainly O and N2. Molecular excitations and generation of new species by collisions of ambient molecules with Station surfaces. They provide a list of resulting species, transition energies, excitation cross sections and relevant time constants. The modeled spectrum of the excited species occurs primarily at wavelengths shorter than 8 micrometer. Emissions at longer wavelengths may become important during rocket firing or in the presence of dust. Author

N89-15798*# Physical Sciences, Inc., Andover, MA. Applied Sciences.

REQUIREMENTS FOR PARTICULATE MONITORING SYSTEM FOR SPACE STATION

BYRON DAVID GREEN *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 47-49 Nov. 1988

Avail: NTIS HC A05/MF A01 CSCL 22/2

We recommend that a stereo camera system be utilized as a diagnostic for the particulate environment surrounding the Space Station. This system should have sufficient sensitivity to identify contaminated periods, to isolate the effects of sources and activities and to determine optical clearing times. A reasonable compromise between sensitivity and other operational constraints is recommended. Sensitivity comparable to the film camera systems should suffice, but long periods of unattended operation and remotely controlled exposure sequences are essential requirements. Author

N89-15801*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

DISPOSITION OF RECOMMENDED MODIFICATIONS OF JSC 30426

JAMES F. SPANN, ed. *In its* Space Station Induced Monitoring p 71-76 Nov. 1988

Avail: NTIS HC A05/MF A01 CSCL 22/2

On May 11, 1988 changes and additions to the Space Station External Contamination Control Document JSC 30426 were addressed at length as part of the charter of this workshop. The modifications and disposition thereof are given below in a concise form in order that a clear understanding of the recommendations and current status be presented. The format is that each paragraph under question is given along with the proposed modified paragraph followed by the workshop's disposition. In some cases, a brief explanation of the issue is given prior to the paragraph in question. Author

N89-15802*# Alabama Univ., Huntsville. Dept. of Electrical and Computer Engineering.

ARCING AND DISCHARGES IN HIGH-VOLTAGE SUBSYSTEMS OF SPACE STATION

N. SINGH *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 77-81 Nov. 1988

Avail: NTIS HC A05/MF A01 CSCL 22/2

Arcing and other types of electrical discharges are likely to occur in high-voltage subsystems of the Space Station. Results from ground and space experiments on the arcing of solar cell arrays are briefly reviewed, showing that the arcing occurs when the conducting interconnects in the arrays are at negative potential above a threshold, which decreases with the increasing plasma density. Furthermore, above the threshold voltages the arcing rate increases with the plasma density. At the expected operating voltages (approximately 200 V) in the solar array for the space station, arcing is expected to occur even in the ambient ionospheric plasma. If the ionization of the contaminants increases the plasma density near the high-voltage systems, the adverse effects of arcing on the solar arrays and the space station are likely to be enhanced. In addition to arcing other discharge processes are likely to occur in high-voltage subsystems. For example, Paschen discharge is likely to occur when the neutral density N sub n greater that 10 to the 12th cu cm, the corresponding neutral pressure P greater than 3 x 10 to the -5 Torr. Author

N89-15978# TRW Space Technology Labs., Redondo Beach, CA.

MEGAWATT SPACE POWER CONDITIONING, DISTRIBUTION, AND CONTROL STUDY Final Report, Sep. 1985 - Sep. 1987

W. T. MORGAN Mar. 1988 192 p

(Contract F33615-85-C-2571)

(AD-A200442; TRW-46568-912; AFWAL-TR-87-2049) Avail: NTIS HC A09/MF A01 CSCL 10/2

This study defined appropriate methodologies for conditioning, distribution, and controlling prime electrical power for megawatt level directed and kinetic energy weapons and identified mission critical and mission enabling technologies. The methodology used was: (1) Identify candidate payloads, (2) Identify candidate power sources, (3) Create a system to interconnect the source and load, (4) Estimate the weight of the system, and (5) Evaluate the selected system against other candidate systems. The key issue identified is the necessity to match the generator to the load with minimum power conditioning equipment. Every additional piece of equipment placed in the power transmission chain adds substantially to the weight. High-voltage transmission is clearly desirable, even though any terminations or exposed parts must be isolated from the space plasma. Only low current (a few hundred amps or less) transmission/distribution lines lend themselves to being uncooled. Everything higher in current probably requires at least some cooling. Development needs include either a high-voltage generator or an efficient generator/transformer combination that can produce high voltage. This latter combination requires either a high frequency generator, or a light-weight transformer, or both. All of the systems require either ac/dc converters (rectifiers) or dc/dc converters (inverter/rectifiers). GRA

N89-16224*# Sanders Associates, Inc., Nashua, NH.

ADVANCED HEAT RECEIVER CONCEPTUAL DESIGN STUDY Final Report, May 1986 - Jul. 1988

JAMES KESSELI, ROGER SAUNDERS, and GARY BATCHELDER Oct. 1988 238 p

(Contract NAS3-24858)

(NASA-CR-182177; NAS 1.26:182177) Avail: NTIS HC A11/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 of the solar dynamic power system is the solar receiver/thermal energy storage (TES) subsystem. Receiver development was conducted by NASA in the late 1960's and since then a very limited amount of work has been done in this area. Consequently the state of the art (SOA) receivers designed for the IOC space station are large and massive. The objective of the Advanced Heat Receiver Conceptual Design Study is to conceive and analyze advanced high temperature solar dynamic Brayton and Stirling receivers. The goal is to generate innovative receiver concepts that are half of the mass, smaller, and more efficient than the SOA. It is also necessary that these innovative receivers offer ease of manufacturing, less structural complexity and fewer thermal stress problems. Advanced Brayton and Stirling receiver storage units are proposed and analyzed in this study which can potentially meet these goals. Author

N89-16917*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

NASA PHOTOVOLTAIC RESEARCH AND TECHNOLOGY

DENNIS J. FLOOD Dec. 1988 12 p Prepared for the Annual Meeting of the American Institute of Chemical Engineers, Washington, DC, 28 Nov. - 2 Dec. 1988

(NASA-TM-101422; E-4522; NAS 1.15:101422) Avail: NTIS HC A03/MF A01 CSCL 10/2

NASA photovoltaic R and D efforts address future Agency space mission needs through a comprehensive, integrated program. Activities range from fundamental studies of materials and devices to technology demonstrations of prototype hardware. The program aims to develop and apply an improved understanding of photovoltaic energy conversion devices and systems that will increase the performance, reduce the mass, and extend the lifetime of photovoltaic arrays for use in space. To that end, there are efforts aimed at improving cell efficiency, reducing the effects of space particulate radiation damage (primarily electrons and protons), developing ultralightweight cells, and developing advanced ray component technology for high efficiency concentrator arrays and high performance, ultralightweight arrays. Current goals that have been quantified for the program are to develop cell and array technology capable of achieving 300 watts/kg for future missions for which mass is a critical factor, or 300 watts/sq m for future missions for which array size is a major driver (i.e., Space Station). A third important goal is to develop cell and array technology which will survive the GEO space radiation environment for at least 10 years. Author

N89-17348# Naval Postgraduate School, Monterey, CA.
A MICROPROCESSOR-BASED, SOLAR CELL PARAMETER MEASUREMENT SYSTEM M.S. Thesis
ROBERT R. OXBORROW Jun. 1988 89 p
(AD-A200227) Avail: NTIS HC A05/MF A01 CSCL 10/2

The effects of the space environment on solar cells has, to date, been largely modeled and approximated in the design of solar arrays. Restrictions such as weight and cost have precluded direct analysis of the long term effects of radiation in space. At the Naval Postgraduate School (NPS), a simple circuit has been devised which facilitates in situ data collection and analysis of these effects. The circuit includes an op-amp and a high beta transistor for cell voltage biasing. When coupled to a microprocessor-based controller system, this circuit has the capability to measure and store data pertaining to solar cell performance I-V curves. The complete system consists of an NSC 800 microprocessor, D/A and A/D components, analog multiplexers and demultiplexers, biasing transistors and op-amps. This design provides a compact, low power, accurate method for I-V measurement and data storage. Such a system may be used to observe and monitor an array of test cells and their performance degradation in both the space environment and terrestrial applications. GRA

N89-18412*# California State Polytechnic Univ., Pomona. Dept. of Aerospace Engineering.
ISAAC: INFLATABLE SATELLITE OF AN ANTENNA ARRAY FOR COMMUNICATIONS, VOLUME 6 Final Report, 1987 - 1988
DEBORAH LODGARD, PATRICK ASHTON, MARGARET CHO, TOM CODIANA, RICHARD GEITH, SHARON MAYEDA, KIRSTEN NAGEL, and STEVEN SZE 11 Jun. 1988 117 p
(Contract NGT-21-002-080)
(NASA-CR-184704; NAS 1.26:184704) Avail: NTIS HC A06/MF A01 CSCL 01/2

The results of a study to design an antenna array satellite using rigid inflatable structure (RIS) technology are presented. An inflatable satellite allows for a very large structure to be compacted for transportation in the Space Shuttle to the Space Station where it is assembled. The proposed structure resulting from this study is a communications satellite for two-way communications with many low-power stations on the ground. Total weight is 15,438 kilograms which is within the capabilities of the Space Shuttle. The satellite will have an equivalent aperture greater than 100 meters in diameter and will be operable in K and C band frequencies, with a total power requirement of 10,720 watts. NASA

N89-18520# Naval Postgraduate School, Monterey, CA.
A PROTOTYPE FAULT DIAGNOSIS SYSTEM FOR NASA SPACE STATION POWER MANAGEMENT AND CONTROL M.S. Thesis
GINA L. HESTER Sep. 1988 145 p
(AD-A202032) Avail: NTIS HC A07/MF A01 CSCL 22/5

The Power Management and Distribution System (PMAD) prototype utilizes a computer graphics interface with a computer expert system running transparent to the user and a computer communications interface that links the two together, all enabling the diagnosis of PMAD system faults. The prototype design is based on the concept that an astronaut on a space station will instruct an expert system through a graphic interface to run a system or component check on the PMAD system. The graphics interface determines which type of evaluations was requested and sends that information through the communications interface to the expert system. The expert system receives the information and, based on the type of evaluation requested, executes the appropriate rules in the knowledge base and sends the resulting status back to the graphics interface and the astronaut. The PMAD System Prototype serves as a proposed training tool for NASA to use in the training of new personnel who will be designing and developing the NASA Space station expert systems. GRA

N89-18927# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
ADVANCED PHASED-ARRAY TECHNOLOGIES FOR SPACEBORNE APPLICATIONS
R. W. ZAHN and E. SCHMIDT *In* ESA, Proceedings of the 1988 International Geoscience and Remote Sensing Symposium (IGARSS) '88 on Remote Sensing: Moving Towards the 21st Century, Volume 2 p 1037-1038 Aug. 1988
Avail: NTIS HC A99/MF A01; ESA Publications Div. ESTEC, Noordwijk, Netherlands, $120 US or 250 Dutch guilders

Design aspects for a spaceborne active phased array synthetic aperture radar antenna are reviewed. A microstrip radiator with improved electrical and thermal performance is proposed. ESA

N89-19354# Hughes Research Labs., Malibu, CA.
FLIGHT MODEL DISCHARGE SYSTEM Report, Mar. 1987 - Apr. 1988
R. R. ROBSON and W. W. WILLIAMSON Jun. 1988 85 p
(Contract F19628-83-C-0143)
(AD-A201605; HAC-REF-F4890; AFGL-TR-88-0150; SR-4) Avail: NTIS HC A05/MF A01 CSCL 22/1

The Flight Model Discharge System (FMDS) Program has completed its fourth year. The FMDS is a spacecraft charge control system designed to overcome the problem of charge buildup on a space vehicle which occurs during periods of adverse space environmental conditions. An overview of the FMDS system is presented, followed by an in-depth treatment of the significant technical developments that have occurred during the past year. The major areas covered include the plasma generator and electrostatic analyzer testing. GRA

N89-19822*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AUTOMATION OF THE SPACE STATION CORE MODULE POWER MANAGEMENT AND DISTRIBUTION SYSTEM
DAVID J. WEEKS *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 25-29 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 22/2

Under the Advanced Development Program for Space Station, Marshall Space Flight Center has been developing advanced automation applications for the Power Management and Distribution (PMAD) system inside the Space Station modules for the past three years. The Space Station Module Power Management and Distribution System (SSM/PMAD) test bed features three artificial intelligence (AI) systems coupled with conventional automation software functioning in an autonomous or closed-loop fashion. The AI systems in the test bed include a baseline scheduler/dynamic rescheduler (LES), a load shedding management system (LPLMS), and a fault recovery and management expert system (FRAMES). This test bed will be part of the NASA Systems Autonomy Demonstration for 1990 featuring cooperating expert systems in various Space Station subsystem test beds. It is concluded that advanced automation technology involving AI approaches is sufficiently mature to begin applying the technology to current and planned spacecraft applications including the Space Station. Author

N89-19825*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AUTOMATIC DETECTION OF ELECTRIC POWER TROUBLES (ADEPT)
CAROLINE WANG, HUGH ZEANAH, AUDIE ANDERSON, CLINT PATRICK, MIKE BRADY, and DONNIE FORD (Alabama A & M Univ., Huntsville.) *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 47-50 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 09/3

Automatic Detection of Electric Power Troubles (A DEPT) is an expert system that integrates knowledge from three different suppliers to offer an advanced fault-detection system. It is designed for two modes of operation: real time fault isolation and simulated modeling. Real time fault isolation of components is accomplished on a power system breadboard through the Fault Isolation Expert System (FIES II) interface with a rule system developed in-house. Faults are quickly detected and displayed and the rules and chain of reasoning optionally provided on a laser printer. This system consists of a simulated space station power module using direct-current power supplies for solar arrays on three power buses. For tests of the system's ability to locate faults inserted via switches, loads are configured by an INTEL microcomputer and the Symbolics artificial intelligence development system. As these loads are resistive in nature, Ohm's Law is used as the basis for rules by which faults are located. The three-bus system can correct faults automatically where there is a surplus of power available on any of the three buses. Techniques developed and used can be applied readily to other control systems requiring rapid intelligent decisions. Simulated modeling, used for theoretical studies, is implemented using a modified version of Kennedy Space Center's KATE (Knowledge-Based Automatic Test Equipment), FIES II windowing, and an ADEPT knowledge base. Author

07

ADVANCED MATERIALS

Includes matrix composites, polyimide films, thermal control coatings, bonding agents, antenna components, manufacturing techniques, and space environmental effects on materials.

A89-10535
MATERIALS AND CONSTRUCTION TECHNIQUES FOR LARGE ORBITAL STRUCTURES [WERKSTOFFE UND BAUWEISEN FUER GROSSE ORBITALSTRUKTUREN]
H. W. BERGMANN (DFVLR, Brunswick, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 414-420. In German. refs
(DGLR PAPER 87-128)

European plans for the development of an orbital infrastructure are reviewed, with a focus on design concepts and their materials requirements. The history of space-station planning is recalled; the currently available materials and designs are surveyed, and particular attention is given to modular truss structures which can be easily unfolded and/or assembled in space, advanced CFRPs for light weight and high stability, and the need for long service life (20-30 years). Extensive diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

A89-11197* National Aeronautics and Space Administration. White Sands Test Facility, NM.
THE BEHAVIOR OF OUTGASSED MATERIALS IN THERMAL VACUUMS
WILLIAM MAHONE and RANDY KAYS (NASA, White Sands Test Facility; Lockheed Engineering and Management Services Co., Inc., Las Cruces, NM) Journal of Environmental Sciences (ISSN 0022-0906), vol. 31, Sept.-Oct. 1988, p. 28-32. refs

Scientists at the NASA White Sands Test Facility (WSTF) are investigating the relationship between outgassing and condensation for aerospace materials in space-like environments. The WSTF throughput test method was validated by previous testing at WSTF using palmitic acid. Data from these tests were compared with data from other preliminary tests by using adipic and behenic acids. The comparison indicates that surface forces between outgassed molecules and the condensing surfaces cause the condensation flux to be different from the incident flux. These forces can also cause the evaporative flux to be different from the expected value. These discrepancies are discussed in terms of both potential and dynamic interactions of outgassed molecules with surfaces. Although these surface forces are noticeable, their overall effect on the test is minimal. Author

A89-11406* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE TECHNOLOGY ISSUES AND THE PROSPECTS FOR THE USE OF LITHIUM BATTERIES IN SPACE
GERALD HALPERT and S. SUBBARAO (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Symposium on Primary and Secondary Ambient Temperature Lithium Batteries, Honolulu, HI, Oct. 18-23, 1987, Proceedings. Pennington, NJ, Electrochemical Society, Inc., 1988, p. 129-145.
(Contract NAS7-918)

Lithium Primary and Secondary Cells are being considered for applications in space to enhance energy storage capability. In this paper the authors describe the past, present and future application and program objectives as well as the technology issues that must be addressed. Author

A89-11893
MECHANISM OF RADIATION-INDUCED DEGRADATION IN MECHANICAL PROPERTIES OF POLYMER MATRIX COMPOSITES
SHIGENORI EGUSA (Takasaki Radiation Chemistry Research Establishment, Japan) Journal of Materials Science (ISSN 0022-2461), vol. 23, Aug. 1988, p. 2753-2760. refs

Four kinds of polymer matrix composites and two kinds of pure resins (epoxy and polyimide) were irradiated at room temperature by gamma rays from a Co-60 source or by 2-MeV electrons from an accelerator. Mechanical tests were then carried out at 77 K and room temperature. It is found that the mechanical properties of the composites depend on the irradiation dose and that this dependence varies not only with the combination of the filler (E-glass or carbon fiber cloth) and the matrix resin but also on the test temperature. Based on a comparison between the dose dependence of the composites and that of the pure resins, a mechanism of radiation-induced degradation of polymer matrix composites is proposed. V.L.

A89-12106#
LEGAL ASPECTS OF ENVIRONMENTAL PROTECTION IN OUTER SPACE REGARDING DEBRIS
I. H. PH. DIEDERIKS-VERSCHOOR (International Institute of Space Law, Paris, France) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 131-134. refs

The problem of man-made space debris is considered from a legal perspective, reviewing the opinions expressed in recent international discussions. Topics examined include the applicable provisions of the Space Treaty of 1967, the Registration Treaty of 1975, and the Moon Agreement of 1979; the definition of a 'space object' in these treaties; the dangers posed to manned spacecraft by even small debris; and the need for more specific international regulations. The GEO communication satellites are shown to be the most likely to produce debris, and particular attention is given to the problem of wastes from manned space stations and the two main solutions proposed to deal with no-longer-functional spacecraft (destruction and removal to a safe space location). T.K.

A89-12107#
MAN-MADE SPACE DEBRIS - DATA NEEDED FOR RATIONAL DECISION
STEPHEN GOROVE (Mississippi, University, University; International Institute of Space Law, Paris, France) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 135-137. refs

This article starts with an emphasis on the growing risks arising from man-made space debris. It calls for a comprehensive study and review of essential data required for informed decision. The data relates not only to the various types of debris but also to the damage that each category of debris may cause and the likelihood of the latter's occurrence. The study and continuous assessment of the debris situation may be undertaken by an appropriate body of scientists, engineers and other professionals under UN auspices. Author

A89-12108#
SPACE POLLUTION
ALESIA MCCLOUD (Denver, University, CO) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 142-146. refs

This article identifies chemical, biological, and radiological pollution sources incidental to current and contemplated outer space exploration. It discusses their negative and unforeseen environmental impact. Then, it surveys international agreements addressing space pollution issues and concludes that they lack the specificity necessary to prevent such inadvertent environmental damage. It is recommended that the scope of these agreements be enlarged to encompass cumulative damage to the outer space environment, and to provide a means for seeking redress and reparation of harm to it. Also urged is the creation of an advisory board to monitor outer space pollution and establish international environmental standards and a separate international regulatory body to enforce those standards. Author

A89-12110#
ENVIRONMENTAL POLLUTION OF OUTER SPACE, IN PARTICULAR OF THE GEOSTATIONARY ORBIT
G. C. M. REIJNEN (Utrecht, Rijksuniversiteit, Netherlands) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 155-162. refs

The factors contributing to the space pollution are reviewed, and the international agreements intended to limit pollution and regulate the use of GEO slots and radio frequencies by communication satellites are discussed from a legal perspective. Topics examined include atmospheric pollution by launch vehicles, the general problem of space debris, the special problems of GEO satellites, the claims of equatorial countries to rights over GEO slots above their territory (and UN treaty provisions clearly denying such rights), radio pollution from GEO (and the overlapping jurisdictions of COPUOS and ITU in regulating it), contamination of other celestial bodies with earth materials, and back-contamination of the earth with extraterrestrial biological materials. Particular attention is given to the provisions of UN space treaties and their specific applicability. T.K.

A89-12576#
SURFACE EFFECTS OF SATELLITE MATERIAL OUTGASSING PRODUCTS
B. E. WOOD, W. T. BERTRAND, R. J. BRYSON, B. L. SEIBER (Calspan Corp., Arnold Air Force Station, TN), PATRICK FALCO, M. (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) et al. Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 2, Oct. 1988, p. 289-295. USAF-sponsored research. Previously cited in issue 19, p. 2974, Accession no. A87-43090. refs

A89-12662* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PIEZOELECTRIC POLYMER-BASED ISOLATION MOUNT FOR ARTICULATED POINTING SYSTEMS ON LARGE FLEXIBLE SPACECRAFT
SAMUEL W. SIRLIN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 613-627. refs
(AAS PAPER 87-456)

When a pointing system is attached to a large flexible body that is subject to continuous excitation, a mechanical isolator becomes a key element in achieving high performance. An active softmount based on the piezoelectric polymer poly (vinylidene fluoride) is considered here for use in a precision pointing system for Space Station. A finite element model of the softmount is developed and added to simple Space Station and payload models for performance analysis. Both linear frequency domain and nonlinear time domain simulations are carried out in order to demonstrate the wideband disturbance rejection capabilities of the design. Nonlinear geometric effects of large nodal deflections are also considered. Author

A89-13936
APPLICATIONS OF HIGH TEMPERATURE CHEMISTRY TO SPACE RESEARCH
EDMOND MURAD (USAF, Geophysics Laboratory, Hanscom AFB, MA) IN: Symposium on High Temperature Materials Chemistry - IV, Honolulu, HI, Oct. 19-23, 1987, Proceedings. Pennington, NJ, Electrochemical Society, Inc., 1988, p. 375-381. refs

This paper discusses the effect of exposure of a spacecraft to the ambient atmosphere of low earth orbits (250-400 km) on the materials of the spacecraft surface. The results of intentional and unintentional material experiments on the Space Shuttle are presented, indicating that the interactions between the surfaces and the low-orbit atmosphere leads to effects resembling those of high-temperature vaporization and oxidation, which can lead to erosion or mass gain in the exposed surfaces and can change the physical properties of the materials. The specific effects that these changes might have on various instruments and sensors on low earth orbit stations are discussed. I.S.

A89-15307
CONTAMINATION INDUCED DEGRADATION OF SOLAR ARRAY PERFORMANCE
DEAN C. MARVIN, WARREN C. HWANG, GRAHAM S. ARNOLD, and DAVID F. HALL (Aerospace Corp., Los Angeles, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 103-105.
(Contract F04701-85-C-0086)

The solar arrays on GPS Navastars 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/yr degradation in excess of the radiation-model estimates. Optical-solar-reflector data from a variety of spacecraft support the idea that contaminants outgassing from the vehicle are photodeposited on the optical surfaces, leading to degradation consistent with the observed behavior of the five Block I vehicles. Author

A89-17753#
A FINITE ELEMENT APPROACH FOR COMPOSITE SPACE STRUCTURES
R. BARBONI, P. GAUDENZI, and P. SANTINI (Roma I, Universita, Rome, Italy) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER 88-273)

A class of finite elements is developed to analyze laminated anisotropic plates for deflections, stresses, natural frequencies, and buckling loads. Particular attention is paid to accurate evaluation of strain field, especially transverse shear strain, due to the three-dimensional character of the problem. Several problems are studied, showing the effects of the aspect ratio and of the Young modulus to shear modulus ratio on bending, vibration, and stability of the plate. The numerical results are compared with those available by classical laminate theory. Author

A89-17758#
EXPERIMENTAL AND THEORETICAL ANALYSIS ON THE EFFECTS OF RESIDUAL STRESSES IN COMPOSITE STRUCTURES FOR SPACE APPLICATIONS
G. BABINI, D. STELLA (Contraves Italiana S.p.A., Rome, Italy), M. MARCHETTI, S. SGUBINI, and S. TIZZI (Roma I, Universita, Rome,

Italy) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 17 p. refs
(IAF PAPER 88-284)

The purpose of this study is the determination of the effects of the residual stresses arising in the manufacturing of a sandwich composite structure. A theoretical model, which provides the deformation field and the manufacturing rms error, is developed. The model is applied to a sandwich paraboloidic antenna reflector (core: aluminum alloy; skins: graphite-epoxy laminates) for space applications and it is verified by comparison with experimental test results. To this aim a high precision computerized three-dimensional bench (DEA type) has been employed. Author

A89-21080
APPLICATION OF COMPOSITE MATERIALS TO SPACE STRUCTURES
D. G. ZIMCIK (CDC, Communications Research Centre, Ottawa, Canada) (Canadian Engineering Centennial Convention, Montreal, Canada, May 1987) Canadian Society for Mechanical Engineering, Transactions (ISSN 0315-8977), vol. 12, no. 2, 1988, p. 49-56. refs

Material requirements for space structures are reviewed with emphasis on composite applications. Specific examples of the use of both polymer and metallic matrix composite in space structures are examined, and problems associated with environmental effects are discussed. The discussion also covers future trends in space structures and their implications for composite materials, as well as examples of current work in polymer and metal matrix composites aimed at satisfying the requirements for future space structures. V.L.

A89-21769* California Univ., Los Angeles.
BEAM-PLASMA INTERACTIONS IN SPACE EXPERIMENTS - A SIMULATION STUDY
P. L. PRITCHETT (California, University, Los Angeles) and R. M. WINGLEE (Colorado, University, Boulder) (Society of Geomagnetism and Earth, Planetary and Space Sciences, Inoue Foundation for Science and the Telecommunications Advancement, and URSI, Workshop on Active Experiments in Space, Kyoto, Japan, Oct. 19, 20, 1987) Journal of Geomagnetism and Geoelectricity (ISSN 0022-1392), vol. 40, no. 10, 1988, p. 1235-1256. refs
(Contract NAGW-78; NAGW-91; NSG-7287; NSF ATM-85-21125; F19628-88-K-0022; F19628-85-K-0027)

The plasma environment in the vicinity of a spacecraft during the injection of dense electron beams is studied using a two-dimensional, isolated-system electrostatic simulation model. The dependence of the beam stagnation time on the beam width and energy is examined. It is found that the relative size of the beam stagnation time and the ambient-plasma response time determines the environment of the spacecraft. The case of cross-field injection with beam stagnation time greater than plasma response time is discussed in detail. Also, the nature of the beam properties, plasma response, and wave spectra are considered. R.B.

A89-23415
ABLATION OF MATERIALS IN THE LOW-EARTH ORBITAL ENVIRONMENT
R. R. LAHER and L. R. MEGILL (Utah State University, Logan) Planetary and Space Science (ISSN 0032-0633), vol. 36, Dec. 1988, p. 1497-1507. Research supported by Morton Thiokol, Inc. refs

The ablation by atmospheric gas particles of materials exposed on the external ram surfaces of a spacecraft in LEO is examined. A physical sputtering model is used to estimate the physical sputtering rates of materials in LEO as a function of orbital altitude in the 100-1000 km range. It is found that the effects of physical sputtering range from significant mass loss after only a few months of exposure time for some materials to no observable effects after tens of years for other materials. Chemical sputtering rates by atomic oxygen and calculated physical sputtering rates are compared. The implications of this work for the Tethered Satellite System, the Space Station, and long-duration exposure facilities are discussed. R.B.

A89-23809
EXHAUST JET CONTAMINATION OF SPACECRAFT [STRAHLBEAUFSCHLAGUNG AN RAUMFAHRZEUGEN]
ROLF-D. BOETTCHER, CARL DANKERT, GEORG DETTLEFF, GEORG KOPPENWALLNER, and HUBERT LEGGE (DFVLR, Institut fuer experimentelle Stroemungsmechanik, Goettingen, Federal Republic of Germany) DFVLR-Nachrichten (ISSN 0011-4901), Nov. 1988, p. 8-11. In German.

The effects of exhaust jet contamination on spacecraft are studied, and methods of coping with them are considered. Models of the exhaust flow and of the contamination are described, and experimental investigations of such contamination are reviewed. Applications of the findings are addressed. C.D.

A89-23976#
PRELIMINARY EXPERIMENTS OF ATOMIC OXYGEN GENERATION FOR SPACE ENVIRONMENTAL TESTING
MICHIO NISHIDA (Kyoto University, Japan) and YASUO WATANABE (National Aerospace Laboratory, Chofu, Japan) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 31, Nov. 1988, p. 123-133. refs

Preliminary experiments of producing atomic oxygen for space environmental testing were conducted. To confirm the generation of O-atoms and to examine possibility of forming a molecular beam from the supersonic freejet, population densities of the electronic excitation levels 3p3 P and 3p5 P of atomic oxygen were measured along the freejet centerline. The results show that the population densities satisfied the low earth orbit conditions. Author

A89-24245#
MODEL FOR RADIATION CONTAMINATION BY OUTGASSING FROM SPACE PLATFORMS
STEPHEN J. YOUNG and RONALD R. HERM (Aerospace Corp., Infrared Sciences Dept., El Segundo, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Nov.-Dec. 1988, p. 413-419. Previously cited in issue 08, p. 1059, Accession no. A87-22416. refs
(Contract F04701-85-C-0086)

A89-24320#
SPREADING SPECTRUM OF REINFORCING FIBERS
ALAN S. BROWN Aerospace America (ISSN 0740-722X), vol. 27, Jan. 1989, p. 14-18.

A development status evaluation is presented for the range of commercially available and emerging fiber compositions that may be used as reinforcements in high-performance matrices to yield composites applicable to aerospace structures. Much recent development work has been prompted by the requirement for high service temperature metal-matrix and ceramic-matrix composites suitable for use in strongly oxidizing environments; SiC and alumina-based fibers have been produced to meet these requirements. For lower-temperature applications, such organic fibers as lightweight polyethylene, poly-paraphenylene benzbisoxazole, liquid-crystal polymers, polyvinyl alcohol, and polyimides are becoming available. O.C.

A89-26292
NDT OF COMPOSITE STRUCTURES USED IN SPACE APPLICATIONS
THOMAS C. KOSHY (ISRO, Vikram Sarabhai Space Centre, Trivandrum, India) IN: Composite materials and structures; Proceedings of the International Conference, Madras, India, Jan. 6-9, 1988. New Delhi, Tata McGraw-Hill Publishing Co., Ltd., 1988, p. 417-423. refs

The nondestructive testing of composite structures used in space applications is discussed. Particular attention is given to visual testing, liquid penetrants, radiography, high-frequency ultrasonics, low-frequency ultrasonics, the Fokker bond tester, IR thermography, beta radiations, holography, and acoustic emission.

It is found that, in some cases, it is necessary to use a combination of NDT techniques to successfully evaluate a composite structure. K.K.

A89-27864* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
LONG-LIFE/DURABLE RADIATOR COATINGS FOR SPACE STATION
STEVE JACOBS (NASA, Johnson Space Center, Houston, TX) and DONALD R. DUFFY (Acurex Corp., Mountain View, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p.
(SAE PAPER 881067)
The anodic coatings developed by anodizing specific aluminum alloys show considerable promise as long-life/durable radiator coatings. These coatings, formed by the sulfuric acid anodizing process, were the best performers of a variety of candidate coatings subjected to ultraviolet radiation and temperature-cycling tests. Author

A89-27883
MATERIAL COMPATIBILITY PROBLEMS FOR AMMONIA SYSTEMS
ELISABETH M. W. PINCHA, BARBARA L. HEIZER, and MICHAEL P. MCHALE (Boeing, Aerospace, Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p.
(SAE PAPER 881087)
Thermal management systems are currently being developed for application on large orbiting platforms, specifically the Space Station. Based upon its thermodynamic properties, ammonia was selected as a working fluid suitable to handle the power and heat rejection requirements of these systems. The Space Station's 30-year design life, minimum maintenance requirement, maximum reliability, and ammonia working fluid have led to new material compatibility issues. Although ammonia is a well understood fluid for ground-based refrigeration uses, it produced some unexpected results when applied to space-based heat transport systems. Author

A89-27916* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TESTING OF MATERIALS FOR PASSIVE THERMAL CONTROL OF SPACE SUITS
BERNADETTE SQUIRE (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p. refs
(SAE PAPER 881125)
An effort is underway to determine the coating material of choice for the AX-5 prototype hard space suit. Samples of 6061 aluminum have been coated with one of 10 selected metal coatings, and subjected to corrosion, abrasion, and thermal testing. Changes in reflectance after exposure are documented. Plated gold exhibited minimal degradation of optical properties. A computer model is used in evaluating coating thermal performance in the EVA environment. The model is verified with an experiment designed to measure the heat transfer characteristics of coated space suit parts in a thermal vacuum chamber. Details of this experiment are presented. Author

A89-28432
STRUCTURAL MATERIALS FOR FUTURE AEROSPACE DEVELOPMENTS [MATERIALES ESTRUCTURALES PARA LOS FUTUROS DESARROLLOS AEROESPACIALES]
JOSE A. GARCIA POGGIO (Congreso Nacional de Ingenieria Mecanica, 6th, Madrid, Spain, Dec. 15-18, 1987) Ingenieria Aeronautica y Astronautica (ISSN 0020-1006), no. 309, 1989, p. 8-20. In Spanish. refs
A comprehensive evaluation is presented of the state-of-the-art and prospective developments in high strength/weight and heat-resistant materials applicable to the primary and secondary airframe structures of such advanced aerospacecraft as those of tilt-rotor VTOL, high-altitude solar propulsion, SST, and hypersonic cruise type; large, complex satellites, OTVs, and the manned NASA Space Station are additional fields of application. The materials discussed are Al-Li alloys, ceramic fiber-reinforced metal-matrix composites, high service temperature Al-Cr-Fe alloys produced by vapor-phase condensation, mechanically alloyed Al alloys, ARALL laminates, and superalloys and ceramics for propulsion-system applications. O.C.

A89-29296* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
REACTION OF ATOMIC OXYGEN (O/3P/) WITH VARIOUS POLYMER FILMS
MORTON A. GOLUB and THEODORE WYDEVEN (NASA, Ames Research Center, Moffett Field, CA) (Canadian High Polymer Forum, 24th, Ottawa, Canada, Aug. 5-7, 1987) Polymer Degradation and Stability (ISSN 0141-3910), vol. 22, 1988, p. 325-338. refs
An attempt is made to obtain the etch rates for various polymer films exposed to O(3P) downstream from, and out of the glow of, the O2 plasma. These rates are compared with published values from the following sources: etching in the glow of an O2 plasma, the Space Shuttle STS-8 flight experiment, and beam experiments. The etch rate data for Kapton fit a logarithmic plot (with a positive slope) of the reaction probability versus O(3P) impact energy. K.K.

A89-29298* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ESCA STUDY OF KAPTON EXPOSED TO ATOMIC OXYGEN IN LOW EARTH ORBIT 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 Communications (ISSN 0263-6476), vol. 29, Oct. 1988, p. 285-288. refs
The ESCA spectra of Kapton polyimide film exposed to atomic oxygen O(3P), either in low earth orbit (LEO) on the STS-8 Space Shuttle or downstream from a radio-frequency oxygen plasma, were compared. The major difference in surface chemistry induced by the two types of exposure to O(3P), both of which caused surface recession (etching), was a much larger uptake of oxygen by Kapton etched in the O2 plasma than in LEO. This difference is attributed to the presence of molecular oxygen in the plasma reactor and its absence in LEO: in the former case, O2 can react with radicals generated in the Kapton molecule as it etches, become incorporated in the etched polymer, and thereby yield a higher steady-state 'surface oxidation' level than in LEO. Author

A89-30404
ELECTRON RADIATION EFFECTS ON MODE II INTERLAMINAR FRACTURE TOUGHNESS OF GFRP AND CFRP COMPOSITES
N. TAKEDA (Tokyo, University, Japan), M. TOHDOH, and K. TAKAHASHI (Kyushu University, Kasuga, Japan) SAMPE Quarterly (ISSN 0036-0821), vol. 20, Jan. 1989, p. 27-32. refs
The degradation properties of epoxy based fiber-reinforced plastics (FRP) composites irradiated by high-energy electrons were studied using the mode II interlaminar fracture toughness G(11c), measured by end-notched flexure tests. The radiation-induced degradation mechanisms were investigated through G(11c) and the scanning electron micrographs of fracture surfaces. For graphite FRP, the significant decrease in G(11c) was found. Debonding of glass fibers and epoxy matrix (or degradation of silane coupling agents) plays an important role in degradation in addition to resin degradation. Thus, the improvement of the radiation resistance of fiber-resin interfaces as well as matrix itself is of supreme importance in order to increase the radiation resistance of graphite FRP. For carbon FRP, on the other hand, no degradation in fiber-resin interfaces was found and the slight decrease in G(11c) seems to be due to the resin degradation. Author

A89-30715#
THERMAL DISTORTION BEHAVIOUR OF GRAPHITE REINFORCED ALUMINUM SPACE STRUCTURES
D. G. ZIMCIK (CDC, Communications Research Centre, Ottawa, Canada) and B. M. KOIKE (Composite Tecnologia, Sao Paulo, Brazil) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 632-639. refs
(AIAA PAPER 89-1228)
The thermal distortion of graphite reinforced aluminum is evaluated, and its performances is compared with that of graphite/epoxy. The analysis introduces the concept of the total thermal distortion coefficient (TTDC) which enables the optimization of laminate ply configuration for minimum thermal distortion. For graphite/aluminum laminates, minimum TTDC values are found to be constant with stacking angle, making it possible to satisfy stiffness or strength requirements with no thermal distortion penalty. A design approach using the TTDC coefficient to optimize material mechanical properties with minimum thermal distortion is presented and illustrated for the case of a large (15 x 1.5 m) slotted waveguide planar array SAR antenna. V.L.

A89-31525
VACUUM STRESSING TECHNIQUE FOR COMPOSITE LAMINATES INSPECTION BY OPTICAL METHOD
N. A. RUBAYI and S. H. LIEW (Southern Illinois University, Carbondale, IL) Experimental Techniques (ISSN 0732-8818), vol. 13, March 1989, p. 17-20. Research sponsored by the Southern Illinois University.
The application of the vacuum-stressing method is discussed as a nondestructive testing tool employed in conjunction with holographic interferometry for the detection of flaws and delaminations on or near the surface of composite laminates. Several eight-ply graphite/epoxy composite rectangular laminates were tested having unidirectional, cross-ply, and multiple-direction ply stacking sequences. The flaws made in the specimens were of either rectangular, equilateral, triangular, or circular shape. The effect of the shape, size, and location of the flaws on their detection and resulting fringe patterns was studied. The effect of the stacking sequence and ply orientation on flaw detection was also investigated. Three real-time holograms give representative results of the vacuum-stressing technique. S.A.V.

N89-10407*# Lockheed Missiles and Space Co., Sunnyvale, CA.
ADVANCED PLANAR ARRAY DEVELOPMENT FOR SPACE STATION Final Report
19 May 1987 68 p
(Contract NAS8-36419)
(NASA-CR-179372; NAS 1.26:179372) Avail: NTIS HC A04/MF A01 CSCL 10A
The objectives are to develop a process for manufacturing superstrate assemblies; demonstrate superstrate technology through fabrication and testing; develop and analyze a preliminary solar array wing design; and fabricate a wing segment based on the wing design. The task description, project flow diagram, and schedule are outlined. The progress to date is presented. Author

N89-10914*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
UTILIZATION OF SPRAY ON FOAM INSULATION FOR MANNED AND UNMANNED SPACECRAFT AND STRUCTURES
THOMAS M. HANCOCK, III *In its* The 1988 Get Away Special Experimenter's Symposium p 81 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22B
The idea of using spray-on foam insulation as a passive thermal and micrometeorite protection system is explored. The benefits of applying an exterior coating of foam insulation can be: (1) the foam can provide a thermally stable shield that can assist in reducing the strain on traditional space radiator systems and can also act as a passive thermal guard, allowing a greater fault tolerance if the standard system should fail; (2) the foam can act as an ablative shell diminishing the effects of natural and manmade debris striking the structure; (3) the foam is lightweight - about 1/2 ounce per sq ft; (4) the foam is low cost and easy to maintain; and (5) the foam is a stable material that does not react when exposed to earth or lunar environments. Author

N89-10932# Los Alamos National Lab., NM.
LABORATORY INVESTIGATIONS OF LOW EARTH ORBIT ENVIRONMENTAL EFFECTS ON SPACECRAFT
JON B. CROSS 1988 16 p Presented at the Uranium and Electricity: the Complete Nuclear Fuel Cycle, Saskatoon, Saskatchewan, 18 Sep. 1988
(Contract W-7405-ENG-36)
(DE88-009135; LA-UR-88-1229; CONF-880943-2) Avail: NTIS HC A03/MF A01
Operations in low earth orbit (100 to 500 km) must take into consideration the highly oxidative character of the environment. Partial pressures in the range of 10 to the 6th - 10 to the 7th torr of atomic oxygen are present which produces extensive oxidation of materials facing the direction of travel (ram direction). The ram oxidation is most severe not only because of the high flux (10 to the 15th O-atoms/s-sq cm) caused by the orbital velocity of the spacecraft but also because of the high collision energy of oxygen atoms with the ram surfaces (translational energy equivalent to approximately 60,000 K). Ground based simulation of these conditions has been accomplished using a CW laser sustained discharge source for the production of 1 to 5 eV beam of O-atoms with a flux of up to 10 to the 17th O-atoms/s-sq cm. The reactions of atomic oxygen with kapton, Teflon, silver, and various coatings have been studied. The oxidation of kapton has an activation energy of 2.3 Kcal/mole over the temperature range of 25 C to 100 C at a beam energy of 1.5 eV and produces low molecular weight gas phase reaction products (H2O, NO, CO2). Teflon reacts with approximately 0.1 to 0.2 efficiency to that of kapton at 25 C and both surfaces show a rug like texture after exposure to the O-atom beam. Angular scattering distribution measurements of O-atoms show a near cosine distribution from reactive surfaces indicating complete accommodation of the translational energy with the surface while a nonreactive surface (nickel oxide) shows specular like scattering with little accommodation (50 percent) of the translational energy with the surface. A technique for simple on orbit chemical experiments using resistance measurements coated silver strips is described. DOE

N89-10937# Physical Sciences, Inc., Andover, MA.
THE DETERMINATION OF THE SPACECRAFT CONTAMINATION ENVIRONMENT Final Report, 12 Sep. 1983 - 28 Feb. 1987
B. D. GREEN, W. T. RAWLINS, G. E. CALEDONIA, W. J. MARINELLI, and C. WHITE Oct. 1987 384 p
(Contract F19628-83-C-0139)
(AD-A196435; PSI-9139/TR-728; AFGL-TR-87-0303) Avail: NTIS HC A17/MF A01 CSCL 03/2
This report details our efforts in the determination of the on-orbit environment surrounding spacecraft. The research was performed for the Spacecraft Interactions Branch of the Space Physics Division of the Air Force Geophysics Laboratory. This report includes contributions from our subcontractors EKTRON Applied Imaging and Miranda Laboratories. The multilayer project consisted of three major tasks: a literature survey, preparation for the data of the Particle Analysis Cameras for Shuttle (PACS), and the analysis of the data to create a model of the orbital particulate environment. During the literature search we discovered that many observations were presented with little or no insight provided. Physical Sciences Inc. (PSI) therefore undertook a critical review of the data in an attempt to reconcile seemingly contractory observations and provide needed understanding of the variety of unexpected processes occurring above spacecraft surfaces in low-earth orbit. We were able to make contributions to the understanding of the neutral molecular contamination cloud; the modifications of the ionic environment; the optical contamination glow; and the earlier observations of particulates. GRA

N89-11776*# National Aeronautics and Space Administration, Washington, DC.
MATERIALS AND STRUCTURES
SAMUEL L. VENNERI *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 315-355 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information on materials and structures for use in space is given in viewgraph form. Information is given on the Materials and Structures Division of NASA's Office of Aeronautics and Space Technology. The Division's space research and development budget is given. Further information is given on space materials and structures, space environmental effects, radiation effects, high temperature materials research, metal matrix composites, SiC fiber reinforced titanium alloys, structural dynamics, and control of flexible structures. R.J.F.

N89-11823# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Structures and Mechanisms Div.
COMPOSITES DESIGN HANDBOOK FOR SPACE STRUCTURE APPLICATIONS, VOLUME 1
D. C. G. EATON Dec. 1986 462 p
(ESA-PSS-03-1101-ISSUE-1-VOL-1; ISSN-0379-4059; ETN-88-93161) Avail: NTIS HC A20/MF A01

Composite material properties and applications; calculation methods for laminates; and composites design aspects for ESA programs are presented. ESA

N89-11824# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Structures and Mechanisms Div.
COMPOSITES DESIGN HANDBOOK FOR SPACE STRUCTURE APPLICATIONS, VOLUME 2
D. C. G. EATON Dec. 1986 462 p
(ESA-PSS-03-1101-ISSUE-1-VOL-2; ISSN-0379-4059; ETN-88-93162) Avail: NTIS HC A20/MF A01

Load transfer and design of joints for composite structures; structural design; integrity control; verification guidelines; and manufacturing aspects for ESA programs are presented. ESA

N89-11910# Consiglio Nazionale delle Ricerche, Frascati (Italy). Ist. di Fisica dello Spazio Interplanetario.
OPERA PROJECT. VARNISHING AND BONDING OF THE SENSORS. ENGINEERING MODEL UNIT [PROGETTO OPERA VERNICIATURA E INCOLLAGGIO DEI SENSORI. UNITA MODELLO INGEGNERISTICO]
P. BALDETTI Jul. 1988 37 p Partly in DUTCH; ENGLISH; and ITALIAN
(IFSI-88-8; ETN-88-93475) Avail: NTIS HC A03/MF A01

The procedures for varnishing and adhesive bonding of the OPERA (plasma waves and auroral radiation) experiment are described. The varnishing shop installation included a 50C oven, compressed air, washing and ventilation units. The bonding is done with epoxy adhesive. The specifications of the materials used are included. ESA

N89-12206*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
HAZARDS PROTECTION FOR SPACE SUITS AND SPACECRAFT Patent Application
JOSEPH J. KOSMO, inventor (to NASA) and FREDERICK S. DAWN, inventor (to NASA) 30 Jun. 1988 16 p
(NASA-CASE-MSC-21366-1; NAS 1.71:MSC-21366-1; US-PATENT-APPL-SN-213880) Avail: NTIS HC A03/MF A01 CSCL 06/11

A flexible multi-layered covering for protection against the hazards of exposure to the environment of outer space is presented. The covering includes an outer layer section comprising an outmost lamina of woven expanded tetrafluorethylene yarns (Gore-Tex) for protecting against abrasion and tearing, an underlying weave of meta-aramid yarns (Nomex) and para-aramid yarns (Kevlar) for particle impact protection, an electrostatic charge dissipation and control system incoporated therein, and a chemical contaminants control barrier applied as a coating. A middle section includes a succession of thermal insulating layers of polymeric thermoplastic or thermoforming material, each of which is coated with a metal deposit of high infrared emissivity and low solar radiation absorption characteristics and separated from adjacent insulating layers by a low thermal conductance material. The covering includes a radiation attenuating layer of a tungsten-loaded polymeric elastomer binder for protecting against bremsstrahlung radiation and an inner layer of rip-stop polyester material for abrasion protection. A chloroprene coating may be supplied by polyester-material for added micrometeroid protection. Securing the means of low heat conductance material secures the multi-layers together as a laminar composite. NASA

N89-12589*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE NASA ATOMIC OXYGEN EFFECTS TEST PROGRAM
BRUCE A. BANKS, SHARON K. RUTLEDGE, and JOYCE A. BRADY *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 51-65 1988
Avail: NTIS HC A21/MF A01 CSCL 07/4

The NASA Atomic Oxygen Effects Test Program was established to compare the low earth orbital simulation characteristics of existing atomic oxygen test facilities and utilize the collective data from a multitude of simulation facilities to promote understanding of mechanisms and erosion yield dependence upon energy, flux, metastables, charge, and environmental species. Four materials chosen for this evaluation include Kapton HN polyimide, FEP Teflon, polyethylene, and graphite single crystals. The conditions and results of atomic oxygen exposure of these materials is reported by the participating organizations and then assembled to identify degrees of dependency of erosion yields that may not be observable from any single atomic oxygen low earth orbital simulation facility. To date, the program includes 30 test facilities. Characteristics of the participating test facilities and results to date are reported. Author

N89-12590*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MATERIALS SELECTION FOR LONG LIFE IN LEO: A CRITICAL EVALUATION OF ATOMIC OXYGEN TESTING WITH THERMAL ATOM SYSTEMS
S. L. KOONTZ, J. KUMINECZ, L. LEGER, and P. NORDINE *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 66-88 1988
Avail: NTIS HC A21/MF A01 CSCL 07/4

The use of thermal atom test methods as a materials selection and screening technique for low-Earth orbit (LEO) spacecraft is critically evaluated. The chemistry and physics of thermal atom environments are compared with the LEO environment. The relative reactivities of a number of materials determined to be in thermal atom environments are compared to those observed in LEO and in high quality LEO simulations. Reaction efficiencies measured in a new type of thermal atom apparatus are one-hundredth to one-thousandth those observed in LEO, and many materials showing nearly identical reactivities in LEO show relative reactivities differing by as much as a factor of 8 in thermal atom systems. A simple phenomenological kinetic model for the reaction of oxygen atoms with organic materials can be used to explain the differences in reactivity in different environments. Certain specific thermal test environments can be used as reliable materials screening tools. Using thermal atom methods to predict material lifetime in LEO requires direct calibration of the method against LEO data or high quality simulation data for each material. Author

N89-12591*# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
ATOMIC OXYGEN STUDIES ON POLYMERS
W. D. MORISON, R. C. TENNYSON, J. B. FRENCH, T.

BRAITHWAITE, M. MOISAN, and J. HUBERT (Montreal Univ., Quebec) *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 89-109 1988
(Contract N60921-86-C-A226; AUSPI-86-207; TP2-325)
Avail: NTIS HC A21/MF A01 CSCL 11/3

The purpose was to study the effects of atomic oxygen on the erosion of polymer based materials. The development of an atomic oxygen neutral beam facility using a SURFATRON surface wave launcher that can produce beam energies between 2 and 3 eV at flux levels as high as approx. 10 to the 17th power atoms/cm (2)-sec is described. Thin film dielectric materials were studied to determine recession rates and and reaction efficiencies as a function of incident beam energy and fluence. Accelerated testing was also accomplished and the values of reaction efficiency compared to available space flight data. Electron microscope photomicrographs of the samples' surface morphology were compared to flight test specimens. Author

N89-12592*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
ATOMIC OXYGEN EFFECTS ON CANDIDATE COATINGS FOR LONG-TERM SPACECRAFT IN LOW EARTH ORBIT
E. H. LAN, CHARLES A. SMITH, and J. B. CROSS (Los Alamos National Lab., N. Mex.) *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 110-121 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

Candidate atomic oxygen protective coatings for long-term low Earth orbit (LEO) spacecraft were evaluated using the Los Alamos National Laboratory O-atom exposure facility. The coatings studied include Teflon, Al2O3, SiO2, and SWS-V-10, a silicon material. Preliminary results indicate that sputtered PTFE Teflon (0.1 micrometers) has a fluence lifetime of 10 to the 19th power O-atoms/cm (2), and sputtered silicon dioxide (0.1 micrometers), aluminum oxide (0.1 micrometers), and SWS-V-10, a silicone, (4 micrometers) have fluence lifetimes of 10 to the 20th power to 10 to the 21st power O-atoms/cm (2). There are large variations in fluence lifetime data for these coatings. Author

N89-12617*# McDonnell-Douglas Corp., Huntington Beach, CA.
COMPARISON OF SULFURIC AND OXALIC ACID ANODIZING FOR PREPARATION OF THERMAL CONTROL COATINGS FOR SPACECRAFT
HUONG G. LE, JOHN M. WATCHER, and CHARLES A. SMITH *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 437-451 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

The development of thermal control surfaces, which maintain stable solar absorptivity and infrared emissivity over long periods, is challenging due to severe conditions in low-Earth orbit (LEO). Some candidate coatings are second-surface silver-coated Teflon; second-surface, silvered optical solar reflectors made of glass or quartz; and anodized aluminum. Sulfuric acid anodized and oxalic acid anodized aluminum was evaluated under simulated LEO conditions. Oxalic acid anodizing shows promise of greater stability in LEO over long missions, such as the 30 years planned for the Space Station. However, sulfuric acid anodizing shows lower solar absorptivity. Author

N89-12786* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRUSS-CORE CORRUGATION FOR COMPRESSIVE LOADS Patent
RANDALL C. DAVIS, inventor (to NASA) and ROBERT JACKSON, inventor (to NASA) 13 Sep. 1988 9 p Filed 5 Mar. 1987 Supersedes N87-25496 (25 - 19, p 2601)
(NASA-CASE-LAR-13438-1; US-PATENT-4,769,968; US-PATENT-APPL-SN-022298; US-PATENT-CLASS-52-814; US-PATENT-CLASS-52-821; US-PATENT-CLASS-428-182)
Avail: US Patent and Trademark Office CSCL 13/2

A corrugated panel structure for supporting compressive loads is described which includes curved cap strips separated by truss-core web segments. The truss-core web segments are formed from first and second flat panels with a corrugated filler in between them. The corrugated filler extends in the direction of the compressive load. As a result, all components of the panel structure have a compressive load carrying capability resulting in a high strength-to-weight ratio when the compressive load is limiting. Application to rocket and aircraft structures is suggested.
Official Gazette of the U.S. Patent and Trademark Office

N89-13504# Joint Publications Research Service, Arlington, VA.
CONTINUOUS FORMING OF CARBON/THERMOPLASTICS COMPOSITE BEAMS
YOSHIAKI SAKATANI, YASUHIRO YAMAGUCHI, and MIKINE YOSHIDA *In its* JPRS Report: Science and Technology. Japan: 12th Composite Materials Symposium p 22-25 23 Sep. 1988 Transl. into ENGLISH from Daijunikai Fukugo Zairyo Symposium (Koen Yoshishu), (Tokyo, Japan), 22-23 Oct. 1987 p 91-92
Avail: NTIS HC A05/MF A01

The continuous forming method of thin, long structural elements with a view to applications for future large-sized space structures is now being developed. Using a band plate shaped material of high elasticity type carbon fiber/PEEK, studies have been conducted on the basic processing conditions for passing it between rolls in stages and continuously forming it into a hat shape. Optimum forming conditions such as the optimum forming temperature and optimum speed have been ascertained by gaining an understanding of formability data on materials from the forming tests conducted by the basic testing machines and from quality evaluation of the formed materials. Author

N89-14331*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ATOMIC OXYGEN EFFECTS MEASUREMENTS FOR SHUTTLE MISSIONS STS-8 AND 41-G
JAMES T. VISENTINE, comp. Sep. 1988 94 p
(NASA-TM-100459-VOL-1; NAS 1.15:100459-VOL-1) Avail: NTIS HC A05/MF A01 CSCL 07/4

The effects of atomic oxygen exposure upon typical spacecraft materials, such as polyimide films, thermal control paints, epoxies, silicones, and fluorocarbons are summarized. B.G.

N89-14332*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ATOMIC OXYGEN EFFECTS MEASUREMENTS FOR SHUTTLE MISSIONS STS-8 AND 41-G
JAMES T. VISENTINE, comp. Sep. 1988 90 p
(NASA-TM-100459-VOL-2; NAS 1.15:100459-VOL-2) Avail: NTIS HC A05/MF A01 CSCL 07/4

The effects of the atomic oxygen interactions upon optical coatings, thin metallized films, and advanced spacecraft materials, such as high temperature coatings for infrared optical systems are summarized. Also included is a description of a generic model proposed by JPL, which may explain the atomic oxygen interaction mechanisms that lead to surface recession and weight loss.
B.G.

N89-14914*# College of William and Mary, Williamsburg, VA. Dept. of Chemistry.
RADIATION EFFECTS ON POLYMERIC MATERIALS Abstract Only
RICHARD L. KIEFER *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 72-74 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 11/3

It is important to study changes in properties of polymeres after irradiation with charged particles, with ultraviolet radiation, and with combinations of both. An apparatus for this purpose has been built at the NASA Langley Research Center. It consists of a chamber 9 inches in diameter and 9 inches high with a port for an electron gun, another port for a mass spectrometer, and a quartz window through which an ultraviolet lamp can be focused. The chamber, including the electron gun and the mass spectrometer, can be evacuated to a pressure of 10 to the 8th power torr. A sample placed in the chamber can be irradiated with electrons and ultraviolet radiation separately, sequentially, or simultaneously, while volatile products can be monitored during all irradiations with the mass spectrometer. The apparatus described above has been used to study three different polymer films: lexan; a polycarbonate; P1700, a polysulfone; and mylar, a polyethylene terephthalate. All three polymers had been studied extensively with both electrons and ultraviolet radiation separately, but not simultaneously. Also, volatile products had not been monitored during irradiation for the materials. A high electron dose rate of 530 Mrads/hr was used so that a sufficient concentration of volatile products would be formed to yield a reasonable mass spectrum. Author

N89-14921*# College of William and Mary, Williamsburg, VA. Dept. of Chemistry.

THE EFFECTS OF ATOMIC OXYGEN ON POLYMERIC MATERIALS Abstract Only

ROBERT A. ORWOLL *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 88-89 Sep. 1988

Avail: NTIS HC A07/MF A01 CSCL 11/3

At the altitudes of low-earth orbit (LEO), atomic oxygen (AO) is the most abundant chemical species. This strong oxidizing agent reacts with virtually any organic material that is not already fully oxidized. Erosion by AO can be extensive and jeopardizes any protective coatings, thermal blankets, adhesives, and structural composites exposed on the exterior of satellites in LEO. Researchers prepared and tested organic materials for their susceptibility to AO using a commercial plasma asher which approximately simulates the oxygen effects in LEO. Experiments were performed on a polyimide, a polysulfone, and two epoxy adhesives into which low molecular-weight additives have been dissolved. Incorporated in the molecular structure of these additives are elements such as silicon whose nonvolatile oxides, which are formed on exposure to AO, remain as a coating on the surface to create a barrier between the remainder of the organic material and the AO. We find that the additives protect the materials, but the low solubility of some limit their utility. Concurrent studies are underway to measure the effect of the additives on the thermal expansion coefficients of the materials. Tows of aramid fibers, which are important components in the proposed tether satellite systems, have been eroded in the asher. The results which show that the square root of the mass remaining decreases linearly with the time of exposure (see the figure) are consistent with a constant rate of surface erosion. The tensile strength of these eroded tows decreases with time of exposure also; additional measurements are in progress. Author

N89-15232*# Virginia Univ., Charlottesville. Dept. of Materials Science.

ENVIRONMENT ASSISTED DEGRADATION MECHANISMS IN ADVANCED LIGHT METALS Progress Report, 1 Jun. - 31 Dec. 1988

R. P. GANGLOFF, G. E. STONER, and R. E. SWANSON Jan. 1989 169 p

(Contract NAG1-7452)

(NASA-CR-181049; NAS 1.26:181049; UVA/528266/MS89/103)

Avail: NTIS HC A08/MF A01 CSCL 11/6

A multifaceted research program on the performance of advanced light metallic alloys in aggressive aerospace environments, and associated environmental failure mechanisms was initiated. The general goal is to characterize alloy behavior quantitatively and to develop predictive mechanisms for environmental failure modes. Successes in this regard will provide the basis for metallurgical optimization of alloy performance, for chemical control of aggressive environments, and for engineering life prediction with damage tolerance and long term reliability. B.G.

N89-15255*# College of William and Mary, Williamsburg, VA. Dept. of Chemistry.

SPACE ENVIRONMENTAL EFFECTS ON POLYMERIC MATERIALS Final Technicaal Report, 1 Jun. 1987 - 15 Jun. 1988

RICHARD L. KIEFER and ROBERT A. ORWOLL 1988 24 p

(Contract NAG1-678)

(NASA-CR-184648; NAS 1.26:184648) Avail: NTIS HC A03/MF A01 CSCL 11/2

Two of the major environmental hazards in the Geosynchronous Earth Orbit (GEO) are energetic charged particles and ultraviolet radiation. The charged particles, electrons and protons, range in energy from 0.1 to 4 MeV and each have a flux of 10 to the 8th sq cm/sec. Over a 30 year lifetime, materials in the GEO will have an absorbed dose from this radiation of 10 to the 10th rads. The ultraviolet radiation comes uninhibited from the sun with an irradiance of 1.4 kw/sq m. Radiation is known to initiate chain sission and crosslinking in polymeric materials, both of which affect their structural properties. The 30-year dose level from the combined radiation in the GEO exceeds the threshold for measurable damage in most polymer systems studied. Of further concern is possible synergistic effects from the simultaneous irradiation with charged particles and ultraviolet radiation. Most studies on radiation effects on polymeric materials use either electrons or ultraviolet radiation alone, or in a sequential combination. Author

N89-15792*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

ENVIRONMENTAL MONITORING FOR SPACE STATION WP01

J. M. ZWIENER *In its* Space Station Induced Monitoring p 5-12 Nov. 1988

Avail: NTIS HC A05/MF A01 CSCL 22/2

External contamination monitoring instrumentation for the Space Station work package one (WP01) elements, were imposed on the contractor as deliverable hardware. The monitoring instrumentation proposed by the WP01 contractor in response to the contract requirement includes both real time measurements and passive samples. Real time measurement instrumentation consists of quartz crystal microbalances for molecular deposition, ion gaseous species identification. Internal environmental contamination monitoring for particulates is included in both Lab and HAB modules. Passive samples consists of four sample mounting plates mounted external to the Space Station modules, two on the U.S. LAB, and two on the HAB module. Author

N89-15799*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

SPACE STATION SURFACE DEPOSITION MONITORING

E. R. MILLER *In its* Space Station Induced Monitoring p 51-57 Nov. 1988

Avail: NTIS HC A05/MF A01 CSCL 22/2

Quartz crystal microbalance sensors are recommended to verify and monitor surface deposition on the early transverse boom as well as the later dual-keel Space Station configurations. Performance and placement of these sensors are discussed and compared to imposed maximum mass deposition rate requirements at the science instrument and critical power locations. Additional measurements are suggested to gain further knowledge on properties of the deposited material. Author

N89-16193*# Ohio State Univ., Columbus. Dept. of Aeronautical and Astronautical Engineering.

A NOVEL APPROACH IN FORMULATION OF SPECIAL TRANSITON ELEMENTS: MESH INTERFACE ELEMENTS Status Report

NESRIN SARIGUL Jan. 1989 67 p

(Contract NAG3-790; RF PROJ. 765939/719301)

(NASA-CR-184768; NAS 1.26:184768) Avail: NTIS HC A04/MF A01 CSCL 20/11

The objective of this research is to develop more accurate and efficient advanced methods for solution of singular problems encountered in various branches of mechanics. The research

program includes the formulation of new class elements called Mesh Interface Elements (MIE) to connect meshes of traditional elements either in three dimensions or in three and two dimensions. The finite element formulations are based on the boolean sum and blending operators. In today's advanced aircraft and space structure applications, steep temperature and/or stress gradients are commonly encountered. The analysis methods need to incorporate these steep gradients into the solution efficiently and accurately. Mesh Interface Elements are formulated and tested to account for the steep gradient effects. At present, the heat transfer and structural analysis problems are formulated from uncoupled theory point of view. The status report, first, summarizes the general formulation for heat transfer and structural analysis by including the newly introduced varying material properties at material nodal points of the elements concept. The the formulation of mesh interface elements is detailed. On the computational efficiency side, a hidden-symbolic computation concept developed by the author is given. Verfication examples are included from the heat transfer and structural analysis problems. The appendix includes listings of the computer modules developed for this purpose.
Author

N89-18519# SRI International Corp., Menlo Park, CA. Electromagnatic Sciences Lab.
TRANSIENT PULSE MONITOR Report, No. 1, 30 Sep. 1986 - 30 Sep. 1987
JEFFREY S. THAYER, JOSEPH E. NANEVICZ, and DAVID R. DANA 20 May 1988 69 p
(Contract F19628-86-C-0231)
(AD-A201211; AFGL-TR-88-0147) Avail: NTIS HC A04/MF A01 CSCL 22/2

Designers of spacecraft and space systems must take into consideration the effects of the space environment to evolve designs capable of functioning satisfactorily in this environment. To achieve this goal, it is necessary to understand both the environment and the system's interactions with it. Sounding rockets and scientific satellites have been used to obtain information regarding the environment, and laboratory experiments and simulations have increased our understanding of the relevant interactions. This experimental work has been complemented by the development of analytical models that guide design evolution. Feedback from operational systems has been used to refine our understanding of the environment and its interactions with the systems and to verify the appropriateness and adequacy of design procedures. Periodically, events occur that require a special program of investigation. Such a program is the Interaction Measurements Payload for Shuttle (IMPS), which is responding to the confluence of two recent developments: current plans for large space structures, and recently available data regarding the polar orbital environment. Large space structures incorporating substantial areas of dielectric material and new generation solar cells are currently being planned. GRA

N89-18521# Rockwell International Corp., Seal Beach, CA. Satellite and Space Electronics Div.
ENVIRONMENTAL EFFECTS ON SPACECRAFT MATERIAL
J. W. HAFFNER, R. J. DEMPSEY, D. E. ANDERSON, and J. G. KELLEY May 1988 60 p
(Contract F19628-88-C-0008)
(AD-A202112; AFGL-TR-88-0128; SR-1) Avail: NTIS HC A04/MF A01 CSCL 22/2

A study of the present state of knowledge concerning the effects of the natural environments on spacecraft materials has been carried out. The study consisted of a literature review, a questionnaire mailing, and some follow-up facility visits. This is the report describing that study and the conclusions reached. At the present time, the effects due to single components of the space environment (radiations, plasmas, gases, particles, fields, etc.) are either well understood or are actively being investigated. Among the most active areas are atomic oxygen effects (erosion and glow), hot plasma charging, space debris object punctures, and nuclear radiation degradation of exposed materials. Some synergistic effects are also being studied. GRA

N89-19375 Salford Univ. (England).
HEAT TRANSFER PROPERTIES OF SATELLITE COMPONENT MATERIALS Ph.D. Thesis
STUART DONALD MCIVOR 1988 150 p
Avail: Univ. Microfilms Order No. BRD-83072

The thermal conductivities of samples of unidirectional fibre reinforced composites were measured both perpendicular to and parallel to the fibres. Two types of samples were measured, Fibredux 914 resin reinforced with R-Glass fibres, and Code 69 resin reinforced with GY80 carbon fibres. A model has been produced which can be used to predict the thermal conductivity of any rectangular unidirectional fibre reinforced composite lamina. The model was constructed using a method of finite difference analysis performed by a computer program written in FORTRAN. Three samples of Code 69 resin reinforced with GY70 carbon fibres were produced with their fibres aligned at 30, 45, and 60 deg to the horizontal and their thermal conductivities measured. In order to examine the accuracy of the model the values of the conductivities of these samples were compared with those calculated using the model. The heat transfer properties of thermal blankets used to insulate satellites were investigated. The heat flow across blankets, placed in a thermal vacuum chamber and subjected to similar temperature differentials as would be found in Earth orbit, was measured and the values for the effective thermal conductance and the effective emissivity of the blankets calculated. Dissert. Abstr.

N89-19385*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE EFFECTS OF SIMULATED SPACE ENVIRONMENTAL PARAMETERS ON SIX COMMERCIALLY AVAILABLE COMPOSITE MATERIALS
JOAN G. FUNK and GEORGE F. SYKES, JR. Apr. 1989 34 p
(NASA-TP-2906; L-16549; NAS 1.60:2906) Avail: NTIS HC A03/MF A01 CSCL 11/4

The effects of simulated space environmental parameters on microdamage induced by the environment in a series of commercially available graphite-fiber-reinforced composite materials were determined. Composites with both thermoset and thermoplastic resin systems were studied. Low-Earth-Orbit (LEO) exposures were simulated by thermal cycling; geosynchronous-orbit (GEO) exposures were simulated by electron irradiation plus thermal cycling. The thermal cycling temperature range was -250 F to either 200 F or 150 F. The upper limits of the thermal cycles were different to ensure that an individual composite material was not cycled above its glass transition temperature. Material response was characterized through assessment of the induced microcracking and its influence on mechanical property changes at both room temperature and -250 F. Microdamage was induced in both thermoset and thermoplastic advanced composite materials exposed to the simulated LEO environment. However, a 350 F cure single-phase toughened epoxy composite was not damaged during exposure to the LEO environment. The simuated GEO environment produced microdamage in all materials tested.
Author

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ASSEMBLY CONCEPTS

Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.

A89-10492
AUTOMATION AND ROBOTICS IN SPACE [AUTOMATION UND ROBOTIK IM WELTRAUM]
E. FREUND (Dortmund, Universitaet, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn,

Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 54-60. In German. refs
(DGLR PAPER 87-096)

The current status of robotics for space applications is surveyed and illustrated with diagrams and drawings, and strategies for future R&D efforts are examined with reference to the FRG Planning Framework for High Technology and Space Flight (OHR). The design structure of a typical manipulator system is outlined; the degree of robot control needed for different space missions (ranging from telepresence and teleoperation to fully autonomous operation) is discussed; and the control-theoretical problem of trajectory determination for three robots and one work platform in free flight is briefly considered. The key technologies to be developed within the OHR include lightweight intelligent sensor-guided manipulators, modular gripping systems and wide-application tools, improved man-machine interfaces, increased decision-making and planning capabilities via knowledge-based systems, and coordination of multiple-armed robots and multiple-robot configurations. T.K.

A89-10666
FUTURE DIRECTIONS IN SPACECRAFT MECHANISMS TECHNOLOGY
STUART H. LOEWENTHAL and W. E. LOMAS, II (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 453-465. refs
(SAE PAPER 872454)

This paper presents a reflective survey of recent developments in spacecraft mechanism technology, focussing on analytical tools, precision gimbal and robotics technologies. These topical areas were highlighted because they are good indicators where new mechanism technology is emerging. Today's mechanical dynamic simulation software permits routine solution of a large class of separation mechanism problems, yielding important time dependent, joint forces and motion information. The requirements for pointing multithousand kilogram scientific payloads to multiarc second levels aboard Space Station is extending gimbal technology. An innovative concept for isolating gimbal payloads from base motion disturbances is described. The goal of augmenting man's capability in space through robotics has virtually spawned a new industry. However, the transition between industrial and space robotic systems is not a particularly easy one, as discussed in this review. Author

A89-11688#
DYNAMICS OF A FLEXIBLE ORBITING PLATFORM WITH MRMS
Y. MORITA, H. YOKOTA (Tokyo, University, Japan), and V. J. MODI (British Columbia, University, Vancouver, Canada) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 631-646. refs

A relatively general formulation for studying the dynamics of a flexible Mobile Remote Manipulator System (MRMS), supported by an orbiting flexible platform, is developed using the Lagrangian approach, with generalized forces accounting for the environmental effects, damping, and control. The effectiveness of the general formulation is demonstrated by analyzing complex interactions between vibrational and librational degrees of freedom in the presence of MRMS maneuver over a range of system parameters and initial conditions. It is shown that translational and slewing maneuver of the MRMS substantially affects the librational response of the platform due to a shift in the center of mass and transient character of the inertia matrix. V.L.

A89-11714* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
EXPERT SYSTEM ISSSUES IN AUTOMATED, AUTONOMOUS SPACE VEHICLE RENDEZVOUS
MARY ANN GOODWIN (NASA, Johnson Space Center, Houston, TX) and DANIEL C. BOCHSLER (LinCom Corp., Houston, TX) IN: Applications of artificial intelligence V; Proceedings of the Meeting, Orlando, FL, May 18-20, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 71-78. refs

The problems involved in automated autonomous rendezvous are briefly reviewed, and the Rendezvous Expert (RENEX) expert system is discussed with reference to its goals, approach used, and knowledge structure and contents. RENEX has been developed to support streamlining operations for the Space Shuttle and Space Station program and to aid definition of mission requirements for the autonomous portions of rendezvous for the Mars Surface Sample Return and Comet Nucleus Sample return unmanned missions. The experience with REMEX to date and recommendations for further development are presented. V.L.

A89-11816* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
TELEROBOT EXPERIMENT CONCEPTS IN SPACE
LYLE M. JENKINS (NASA, Johnson Space Center, Houston, TX) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 92-94.

A unique set of problems will be encountered in the development of telerobotic systems for space applications such as the Flight Telerobotic System. The dexterous manipulation of objects in zero g will be significantly different. Issues arise from mechanical response and operator interaction with the controls and displays. To reduce development risk, a series of experiments are conceived for the Space Shuttle. Author

A89-11818* Carnegie-Mellon Univ., Pittsburgh, PA.
PLANNING ASSEMBLY/DISASSEMBLY OPERATIONS FOR SPACE TELEROBOTICS
ARTHUR C. SANDERSON and LUIZ HOMEM DE MELLO (Carnegie-Mellon University, Pittsburgh, PA) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 109-115. Research supported by the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico of Brazil, Carnegie-Mellon University, and NASA. refs

Space telerobotic systems will perform complex tasks of assembly, disassembly, and repair of space-based equipment. Planning such tasks requires reasoning about the functional, physical, and geometrical properties of the equipment, as well as a representation of the characteristics and capabilities of the manipulators and sensors available for the task. The And/Or graph is a useful approach to representation of feasible assembly/disassembly sequences and provides the basis for search among alternative strategies. The paper describes the use of parts entropy measures as evaluation criteria for search in the And/Or graph space. This approach leads to candidate task plans which minimize the complexity of intermediate geometrical states. Author

A89-11825* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
AUTOMATION AND ROBOTICS AND RELATED TECHNOLOGY ISSUES FOR SPACE STATION CUSTOMER SERVICING
HELMUT P. CLINE (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 161-168.

Several flight servicing support elements are discussed within the context of the Space Station. Particular attention is given to the servicing facility, the mobile servicing center, and the flight telerobotic servicer (FTS). The role that automation and robotics can play in the design and operation of each of these elements is discussed. It is noted that the FTS, which is currently being developed by NASA, will evolve to increasing levels of autonomy to allow for the virtual elimination of routine EVA. Some of the features of the FTS will probably be: dual manipulator arms having reach and dexterity roughly equivalent to that of an EVA-suited astronaut, force reflection capability allowing efficient teleoperation, and capability of operating from a variety of support systems. K.K.

A89-12026
REAL-TIME OBJECT DETERMINATION FOR SPACE ROBOTICS
GORDON T. UBER and MARK F. DOHERTY (Lockheed Digital Image Processing Laboratory, Palo Alto, CA) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 2. Washington, DC, Computer Society Press, 1988, p. 1320, 1321. refs

The successful creation of an autonomous space robot for on-orbit satellite servicing and inspection depends greatly upon the vision understanding subsystem. Off-the-shelf vision systems do not provide the three spatial and one temporal dimension modeling necessary for this complex task. Prior research has generally investigated the four-dimensional scene understanding problem at the expense of a true real-time capability. The authors have begun research at the Lockheed Digital Image Processing Laboratory on a space robot vision subsystem providing both a real-time processing and four-dimensional object determination. The authors describe their initial approach. I.E.

A89-15114
SPACE-CABIN ATMOSPHERE AND EVA [ATMOSPHERE D'UNE CABINE SPATIALE ET SORTIE EXTRA-VEHICULAIRE]
H. MAROTTE (Centre d'Essais en Vol, Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge, France) and M. WEIBEL (Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 131, 1988, p. 4-11. In French. refs

The conditions for aeroembolism formation are reviewed, and preventive measures are discussed with respect to pressure-suit and pressurization-system design. A discrepancy exists between the requirements for space cabin pressurization and EVA. Decompression sickness during EVA can be prevented by either direct denitrogenation or a mixed procedure. The EVA requirements of the Space Station dictate a pressure-suit pressure of 659 hPa, while the requirements of Hermes dictate a pressure of about 400-450 hPa. For the case of an emergency EVA pressure suit, the highest possible pressure is recommended as a means of preventing aeroembolism formation. R.R.

A89-15115
TASKS PROJECTED FOR SPACE ROBOTS AND AN EXAMPLE OF ASSOCIATED ORBITAL INFRASTRUCTURE [TACHES ENVISAGEES POUR LES ROBOTS SPATIAUX ET EXEMPLE D'INFRASTRUCTURE ORBITALE ASSOCIEE]
P. DUTTO (CNES, Toulouse, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 131, 1988, p. 12-20. In French.

Following a review of the orbital infrastructure projected up to the beginning of the 21st century, the application of robotics to manned and unmanned missions is discussed. Particular attention is given to the Space Station, MIR, the attached presurized module, Hermes, and Ariane V. The use of AI to increase the level of autonomy and automation of space systems is considered. Possible roles for robotic systems include routine activities on manned and unmanned space flights, the execution of dangerous tasks (such as those on platforms exposed to elevated radiation levels or those involving nuclear reactors), and probing on distant missions. R.R.

A89-16522*# Booz-Allen and Hamilton, Inc., Arlington, VA.
SPACE STATION ASSEMBLY SEQUENCE PLANNING - AN ENGINEERING AND OPERATIONAL CHALLENGE
JAMES T. KAIDY and WILLIAM G. BASTEDO (Booz-Allen and Hamilton, Inc., Reston, VA) AIAA, Space Programs and Technologies Conference, Houston, TX, June 21-24, 1988. 10 p. refs
(Contract NASW-4300)
(AIAA PAPER 88-3500)

This paper discusses the Space Station assembly sequence planning and development process. It presents the planning methodologies from both historial and current perspectives. It is shown that planning the assembly sequence is a new and unique challenge and its solution requires the simultaneous satisfaction of many diverse variables and constants. The considerations which influence the development of the assembly sequence include launch vehicle integration and lift capabilities, on-orbit assembly flight operations, vehicle flight dynamics, spacecraft system capabilities and resource availability. Many of these considerations are described in this paper. In addition, the examples presented demonstrate the current process for assembly sequence planning and show many of the complex trade-offs that must be performed. Author

A89-16523#
SPACECRAFT MODULE BERTHING USING TODAY'S TECHNOLOGY
STEWART W. JACKSON, ANTHONY P. MATTHEWS, and OSVALDO L. REGALADO (General Electric Co., Astro-Space Div., Princeton, NJ) AIAA, Space Programs and Technologies Conference, Houston, TX, June 21-24, 1988. 7 p.
(AIAA PAPER 88-3512-A)

An interface device, the intermodule connector (IMC), which will facilitate the on-orbit berthing and assembly of spacecraft modules using the remote manipulator system (RMS), has been developed. An IMC proof-of-concept test was carried out at the Johnson Space Center Manipulator Development Facility to validate the IMC concept and its compatibility with the RMS. The enhanced berthing latch IMC with the Y guide and trunnion alignment system was found to be the most promising near-term configuration for the IMC. K.K.

A89-16544#
SPACE STATION - GETTING MORE OUT OF EVA
FRED ABELES (Grumman Aerospace Corp., Bethpage, NY) Aerospace America (ISSN 0740-722X), vol. 26, Nov. 1988, p. 29, 30.

The NASA Space Station's EVA System will encompass an Extravehicular Mobility Unit (EMU), comprising space suit, life support system, and communications system, and the thruster-powered Manned Maneuvering Unit, mounted on the astronaut's back. An account is presently given of the differences between the Space Shuttle Orbiter and Space Station that have most significantly affected the design of the EMU. O.C.

A89-17659#
U.S. SPACE STATION FREEDOM - ORBITAL ASSEMBLY AND EARLY MISSION OPPORTUNITIES
DAVID C. WENSLEY (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 15 p.
(IAF PAPER 88-065)

The launch and assembly sequence and mission support capabilities of the man-tended and permanently manned modes of the Space Station are discussed. Launch packaging and construction in orbit, extravehicular activities associated with the Space Station, operational phases, mission opportunities, and payloads are examined. R.B.

A89-17750#
INTRODUCING INTELLIGENCE INTO STRUCTURES
KORYO MIURA (Tokyo, University, Japan) and SABURO MATUNAGA IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 11 p.
(IAF PAPER 88-267)

Intelligent truss structures to be assembled by AI-directed robotic means in orbit will, after sufficient development and optimization, be capable of arbitrarily changing their configuration and sensing their own internal geometry, while the assembly robot furnishes external-geometry data as well as the power required for structure actuators' operation. It is shown that the work space required by such a structure is different from that of a manipulator arm. Work space solutions are presented for continuous models and for general discrete models; the work spaces are oval-shaped. O.C.

A89-17845*# NASA Space Station Program Office, Reston, VA.
A SPACE STATION CREW RESCUE AND EQUIPMENT RETRIEVAL SYSTEM
RUDOLPH J. ADORNATO and RONALD A. BO (NASA, Space Station Freedom Program Office, Reston, VA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p.
(IAF PAPER 88-516)

This paper studies the possible use of a Space Station crew rescue and equipment retrieval system as a safeguard against the inadvertent separation of crew or equipment from the Space Station. The time to effect rescue and retrieval and the problem of crew separation are discussed. Alternate rescue/retrieval systems are evaluated. It is concluded that telerobotic vehicles provide the lowest cost rescue capability. R.B.

A89-18130*# Sterling Software, Palo Alto, CA.
AN EVALUATION OF INTERACTIVE DISPLAYS FOR TRAJECTORY PLANNING AND PROXIMITY OPERATIONS
ADAM R. BRODY (Sterling Software, Inc., Palo Alto, CA), STEPHEN R. ELLIS, ART GRUNWALD, and RICHARD F. HAINES (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 542-547.
(AIAA PAPER 88-3963)

Rendezvous, docking, and other Space Station proximity operations will be routine in nature in years to come. However, the specific parameters describing each maneuver, such as initial range and position, will vary from mission to mission so a means for depicting and interacting with graphic representations of proposed mission plans is necessary. Orbital operations are inherently non-intuitive due to non-linearities in the equations of motion of orbiting vehicles. Consequently, relative motion between two spacecraft cannot always be easily visualized. For these reasons, real time interactive visual aids and planning tools will be helpful, if not necessary, for future missions both in pre-flight training and on-orbit. Two such displays, Navie and eivaN, are currently available for examination and human factors testing. Since the docking tasks were fundamentally different with each device and because Navie imposed more constraints on the users than eivaN did, the orbital mechanics effects had a more pronounced effect on the Navie results. Author

A89-18136#
TELEROBOTICS (SUPERVISED AUTONOMY) FOR SPACE APPLICATIONS
W. S. OTAGURO, L. O. KESLER, and D. D. BEEBE (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 580-584.
(AIAA PAPER 88-3970)

This paper describes a telerobotic implementation as applied to autonomous guidance and control of platforms such as the Manned Maneuvering Unit (MMU), and mechanisms such as the Remote Manipulator System (RMS) using developed imaging tracker technology. With space qualified hardware such as the MMU and RMS which use cameras to monitor its operation under man's control, the approach adopted by MDAC used a developed imaging tracker system with enhanced positioning algorithms to provide the autonomous guidance and control of platforms and mechanisms. The modification of this imaging tracker into a robotic controller is presented. Its application to NASA's Extra-Vehicular Activity (EVA) retriever development and telerobotic operation is described. Author

A89-18316#
MAINTENANCE AND REPAIR ON SPACELAB
BYRON LICHTENBERG (Payload Systems, Inc., Wellesley, MA) and WILLIAM C. LEWIS (Grand Valley State University, Allendale; Research and Technology Institute, Grand Rapids, MI) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 4 p.
(AIAA PAPER 88-4739)

An effort is made to correct the paucity of basic and systematic consideration concerning the choice of spacecraft equipment that ought to be repaired, modified, or maintained in orbit; the choice of tools and astronaut training methods and goals hace also been neglected. The present discussion of the nature of maintenance and repair applies its conclusions to the various equipment classifications encompassed by Spacelab, in order to arrive at a systematic and rigorous first-principles approach. User, intermediate, and depot maintenance-categories are identified. O.C.

A89-18318*# Grumman Aerospace Corp., Bethpage, NY.
WORKSHOP IN THE SKY
LOUIS LEVOY, DONALD F. REIS (Grumman Corp., Grumman Aircraft Systems Div., Bethpage, NY), and ALBERTA QUINN (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 8 p.
(AIAA PAPER 88-4742)

An evaluation of the historical experience of Apollo, Skylab, and the Space Shuttle shows it to be both feasible and prudent to furnish a minimal capability for Space Station maintenance. The ability to perform orbital replacement unit-related maintenance, as well as opportune in-orbit repair, is believed to be essential for crew and Station survival, mission effectiveness, and maximum productivity. Attention is given to problems associated with mechanical repair, welding, and composite bonding, as well as to recommended tools and procedures. O.C.

A89-18321*# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
SPACE STATION MAINTENANCE CONCEPT STUDY
ERIC E. NELSON (NASA, Kennedy Space Center; McDonnell Douglas Astronautics Co., Cocoa Beach, FL) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 3 p.
(AIAA PAPER 88-4745)

The relationships among NASA Space Station operational constraints and logistical requirements are presently investigated. The concepts studied locate organizational, intermediate, and depot maintenance at the Space Station, at the Kennedy Space Center (KSC), and at a depot remote from the KSC. Measures of reliability, maintainability, and availability were selected; a life-cycle study was then conducted to ascertain the optimum Space Station system maintenance concept. The results obtained indicate that orbital replacement unit MTBFs should not be less than 36,000 hours. O.C.

A89-18322#
ON-ORBIT MAINTENANCE - A PERSPECTIVE
WALBERT G. MCCOY (U.S. Space Command, Peterson AFB, CO) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 4 p.
(AIAA PAPER 88-4746)

An evaluation is made of the requirements and events leading to the establishment of a space-based assembly/maintenance/servicing capability. The aggregate analysis that has been conducted, which treats the space logistics infrastructure as one consolidated group of requirements in order to define an integrated space-based system, is expected to yield cost-savings in both the development and operation of such programs as SDI satellites and the NASA Hubble Space Telescope through the identification of common requirements and potential supportability overlaps. O.C.

A89-19566* Lockheed Engineering and Management Services Co., Inc., Houston, TX.
REAL-TIME SIMULATION OF THE SPACE STATION MOBILE SERVICE CENTER
SEGUN THOMAS (Lockheed Engineering and Management Services Co., Inc., Houston, TX) IN: Aerospace simulation III; Proceedings of the SCS Multiconference, San Diego, CA, Feb. 3-5, 1988. San Diego, CA, Society for Computer Simulation International, 1988, p. 209-228. refs
(Contract NAS9-17900)
A method for building a generic N-joint simulation program is presented. It is shown that the multibody program can be operated in real time using a careful connection-array numbering scheme and a preprocessor. An example of a rigid manipulator on the Shuttle Orbiter was used to demonstrate the implementation technique. K.K.

A89-20112*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE FLIGHT TELEROBOTIC SERVICER PROJECT AND SYSTEMS OVERVIEW
HARRY G. MCCAIN and JAMES F. ANDARY (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: EASCON '88; Proceedings of the Twenty-first Annual Electronics and Aerospace Conference, Arlington, VA, Nov. 9-11, 1988. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 97-102. refs
As part of the Flight Telerobotic Servicer (FTS) project an advanced telerobotic system is being developed to assist in and reduce crew extravehicular activity (EVA) for the U.S. Space Station. The FTS will be used for assembly, maintenance, servicing, and inspection throughout the lifetime of the Space Station. A brief overview of the FTS program is given, and some of the technical and system engineering issues associated with the development of the FTS are explored. A key to the evolutionary capability of the FTS design is the NASREM (NASA Standard Reference Model for telerobot control system) architecture. This architecture provides the framework for future growth and permits a logical blend of teleoperation and autonomous operations as required. I.E.

A89-20113* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
GROUND OPERATION OF SPACE-BASED TELEROBOTS WILL ENHANCE PRODUCTIVITY
WAYNE R. SCHOBER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: EASCON '88; Proceedings of the Twenty-first Annual Electronics and Aerospace Conference, Arlington, VA, Nov. 9-11, 1988. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 103-105. refs
Due to the limited human resources which will be available on the U.S. Space Station, automation and robotics technologies are being developed to enhance the productivity on the Space Station. The need for space telerobots which can be operated from the ground is explored, taking into consideration the resulting time delay, the technology involved, and some currently planned experiments. The proposed experiments include a remote link with the Kennedy Space Center robotics laboratory and the Telerobot Intelligent Interface Flight Experiment (TRIIFEX). It is concluded that there is a need to develop and implement ground-remote telerobotics technology which can effectively operate in the time-delay environment. This capability will enable servicing operations in polar and geosynchronous orbits and assist EVA astronauts on the Space Station. I.E.

A89-20653#
SPACE ROBOT FOR JAPAN'S ORBIT
YOJI UMETANI (Tokyo Institute of Technology, Japan) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 3 p.
(AIAA PAPER 88-5003)
The basic policy for the development of space robots is discussed from the point of view of civilian space utlization of LEO. Technological problems are discussed and a definition of the stage and scenario is provided. Proposals are presented which include the Cosmo-lab project, earth-orbiting platform construction by the robot, and test facility construction for the robot. K.K.

A89-20654#
THE SPECIAL PURPOSE DEXTEROUS MANIPULATOR (SPDM) - A CANADIAN FOCUS FOR AUTOMATION AND ROBOTICS ON THE SPACE STATION
RICHARD C. HUGHES and DAVID G. HUNTER (National Research Council of Canada, Ottawa) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 8 p.
(AIAA PAPER 88-5004)
The development of the Special Purpose Dexterous Manipulator (SPDM) as part of the Mobile Servicing System for the Space Station is examined. The SPDM is a robot with two arms, an articulated body, and sophisticated vision, force sensing, and control systems. The robot operates in both teleoperated and semiautonomous modes. The functional requirements for assembly, restoration, consumable replenishment, temporary storage, and transportation support are presented. The program to develop technologies to meet these requirements is discussed. R.B.

A89-20655#
SPACE ROBOTICS IN JAPAN
MASAMI IKEUCHI (National Space Development Agency of Japan, Tokyo) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 7 p.
(AIAA PAPER 88-5005)
The current R & D status of Japanese Space Robotics and related activities is reviewed. The Japanese Experiment Module/Remote Manipulator System is described with attention given to the control mode and ground simulation. Research being conducted by NASDA on an advanced space robot to meet EVA requirements is described. A development scenario of the operational platforms and the servicing vehicles is presented. K.K.

A89-20656#
AIR FORCE SPACE AUTOMATION AND ROBOTICS - AN ARTIFICIAL INTELLIGENCE ASSESSMENT
THOMAS R. FERGUSON and MARK A. GERSH (USAF, Systems Command, Andrews AFB, MD) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 7 p.
(AIAA PAPER 88-5006)
Space applications requiring automation and robotics technology are discussed. The relationship between the Air Force and NASA is used to demonstrate the value of joint cooperation. Topics include mission requirements, technology challenges, Air Force initiatives, and future directions. K.K.

A89-20659#
TECHNOLOGICAL ACTIVITIES OF ESA IN VIEW OF THE ROBOTIC AND AUTOMATIC APPLICATION IN SPACE
I. BRAGA (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 11 p.
(AIAA PAPER 88-5010)
ESA activities related to robotics and automatic space applications are reviewed. The internal robotics systems for the Man-tended Free Flyer are discussed, including the central robot system, the manipulator arm, wrist, and end-effector subsystems, the movable manipulator base subsytem, and the multirack robot system. External robotics applications for the Hermes Robot Arm (HERA) are examined. The HERA tasks are outlined, and the

HERA structure, vision system, and control concept are described. Support facilities for robotics research are outlined, including simulators and demonstrators. R.B.

A89-20660*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

SPACE TELEROBOTS AND PLANETARY ROVERS

CARL F. RUOFF (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 21 p. refs

(AIAA PAPER 88-5011)

Space telerobots and planetary rovers are advanced forms of space automation that are being studied for missions beginning in the 1990s. This paper describes telerobots and planetary rovers, points out that pure autonomy is far beyond the state of the art, and goes on to discuss how useful, realizable telerobots and rovers can be developed in the context of human-machine systems. Telerobot and rover computational and architectural requirements are also briefly examined, and examples of current work, including the development of dedicated analog processing chips based upon neural networks are described. The paper closes with some speculations on the terrestrial implications of space robotics and some general conclusions. Author

A89-20835* Massachusetts Inst. of Tech., Cambridge.

MINIMIZATION OF SPACECRAFT DISTURBANCES IN SPACE-ROBOTIC SYSTEMS

ZIA VAFA and STEVEN DUBOWSKY (MIT, Cambridge, MA) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 91-108. refs

(Contract NAG1-489; NAG1-801)

(AAS PAPER 88-006)

Virtual manipulators for an arbitrary point of a real open chain space manipulator are presented. These virtual manipulators can be used to generate a disturbance map which can be used to select paths that reduce spacecraft disturbances. The present technique is applied to a simple two-link manipulator mounted on a free-floating spacecraft. K.K.

A89-21177* Jet Propulsion Lab., California Inst. of Tech., Pasadena.

NASA RESEARCH AND DEVELOPMENT FOR SPACE TELEROBOTICS

PAUL S. SCHENKER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) (California Institute of Technology, Workshop on Space Telerobotics, Pasadena, Jan. 1987) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Sept. 1988, p. 523-534. refs

The goal of this research is to explore and prove out robust concepts for telerobotic support of space servicing, assembly, maintenance, and telescience tasks. This goal is being addressed through a program of coordinated work in artificial intelligence, robotics, and human factors. The general research objective is the fusion of robot sensing and manipulation, teleoperation, and human and machine cognitive skills into an effective architecture for supervised task automation. NASA is evaluating results of this research program in a ground laboratory telerobot testbed under development at JPL. The testbed development activity includes integrated technology demonstrations. The demonstrations will show telerobot capabilities to perform tasks of increasing complexity, and duration in increasingly unstructured environments. The first such demonstration is the ground-based grappling, dockling, and servicing of a satellite taskboard. I.E.

A89-21178

HIERARCHICAL CONTROL OF INTELLIGENT MACHINES APPLIED TO SPACE STATION TELEROBOTS

J. S. ALBUS, R. LUMIA, and H. MCCAIN (NBS, Gaithersburg, MD) (California Institute of Technology, Workshop on Space Telerobotics, Pasadena, Jan. 1987) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Sept. 1988, p. 535-541. refs

A hierarchical architecture is described which supports space station telerobots in a variety of modes. The system is divided into three hierarchies: task decomposition, world model, and sensory processing. Goals at each level of the task decomposition hierarchy are divided both spatially and temporarily into simpler commands for the next lower level. This decomposition is repeated until, at the lowest level, the drive signals to the robot actuators are generated. To accomplish its goals, task decomposition modules must often use information stored in the world model. The purpose of the sensory system is to update the world model as rapidly as possible to keep the model in registration with the physical world. The architecture of the entire control system hierarchy and how it can be applied to space telerobot applications are discussed. I.E.

A89-21179* California Univ., Berkeley.

TELEROBOTICS - PROBLEMS AND RESEARCH NEEDS

LAWRENCE STARK, FRANK TENDICK, WON SOO KIM, RUSSELL ANDERSON, MICHAEL HISEY (California, University, Berkeley) et al. (California Institute of Technology, Workshop on Space Telerobotics, Pasadena, Jan. 1987) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Sept. 1988, p. 542-551. Research supported by NASA. refs

With major emphasis on simulation, a university laboratory telerobotics facility permits problems to be approached by groups of graduate students. Helmet-mounded displays provide realism; the slaving of the display to the human operator's viewpoint gives a sense of 'telepresence' that may be useful for prolonged tasks. Using top-down three-dimensional model control of distant images allows distant images to be reduced to a few parameters to update the model used for display to the human operator in a preview mode to circumvent, in part, the communication delay. Also, the model can be used as a format for supervisory control and permit short-term local autonomous operations. Image processing algorithms can be made simpler and faster without trying to construct sensible images from the bottom. Control studies of telerobots lead to preferential manual control modes and basic paradigms for human motion and thence, perhaps, to redesign of robotic control, trajectory path planning, and rehabilitation prosthetics. I.E.

A89-21187

TASK PLANNING FOR ROBOTIC MANIPULATION IN SPACE APPLICATIONS

A. C. SANDERSON, M. A. PESHKIN, and L. S. HOMEM DE MELLO (Carnegie-Mellon University, Pittsburgh, PA) (California Institute of Technology, Workshop on Space Telerobotics, Pasadena, Jan. 1987) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Sept. 1988, p. 619-629. refs

Space-based robotic systems will require novel technologies of planning and manipulation to accomplish complex tasks such as diagnosis, repair, and assembly. This paper reviews recent results on task representation, discrete task planning, and control synthesis which provide a design environment for assembly systems, and which extend to the planning of manipulation operations in unstructured environments. In this approach, assembly planning is carried out using the AND/OR graph representation which encompasses all possible partial orders of operations and may be used to plan assembly sequences. A novel algorithm for planning disassembly and repair using the AND/OR graph is introduced, and examples of repair sequences generated for a satellite electrical module are described. For discrete task planning, the configuration map facilitates search over discrete parameters in the space of bounded configuration sets. I.E.

A89-21403

EVA SAFETY [SECURITE DES ACTIVITES SPATIALES EXTRA-VEHICULAIRES]

J. LALOE (Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 132, 1988, p. 23-30. In French.

The applications, risks, and safety objectives of EVA are discussed. Goals of EVA safety include protecting the astronaut from external hazards such as radiation and debris, controlling the internal space-suit environment, and assuring the physical and psychological health of the astronaut. Other factors considered include the mobility and dexterity of digits and limbs, EVA locomotion, the mother-vessel/space-suit interface, and EVA procedures such as prebreathing prior to partial depressurization and airlock tests. R.R.

A89-23537* Texas A&M Univ., College Station.
DISPARITY CODING - AN APPROACH FOR STEREO RECONSTRUCTION
N. C. GRISWOLD and W. B. BELL (Texas A & M University, College Station) IN: Digital and optical shape representation and pattern recognition; Proceedings of the Meeting, Orlando, FL, Apr. 4-6, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 109-119.
(Contract NAG9-192)

As the possibility of stereo-controlled robots becomes a reality, the need to transmit the stereo pair of images to a ground station or space station for man-in-the-loop supervision will be a necessity. The complexity of transmitting stereo images by coding the preprocessed disparity is presently discussed. The approach demonstrates the quantization, modulation, and reconstruction of the stereo images. Results indicate the accuracy of reconstruction in terms of mean-square-error criterion as a function of the signal-to-noise ratio. Key research issues of interpolation from sparse disparity maps and reconstruction of the stereo pairs in the presence of spatial noise are presented. It is concluded that stereo reconstruction is possible, and the noise constraints are given. Author

A89-25333*#
OPPORTUNITIES FOR SPACE STATION ASSEMBLY OPERATIONS DURING CREW ABSENCE
JOSEPH C. PARRISH (Ocean Systems Engineering, Inc., Falls Church, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by Ocean Systems Engineering, Inc. refs
(Contract NASW-4300)
(AIAA PAPER 89-0398)

Prior to Permanently Manned Capability (to be achieved approximately 21 months after the First Element Launch), the Space Station will be manned for less than 10 percent of its total staytime on orbit. The most intensive and critical Station assembly operations will occur during these early flights. Some robotic resources may be available to perform assembly operations while the Station crew is absent; however, the use of robotic devices for assembly operations during unmanned phases has not yet been adopted by the Space Station program. This paper studies the relevant aspects of teleoperated and autonomous assembly activities, and presents candidate assembly operations that could be performed during crew absence. From this analysis, the potential benefits of remote control of robotic resources can be weighed against any associated increase in cost and complexity that would accompany implementation of this capability. Author

A89-25625*# Computer Technology Associates, Inc., Lanham, MD.
MIL-C-38999 ELECTRICAL CONNECTOR APPLICABILITY TESTS FOR ON-ORBIT EVA SATELLITE SERVICING
THOMAS J. GRIFFIN (Computer Technology Associates, Inc., Lanham, MD) and RUTHAN LEWIS (NASA, Goddard Space Flight Center, Greenbelt, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0860)

MIL-C-38999 electrical connectors were tested for their applicability to the on-orbit EVA satellite servicing environment. The investigation provided a methodical approach to the evaluation of the human-machine interface of these connectors. The physical characteristics of thirty-five MIL-C-38999 connectors were tested in two simulated space environments, the NASA Johnson Space Center Weightless Environment Training Facility and an evacuated glovebox which incorporated the Extravehicular Maneuvering Unit series 3000 gloves. Physical characteristics of the connectors were documented, including operating torque and work profiles. STS crewmembers tested a select group of connectors in two WETF test and subjectively ranked the G&H PMM Wing-Tab connectors as most applicable to the on-orbit servicing environment. WETF performance times indicated that the G&H PMM Wing-Tab connector had the fastest operating time. The evacuated glovebox participants ranked the G&H 64600 Wing-Tab and the G&H PMM Wing-Tab connectors as those most applicable to the on-orbit servicing environment. During the evacuated glovebox tests, the G&H 64600 Wing-Tab connector had the fastest operating time. Author

A89-26382#
THE TECHNIQUES OF MANNED ON-ORBIT ASSEMBLY
LEON B. WEAVER (Weaver Enterprises, Aptos, CA) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 85-95.

The activities required to design, test, place, and activate large space systems are discussed, focusing on the manned on-orbit assembly of space systems. The development of the assembly process, the selection of a specific design solution, and the use of EVA simulations and analysis are considered. The requirements for valid manned EVA simulations are outlined. The major simulation mediums are examined, including one-G, neutral buoyancy, zero-G, and reduced-G atmospheric flight. R.B.

A89-26968* Cubic Corp., San Diego, CA.
TARGET ACQUISITION AND TRACK IN THE LASER DOCKING SENSOR
TED J. CLOWES (Cubic Corp., Defense Systems Div., San Diego,CA) and RICHARD F. SCHUMA (Cubic Corp., Electro-Optical Div., Teterboro, NJ) IN: Sensor fusion; Proceedings of the Meeting, Orlando, FL, Apr. 4-6, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 143-148.
(Contract NAS9-17846)

A sensor designed to aid in the docking of spacecraft is under development for NASA. This sensor uses three lasers to track the prospective target and to determine the required parameters necessary to calculate the ideal approach maneuver. The system combines the inputs from several sensors, including polarization, continuous tone DME, and a CID to achieve the desired results. Author

A89-27836* Rockwell International Corp., Downey, CA.
NODES PACKAGING OPTION FOR SPACE STATION APPLICATION
KENNETH T. SO (Rockwell International Corp., Downey, CA) and JOHN B. HALL, JR. (NASA, Langley Research Center, Hampton, VA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 6 p.
(SAE PAPER 881035)

Space Station nodes packaging analyses are presented relative to moving environmental control and life support system (ECLSS) equipment from the habitability (HAB) module to node 4, in order to provide more living space and privacy for the crew, remove inherently noisy equipment from the crew quarter, retain crew waste collection and processing equipment in one location, and keep objectionable odor away from the living quarters. In addition, options for moving external electronic equipment from the Space Station truss to pressurized node 3 were evaluated in order to reduce the crew extravehicular-activity time required to install and maintain the equipment. Node size considered in this analysis is 3.66 m in diameter and 5.38 m long. The analysis shows that significant external electronic equipment could be relocated from the Space Station truss structure to node 3, and nonlife critical ECLSS HAB module equipment could be moved to node 4. Author

A89-27857* Rockwell International Corp., Downey, CA.
SPACE STATION EVA TEST BED OVERVIEW
RICHARD G. STINSON (Rockwell International Corp., Downey, CA) and MICHAEL E. MONTZ (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 19 p. refs
(SAE PAPER 881060)

Current testing activities, testbed design goals, and future plans to support extravehicular activities (EVAs) of the Space Station are discussed. Developments include: (1) regenerative systems for carbon dioxide provision and removal; (2) increased space suit pressure to minimize prebreathe time; and (3) improved operational efficiencies for the extravehicular mobility units. Much novel technology will undergo integration to constitute the Space Station EVA System. A.A.F.

A89-27858* Life Systems, Inc., Cleveland, OH.
ELECTROCHEMICALLY REGENERABLE METABOLIC CO2 AND MOISTURE CONTROL SYSTEM FOR AN ADVANCED EMU APPLICATION
M. C. LEE (Life Systems, Inc., Cleveland, OH), P. S. BECKSTROM (Rockwell International Corp., Houston, TX), and R. J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p. refs
(Contract NAS9-17307)
(SAE PAPER 881061)

Regenerable CO2 and moisture removal techniques that reduce expendables and logistics requirements are needed to sustain people undertaking extravehicular activities for the Space Station. NASA has been investigating ways to advance the Electrochemically Regenerable CO2 and Moisture Absorption (ERCA) technology to replace the nonregenerable solid lithium hydroxide absorber for the advanced Portable Life Support System (PLSS). The ERCA technology, due to its use of liquid absorbent, has the ability to effectively satisfy the high metabolic CO2 and moisture removal requirements of PLSS applications. This paper defines the ERCA technology concept and its advantages for the PLSS application, reviews breadboard and subscale testdata and presents the results of design concepts for a prototype Absorber Module of improved performance and the physical characteristics of the projected flight hardware. Author

A89-27859* United Technologies Corp., Windsor Locks, CT.
DEVELOPMENT OF AN ADVANCED SOLID AMINE HUMIDITY AND CO2 CONTROL SYSTEM FOR POTENTIAL SPACE STATION EXTRAVEHICULAR ACTIVITY APPLICATION
TIMOTHY A. NALETTE, ROBERT W. BLASER (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT), WESLEY D. COLEMAN (Rockwell International Corp., Space Transportation Systems Div., Downey, CA), and ROBERT J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p. refs
(SAE PAPER 881062)

A system for removing metabolic carbon dioxide and water vapor from breathing air within a space suit during NASA Space Station EVA is discussed. The solid amine compound used is packed within a water-cooled metal foam matrix heat-exchanger to remove the exothermic heat of chemical reaction. Details of the design of a canister for humidity and carbon dioxide control and performance of the system are presented. A.A.F.

A89-27860* United Technologies Corp., Windsor Locks, CT.
A NONVENTING COOLING SYSTEM FOR SPACE ENVIRONMENT EXTRAVEHICULAR ACTIVITY, USING RADIATION AND REGENERABLE THERMAL STORAGE
STEPHEN A. BAYES (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT), LUIS A. TREVINO (NASA, Johnson Space Center, Houston, TX), and CRAIG E. DINSMORE (Rockwell International Corp., Pittsburgh, PA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p.
(SAE PAPER 881063)

This paper outlines the selection, design, and testing of a prototype nonventing regenerable astronaut cooling system for extravehicular activity space suit applications, for mission durations of four hours or greater. The selected system consists of the following key elements: a radiator assembly which serves as the exterior shell of the portable life support subsystem backpack; a layer of phase change thermal storage material, n-hexadecane paraffin, which acts as a regenerable thermal capacitor; a thermoelectric heat pump; and an automatic temperature control system. The capability for regeneration of thermal storage capacity with and without the aid of electric power is provided. Author

A89-27862* Grumman Aerospace Corp., Bethpage, NY.
DEVELOPMENT OF AN AUTOMATED CHECKOUT, SERVICE AND MAINTENANCE SYSTEM FOR A SPACE STATION EVAS
FRED J. ABELES (Grumman Corp., Space Station Program Support Div., Bethpage, NY), TERRY TRI (NASA, Johnson Space Center, Houston, TX), and ROBERT BLASER (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p.
(SAE PAPER 881065)

The development of a new operational system for the Space Station will minimize the time normally spent on performing on-orbit checkout, servicing, and maintenance of an extravehicular activity system of the Space Station. This system, the Checkout, Servicing, and Maintenance System (COSM), is composed of interactive control software interfacing with software simulations of hardware components. The major elements covered in detail include the controller, the EMU simulator and the regenerative life support system. The operational requirements and interactions of the individual elements as well as the protocols are also discussed. A.A.F.

A89-27867
OXYGEN TOXICITY DURING FIVE SIMULATED EIGHT-HOUR EVA EXPOSURES TO 100 PERCENT OXYGEN AT 9.5 PSIA
J. T. WEBB, R. M. OLSON, R. W. KRUTZ, JR. (Krug International, San Antonio, TX), G. A. DIXON, and P. T. BARNICOTT (USAF, School of Aerospace Medicine, Brooks AFB, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p. refs
(Contract F33615-85-C-4503)
(SAE PAPER 881071)

A study was conducted to determine if oxygen toxicity occurs in a proposed extravehicular activity (EVA) pressure suit environment. Twelve male subjects were exposed to 100 percent oxygen at 9.5 psia for five consecutive days, 8 h/day, while performing moderate exercise. No decompression sickness or venous gas bubbles were detected. Pulmonary function tests, physical exams, blood analyses, arterial oxygen saturation monitoring, and X-rays showed no evidence of oxygen toxicity. These results suggest that a 100 percent oxygen, 9.5 psia pressure suit environment could avoid both decompression sickness and oxygen toxicity during EVAs of comparable duration and physical activity. Author

A89-27868
PHYSIOLOGICAL EFFECTS OF REPEATED DECOMPRESSION AND RECENT ADVANCES IN DECOMPRESSION SICKNESS RESEARCH - A REVIEW
PAUL A. FURR (Grumman Corp., Space Systems Div., Bethpage, NY) and WILLIAM J. SEARS (Aerospace Associates, Inc., Saint Louis, MO) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 7 p. refs
(SAE PAPER 881072)

The objective of this paper is to review the intermediate or long-term physiological effects which may develop on spacecrew members who engage in repetitive EVAs and their subsequent effects on EVA performance, with particular concern for future Space Station activities. The potential for decompression sickness

(DCS) is further affected by a variety of environmental effects that cause physiological change during exposure to spaceflight. A literature review is then given which outlines the effects of repeated exposure to subatmospheric pressures on DCS symptomatology, with attention given to studies indicating increased susceptibility to DCS and studies indicating no change or decreased susceptibility to DCS. A brief discussion about data as regards metabolic changes that occur during decompression to subatmospheric pressures concludes the paper. S.A.V.

A89-27884
APPLICATIONS OF MAN-SYSTEMS INTEGRATION STANDARDS TO EVA
CHARLES W. GEER (Boeing Aerospace, Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p.
(SAE PAPER 881089)

The NASA Man-Systems Integration Standards (MSIS) are examined, focusing on the implications of the standards for EVA and human engineering. The process used to develop these standards and the MSIS documents and data base are described. The discussion of EVA design considerations and requirements in the MSIS documents is reviewed, including physiology, anthropometry, workstations and restraints, mobility and translation, enhancement systems, and tools, fasteners, and connectors. Also, the distribution, implementation, and maintenance of the standards are considered. R.B.

A89-27885
EVA EQUIPMENT DESIGN - HUMAN ENGINEERING CONSIDERATIONS
H. T. FISHER (Lockheed Missiles and Space Co., Inc., Astronautics Div., Sunnyvale, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p.
(SAE PAPER 881090)

The Space Station presents a plethora of human factors engineering opportunities. In particular, design for the space suited EVA crewperson is critical from aspects including: safety, ease of task conduct, timeline reductions, risk elimination, and productivity enhancement. This paper will address the human factors engineering effort undertaken to aid in the early-on design of the Space Station structure, with particular emphasis on structural assembly operations. Author

A89-27886* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE RECOVERY AND UTILIZATION OF SPACE SUIT RANGE-OF-MOTION DATA
AL REINHARDT (NASA, Ames Research Center, Moffett Field, CA) and JAMES S. WALTON SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p. refs
(SAE PAPER 881091)

A technique for recovering data for the range of motion of a subject wearing a space suit is described along with the validation of this technique on an EVA space suit. Digitized data are automatically acquired from video images of the subject; three-dimensional trajectories are recovered from these data, and can be displayed using three-dimensional computer graphics. Target locations are recovered using a unique video processor and close-range photogrammetry. It is concluded that such data can be used in such applications as the animation of anthropometric computer models. A.A.F.

A89-27887* Sterling Software, Palo Alto, CA.
MEASUREMENT OF METABOLIC RESPONSES TO AN ORBITAL-EXTRAVEHICULAR WORK-SIMULATION EXERCISE
RENEE LANTZ (Sterling Software, Inc., Palo Alto, CA) and BRUCE WEBBON (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs
(SAE PAPER 881092)

This paper describes a new system designed to simulate orbital EVA work and measure metabolic responses to these space-work exercises. The system incorporates an experimental protocol, a controlled-atmosphere chamber, an EVA-work exercise device, the instrumentation, and a data acquisition system. Engineering issues associated with the design of the proposed system are discussed. This EVA-work simulating system can be used with various types of upper-body work, including task boards, rope pulling, and arm ergometry. Design diagrams and diagrams of various types of work simulation are included. I.S.

A89-27893* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT OF THE NASA ZPS MARK III 57.2-KN/SQ M (8.3 PSI) SPACE SUIT
JOSEPH J. KOSMO, WILLIAM E. SPENNY (NASA, Johnson Space Center, Houston, TX), ROB GRAY, and PHIL SPAMPINATO (ILC Dover, Frederica, DE) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 23 p.
(SAE PAPER 881101)

The zero-prebreathe Mark III, 8.3-psi EVA-capable space-suit assembly represents a significant evolutionary development stage toward the creation of an operational space-suit system for the NASA Space Station Program. The unique implementation of the Ortman cable coupling arrangement allows rapid assembly and disassembly of major suit component hardware; this will in turn facilitate on-orbit maintainability and resizing operations. Advanced thermal/micrometeoroid garment-type protection features were investigated in anticipation of Space Station construction-related EVA hazards, and duly incorporated in the final Mark III suit design. O.C.

A89-27894* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT OF HIGHER OPERATING PRESSURE EXTRAVEHICULAR SPACE-SUIT GLOVE ASSEMBLIES
JOSEPH J. KOSMO (NASA, Johnson Space Center, Houston, TX), JOHN BASSICK (David Clark Co., Inc., Worcester, MA), and KIM PORTER (ILC Dover, Frederica, DE) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p.
(SAE PAPER 881102)

Longer space flights and the advent of extravehicular (EV) operations required drastic improvements in the areas of comfort and mobility, and the incorporation of an EV-hazards protective coverlayer. The current advanced glove designs represent a series of evolutionary engineering efforts aimed at systematically improving higher operating pressure EV glove performance capabilities. Glove design complexity increases with the differential pressure between the glove and the vacuum of space and with the EV activity mobility task requirements. Current space-suit glove design activities associated with the development of candidate higher operating pressure (57.2 kN/sq m) glove assemblies are described. Author

A89-27895* Grumman Aerospace Corp., Bethpage, NY.
THE DEVELOPMENT OF A TEST METHODOLOGY FOR THE EVALUATION OF EVA GLOVES
JOHN M. O'HARA (Grumman Space Systems, Bethpage, NY), JOHN CLELAND, and DAN WINFIELD (Research Triangle Institute, Research Triangle Park, NC) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs
(Contract NAS9-17702)
(SAE PAPER 881103)

This paper describes the development of a standardized set of tests designed to assess EVA-gloved hand capabilities in six measurement 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 measurement domain were developed to provide a comprehensive evaluation. All tests were designed to be conducted in a glove box with the bare hand as a baseline and the EVA glove at operating pressure. Author

A89-27896* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

A SIMULATION SYSTEM FOR SPACE STATION EXTRAVEHICULAR ACTIVITY

JOSE A. MARMOLEJO (NASA, Johnson Space Center, Houston, TX) and CHARLES K. SHEPHERD, JR. SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p.
(SAE PAPER 881104)

A simulation program has been developed which addresses the human factors required to provide a crewmember with productive information during Space Station EVA. The operation of the voice recognition and control system and helmet-mounted projection display in the Space Station Extravehicular Mobility Unit (EMU) is reviewed. The features of the simulation program are discussed, including logic flow, information types, and the man-machine interface techniques used in the simulation program, voice recognizer, and helmet-mounted display. R.B.

A89-27906

EUROPEAN SPACE SUIT SYSTEM BASELINE

NIKOLAUS HERBER and ROLAND VAETH (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 15 p.
(SAE PAPER 881115)

This paper provides a description of the current European Space Suit System (ESSS) status. The ESSS is foreseen for servicing of various elements of space infrastructure within typical operational scenarios based on Hermes. As a result of different EVA studies, the ESSS concept has been defined and structured in three modules: the EVA Suit Enclosure Module (ESEM), the EVA Life Support Module (ELSM), and the EVA Information and Communication Module (EICM). The main portion of the description herein is provided for the ELSM, since this module has been studied in more detail up to now in comparison with the ESEM and the EICM. Author

A89-28216* Grumman Aerospace Corp., Bethpage, NY.

PLANNING FOR ORBITAL REPAIRS TO THE SPACE STATION AND EQUIPMENT

HARRY S. HABER (Grumman Corp., Integrated Logistics Support Dept., Bethpage, NY) and ALBERTA QUINN (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 12 p. refs
(SAE PAPER 881446)

This paper summarizes an extensive study that was performed to establish a baseline for tools, materials, and repair techniques that will be needed for an astronaut to repair structures in an orbital environment, with a view towards future on-orbit repairs to the Space Station. The study program confirmed the premise that repairs must and can be made by astronauts while in an orbital environment. Scenarios for both welding repair and composite repair techniques are presented, along with a discussion of human factors considerations. A Space Station maintenance work station module is described, followed by a discussion of the Neutral Buoyancy Simulator test facility used to evaluate crew work performance in zero g conditions. S.A.V.

A89-28628

PERFORMANCE IN ADAPTIVE MANIPULATOR CONTROL

GUNTER NIEMEYER and JEAN-JACQUES E. SLOTINE (MIT, Cambridge, MA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1585-1591. Research supported by the Perry Foundation. refs
(Contract NSF MSM-88-03767; N00014-86-K-0685; N00015-85-K-0214)

The authors explore the performance issues linked to the effective implementation of adaptive manipulator controllers. Specifically, they detail issues of computational efficiency and recursive implementation, the treatment of closed chains, and minimal parameterizations. The authors also discuss extensions to interactions with mobile environments, whole-arm adaptive manipulation, adaptive impedance control, and adaptive control of spacecraft and space manipulators. The development is illustrated experimentally on a four-degree-of-freedom articulated robot arm, and suggests that the range of application of adaptive tracking controllers may extend well beyond adaptation to grasped loads. I.E.

A89-29110

REPORT OF RESEARCH FORUM ON SPACE ROBOTICS AND AUTOMATION: EXECUTIVE SUMMARY

YOJI UMETANI, KAZUYA YOSHIDA (Tokyo Institute of Technology, Japan), YOSHIAKI OKAMI (National Aerospace Laboratory, Tokyo, Japan), MASARU UCHIYAMA (Tohoku University, Sendai, Japan), TSUTOMU IWATA (National Space Development Agency of Japan, Tokyo) et al. Research supported by the National Space Development Agency of Japan. Tokyo, Japan Space Utilization Promotion Center, 1988, 37 p.

A NASDA report on Japanese policies concerning space robotics and automation development is summarized. A scenario in which orbiting robots construct and operate space structures is presented and the element technologies needed to realize the scenario are discussed. Recommendations for Japanese policy are given, focusing on three project proposals: the construction of space structures using robots, the development of a space experiment module, and the creation of ground-based testing facilities for the performance evaluation and verification of space robots. R.B.

A89-29654#

PATCHING UP THE SPACE STATION

MARTIN N. GIBBINS and PAUL H. STERN (Boeing Aerospace, Seattle, WA) Aerospace America (ISSN 0740-722X), vol. 27, March 1989, p. 32, 33.

The emergency procedures for the repair of punctures in the Space Station pressure-wall seal are outlined. Several repair patch designs are described. Special repair tools with tether attachment ring and Velcro-lined handles are discussed. Also, the processes for cleaning and marking the repaired puncture are considered. Preliminary results from laboratory and simulation tests of these procedures are presented. R.B.

A89-30771#

AN ATTEMPT TO INTRODUCE INTELLIGENCE IN STRUCTURES

KORYO MIURA (Tokyo, University, Kanagawa, Japan) and SABURO MATUNAGA IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1145-1153. refs
(AIAA PAPER 89-1289)

The potential of intelligent structure is explored by studying a specific scenario whereby a large structure is constructed by assembling free-flying linear multilink intelligent structures using a robot. The intelligence of the structures includes: the ability to change their configuration arbitrarily and the ability of sensing their own geometry; the robot provides information on the external geometry of the structures and the power to operate the structures. Some problems arising with the use of intelligent structures and their possible solutions are briefly discussed. V.L.

A89-31076* Heer Associates, Inc., LaCanada, CA.

MACHINE INTELLIGENCE AND AUTONOMY FOR AEROSPACE SYSTEMS

EWALD HEER, ED. (Heer Associates, Inc., La Canada, CA) and

HENRY LUM, ED. (NASA, Ames Research Center, Moffett Field, CA) Washington, DC, American Institute of Aeronautics and Astronautics, Inc. (Progress in Astronautics and Aeronautics. Volume 115), 1988, 369 p. For individual items see A89-31077 to A89-31091.

The present volume discusses progress toward intelligent robot systems in aerospace applications, NASA Space Program automation and robotics efforts, the supervisory control of telerobotics in space, machine intelligence and crew/vehicle interfaces, expert-system terms and building tools, and knowledge-acquisition for autonomous systems. Also discussed are methods for validation of knowledge-based systems, a design methodology for knowledge-based management systems, knowledge-based simulation for aerospace systems, knowledge-based diagnosis, planning and scheduling methods in AI, the treatment of uncertainty in AI, vision-sensing techniques in aerospace applications, image-understanding techniques, tactile sensing for robots, distributed sensor integration, and the control of articulated and deformable space structures. O.C.

A89-31077*# Heer Associates, Inc., LaCanada, CA.
TOWARD INTELLIGENT ROBOT SYSTEMS IN AEROSPACE
EWALD HEER (Heer Associates, Inc., La Canada, CA) and HENRY LUM (NASA, Ames Research Center, Moffett Field, CA) IN: Machine intelligence and autonomy for aerospace systems. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 1-13. refs

The incorporation of progressively more autonomous capabilities in spacecraft has been made possible by advancements in electronics technologies for sensors, communication, and computing equipment; as a result, space missions have been able to cope with ever-increasing complexity and data throughputs, as demonstrated by the six-order-of-magnitude increase in planetary mission data rates. In order to continue this pace of development into the Space Station era, NASA has accelerated its R&D in automation and robotics, with emphasis on autonomous, knowledge-based and expert system-employing technologies and AI. O.C.

A89-31078#
MANDATE FOR AUTOMATION AND ROBOTICS IN THE SPACE PROGRAM
DAVID R. CRISWELL (Universities Space Research Association, La Jolla, CA) IN: Machine intelligence and autonomy for aerospace systems. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 15-30. refs

The U.S. Congress has been so concerned about the role of automation and robotics (A&R) technologies in the NASA Space Station that NASA's Advanced Technology Advisory Committee has been directed to report on progress made on the implementation of its 13-point April 1, 1985 recommendations. One NASA objective pursuant to this A&R development thrust has been the enhancement of personnel and procedures' sophistication on A&R-related matters to the point where only the most dynamically technology-driving design requirements for the Space Station will be countenanced. Attention has also been given to prospective A&R technology spinoffs in the rest of the U.S. economy. Author

A89-31608
THE HELMET-MOUNTED DISPLAY AS A TOOL TO INCREASE PRODUCTIVITY DURING SPACE STATION EXTRAVEHICULAR ACTIVITY
C. K. SHEPHERD, JR. (Lockheed Engineering and Sciences Co., Houston, TX) IN: Human Factors Society, Annual Meeting, 32nd, Anaheim, CA, Oct. 24-28, 1988, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1988, p. 40-43. refs

The human factors issues related to the helmet-mounted displays (HMDs) designed for the information system of the Space Station Extravehicular Mobility Unit are discussed. The amount and type of information that must be presented by the HMD and the physical capabilities of a suited astronaut are examined. A voice-interactive rapid prototyping system used to simulate and evaluate the use of the HMD in EVA is described. It is concluded that the HMD is safe for use in Space Station EVA. R.B.

A89-31760
ABOVE THE PLANET - SALYUT EVA OPERATIONS
NEVILLE KIDGER Spaceflight (ISSN 0038-6340), vol. 31, March 1989, p. 102-105.

EVA operations on the Salyut station between August 1979 and November 1983 are reviewed. The first unscheduled EVA on the station, the removal of a jammed radio telescope dish, is discussed. Other operations include the collection of samples of organic compounds and metals as part of external experiments and the installation of solar panels. R.B.

N89-10087*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SPACE TRUSS ASSEMBLY USING TELEOPERATED MANIPULATORS
WALTER W. HANKINS, III, RANDOLPH W. MIXON, HOWARD C. JONES, and THOMAS W. BURGESS (Oak Ridge National Lab., Tenn.) *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 18 p 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Teleoperator experiments were conducted which have demonstrated that a realistic, complex task, typical of those accomplished on-orbit by EVA astronauts, can be done in a smooth, timely manner with manipulators remotely controlled by humans. The real concerns were: (1) do manipulators have sufficient dexterity for these tasks, (2) can sufficient information from the remote site be provided to permit adequate teleoperator control, (3) can reasonable times relative to EVA times be achieved, (4) can the task be completed without frequent and/or damaging impacts among the task components and the manipulators? Positive answers were found to all of these concerns. Tasks times, operator fatigue, and smoothness of operation could be improved by designing the task components and the manipulators for greater compatibility. The data recorded supplements a data base of performance metrics for the same task done in the water immersion training facility as well as space flight and provides management with an objective basis for deciding how and where to apply manipulators in space. Author

N89-10089*# Grumman Aerospace Corp., Bethpage, NY.
OPEN CONTROL/DISPLAY SYSTEM FOR A TELEROBOTICS WORK STATION
SAUL KESLOWITZ *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 21 p 1987
Avail: NTIS HC A99/MF E03 CSCL 05H

A working Advanced Space Cockpit was developed that integrated advanced control and display devices into a state-of-the-art multimicroprocessor hardware configuration, using window graphics and running under an object-oriented, multitasking real-time operating system environment. This Open Control/Display System supports the idea that the operator should be able to interactively monitor, select, control, and display information about many payloads aboard the Space Station using sets of I/O devices with a single, software-reconfigurable workstation. This is done while maintaining system consistency, yet the system is completely open to accept new additions and advances in hardware and software. The Advanced Space Cockpit, linked to Grumman's Hybrid Computing Facility and Large Amplitude Space Simulator (LASS), was used to test the Open Control/Display System via full-scale simulation of the following tasks: telerobotic truss assembly, RCS and thermal bus servicing, CMG changeout, RMS constrained motion and space constructible radiator assembly, HPA coordinated control, and OMV docking and tumbling satellite retrieval. The proposed man-machine interface standard discussed has evolved through many iterations of the tasks, and is based on feedback from NASA and Air Force personnel who performed those tasks in the LASS. Author

N89-10097*# Little (Arthur D.), Inc., Cambridge, MA.
ROBOT HANDS AND EXTRAVEHICULAR ACTIVITY
BETH MARCUS *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 16 p 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Extravehicular activity (EVA) is crucial to the success of both current and future space operations. As space operations have evolved in complexity so has the demand placed on the EVA crewman. In addition, some NASA requirements for human capabilities at remote or hazardous sites were identified. One of the keys to performing useful EVA tasks is the ability to manipulate objects accurately, quickly and without early or excessive fatigue. The current suit employs a glove which enables the crewman to perform grasping tasks, use tools, turn switches, and perform other tasks for short periods of time. However, the glove's bulk and resistance to motion ultimately causes fatigue. Due to this limitation it may not be possible to meet the productivity requirements that will be placed on the EVA crewman of the future with the current or developmental Extravehicular Mobility Unit (EMU) hardware. In addition, this hardware will not meet the requirements for remote or hazardous operations. In an effort to develop ways for improving crew productivity, a contract was awarded to develop a prototype anthromorphic robotic hand (ARH) for use with an extravehicular space suit. The first step in this program was to perform a a design study which investigated the basic technology required for the development of an ARH to enhance crew performance and productivity. The design study phase of the contract and some additional development work is summarized. Author

N89-10100*# RCA Astro-Electronics Div., Princeton, NJ. Space Div.
KINEMATIC STUDY OF FLIGHT TELEROBOTIC SERVICER CONFIGURATION ISSUES
R. H. LEWIS, R. D. SCOTT, and W. S. HOWARD *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 17 p 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Several factors, such as body size and shape, and the number of arms and their placement, will influence how well the Flight Telerobotic Servicer (FTS) is suited to its potential duties for the Space Station Program. In order to examine the implications of these configuration options, eight specific 2, 3, and 4 armed FTS configuration were simulated and used to perform a Space Station Orbital Replacement Unit (ORU) exchange. The strengths and weaknesses of each configuration were evaluated. Although most of the configurations examined were able to perform the exchange, several of the 3 and 4 arm configurations had operational advantages. The results obtained form these simulations are specific to the assumptions associated with the ORU exchange scenario examined. However, they do illustrate the general interrelationships and sensitivities which need to be understood. Author

N89-10916*# California Polytechnic State Univ., San Luis Obispo. Space Systems Space Welding Project.
THE POTENTIAL OF A GAS CAN WITH PAYLOAD G-169
DAVID TAMIR *In* NASA, Goddard Space Flight Center, The 1988 Get Away Special Experimenter's Symposium p 89-96 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22A

The feasibility of using welding for the construction, expansion and emergency repair of space based structures is discussed and the advantages of gas tungsten arc welding (GTAW) over other welding techniques are briefly examined. The objective and design concept for the G-169 Get Away Special payload are described. The G-169 experiment will allow the comparison of a space GTA welded joint with a terrestrial GTA welded joint with all parameters held constant except for gravitational forces. Specifically, a bead-on-plate weld around the perimeter of a 2 inch diameter stainless steel pipe section will be performed. The use of Learjet microgravity simulation for the G-169 and other Get Away Special experiments is also addressed. M.G.

N89-11237*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE-BASED MULTIFUNCTIONAL END EFFECTOR SYSTEMS FUNCTIONAL REQUIREMENTS AND PROPOSED DESIGNS
A. H. MISHKIN and B. M. JAU 15 Apr. 1988 119 p
(Contract NAS7-918)
(NASA-CR-180390; JPL-PUBL-88-16; NAS 1.26:180390) Avail: NTIS HC A06/MF A01 CSCL 13/9

The end effector is an essential element of teleoperator and telerobot systems to be employed in space in the next decade. The report defines functional requirements for end effector systems to perform operations that are currently only feasible through Extra-Vehicular Activity (EVA). Specific tasks and functions that the end effectors must be capable of performing are delineated. Required capabilities for forces and torques, clearances, compliance, and sensing are described, using current EVA requirements as guidelines where feasible. The implications of these functional requirements on the elements of potential end effector systems are discussed. The systems issues that must be considered in the design of space-based manipulator systems are identified; including impacts on subsystems tightly coupled to the end effector, i.e., control station, information processing, manipulator arm, tool and equipment stowage. Possible end effector designs are divided into three categories: single degree-of-freedom end effectors, multiple degree of freedom end effectors, and anthropomorphic hands. Specific design alternatives are suggested and analyzed within the individual categories. Two evaluations are performed: the first considers how well the individual end effectors could substitute for EVA; the second compares how manipulator systems composed of the top performers from the first evaluation would improve the space shuttle Remote Manipulator System (RMS) capabilities. The analysis concludes that the anthropomorphic hand is best-suited for EVA tasks. A left- and right-handed anthropomorphic manipulator arm configuration is suggested as appropriate to be affixed to the RMS, but could also be used as part of the Smart Front End for the Orbital Maneuvering Vehicle (OMV). The technical feasibility of the anthropomorphic hand and its control are demonstrated. An evolutionary development approach is proposed and approximate scheduling provided for implementing the suggested manipulator systems in time for space stations operations in the early 1990s. Author

N89-11775*# National Aeronautics and Space Administration, Washington, DC.
HUMANS IN SPACE
JAMES P. JENKINS *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 305-314 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information is given in viewgraph form on humans in space. Information is given on extravehicular activity/space suit project objectives and program schedule, and space human factors objectives and products. R.J.F.

N89-12199*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
STEREO DEPTH DISTORTIONS IN TELEOPERATION
DANIEL B. DINER and MARIKA VONSYDOW 15 May 1988 57 p
(Contract NAS7-918)
(NASA-CR-180242; JPL-PUB-87-1-REV-1; NAS 1.26:180242)
Avail: NTIS HC A04/MF A01 CSCL 05/8

In teleoperation, a typical application of stereo vision is to view a work space located short distances (1 to 3m) in front of the cameras. The work presented here treats converged camera placement and studies the effects of intercamera distance, camera-to-object viewing distance, and focal length of the camera lenses on both stereo depth resolution and stereo depth distortion.

While viewing the fronto-parallel plane 1.4 m in front of the cameras, depth errors are measured on the order of 2cm. A geometric analysis was made of the distortion of the fronto-parallel plane of divergence for stereo TV viewing. The results of the analysis were then verified experimentally. The objective was to determine the optimal camera configuration which gave high stereo depth resolution while minimizing stereo depth distortion. It is found that for converged cameras at a fixed camera-to-object viewing distance, larger intercamera distances allow higher depth resolutions, but cause greater depth distortions. Thus with larger intercamera distances, operators will make greater depth errors (because of the greater distortions), but will be more certain that they are not errors (because of the higher resolution). Author

N89-12595*# Control Dynamics Co., Huntsville, AL.
THE FLIGHT ROBOTICS LABORATORY
PATRICK A. TOBBE, MARLIN J. WILLIAMSON, and JOHN R. GLAESE *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 158-167 1988
(Contract NAS8-36570)
Avail: NTIS HC A21/MF A01 CSCL 14/2

The Flight Robotics Laboratory of the Marshall Space Flight Center is described in detail. This facility, containing an eight degree of freedom manipulator, precision air bearing floor, teleoperated motion base, reconfigurable operator's console, and VAX 11/750 computer system, provides simulation capability to study human/system interactions of remote systems. The facility hardware, software and subsequent integration of these components into a real time man-in-the-loop simulation for the evaluation of spacecraft contact proximity and dynamics are described. Author

N89-12596*# Control Dynamics Co., Huntsville, AL.
SPACE STATION DOCKING MECHANISM DYNAMIC TESTING
THOMAS G. HOWSMAN and JOHN R. GLAESE *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 168-175 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

A prototype docking mechanism for the Space Station was designed and fabricated for NASA. This docking mechanism is actively controlled and uses a set of electromechanical actuators for alignment and load attenuation. Dynamic tests are planned using the Marshall Space Flight Center's 6-DOF Motion Simulator. The proposed tests call for basic functionality verification as well as complete hardware-in-the-loop docking dynamics simulations. Author

N89-12621* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION ERECTABLE MANIPULATOR PLACEMENT SYSTEM Patent
MARGARET E. GRIMALDI, inventor (to NASA) 20 Sep. 1988 7 p Filed 13 Nov. 1986 Supersedes N87-18596 (25 - 11, p 1446)
(NASA-CASE-MSC-21096-1; US-PATENT-4,772,175; US-PATENT-APPL-SN-929865; US-PATENT-CLASS-414-689; US-PATENT-CLASS-414-718; US-PATENT-CLASS-414-735; US-PATENT-CLASS-212-225; US-PATENT-CLASS-212-257; US-PATENT-CLASS-182-103) Avail: US Patent and Trademark Office CSCL 22/1

A habitable space station was proposed for low earth orbit, to be constructed from components which will be separately carried up from the earth and thereafter assembled. A suitable manipulating system having extraordinary manipulative capability is required. The invention is an erectable manipulator placement system for use on a space station and comprises an elongate, lattice-like boom having guide tracks attached thereto, a carriage-like assembly pivotally mounted on and extending from said dolly. The system further includes a turntable base pivotally interconnected with the proximal end of the boom and positioned either on a part of a transferring vehicle, or on another payload component being carried by the said transferring vehicle, or on the space station. Novelty resides in the use of a turntable base having a hinged boom with a dolly translatable therealong to carry the arm-like assembly, thus providing an additional 3 degrees of freedom to the arm.
Official Gazette of the U.S. Patent and Trademark Office

N89-13483*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RESULTS OF EVA/MOBILE TRANSPORTER SPACE STATION TRUSS ASSEMBLY TESTS
JUDITH J. WATSON, WALTER L. HEARD, JR., HAROLD G. BUSH, M. S. LAKE, J. K. JENSEN, R. E. WALLSOM, and J. E. PHELPS (PRC Kentron, Inc., Hampton, Va.) Nov. 1988 31 p
(NASA-TM-100661; NAS 1.15:100661) Avail: NTIS HC A03/MF A01 CSCL 22/2

Underwater neutral buoyance tests were conducted to evaluate the use of a Mobile Transporter concept in conjunction with EVA astronauts to construct the Space Station Freedom truss structure. A three-bay 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 (mobile foot restraints). The average unit assembly time (which included integrated installation of utility trays) was 27.6 s/strut, or 6 min/bay. The results of these tests indicate that EVA assembly of space station size structures can be significantly enhanced when using a Mobile Transporter equipped with astronaut positioning devices. Rapid assembly time can be expected and are dependent primarily on the rate of translation permissible for on-orbit operations. The concept used to demonstate integrated installation of utility trays requires minimal EVA handling and consequentially, as the results show, has little impact on overall assembly time. Author

N89-13487*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE VERSATILITY OF A TRUSS MOUNTED MOBILE TRANSPORTER FOR IN-SPACE CONSTRUCTION
HAROLD G. BUSH, MARK S. LAKE, JUDITH J. WATSON, and WALTER L. HEARD, JR. Nov. 1988 19 p
(NASA-TM-101514; NAS 1.15:101514) Avail: NTIS HC A03/MF A01 CSCL 22/2

The Mobile Transporter (MT) evolution from early erectable structures assembly activities is detailed. The MT operational features which are required to support astronauts performing on-orbit structure construction or spacecraft assembly functions are presented and discussed. Use of the MT to perform a variety of assembly functions is presented. Estimated EVA assembly times for a precision segmented reflector approximately 20 m in diameter are presented. The EVA/MT technique under study for construction of the reflector (and the entire spacecraft) is illustrated. Finally, the current status of development activities and test results involving the MT and Space Station structural assembly are presented. Author

N89-13815*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A SPACE CRANE CONCEPT: PRELIMINARY DESIGN AND STATIC ANALYSIS
MARTIN M. MIKULAS, JR., ROBERT C. DAVIS, and WILLIAM H. GREENE Nov. 1988 18 p
(NASA-TM-101498; NAS 1.15:101498) Avail: NTIS HC A03/MF A01 CSCL 20/11

Future in-space construction and assembly facilities will require the use of space cranes capable of supporting and manipulating large and massive loads. The large size of the space components being considered for construction will require that these cranes have a reach on the order of 100 meters. A space crane constructed from an erectable four-longeron truss beam with 19 5-sq-m truss bays is considered. This concept was selected to be compatible with the Space Station truss. This truss is hinged at three locations along its bottom edge and attached at one end to a rotary joint cantilevered to the assembly depot's main truss structure. The crane's boom sections are rotated by extensible longeron actuators located along the top edge of the beam. To achieve maximum position maneuvering capability for the crane requires that the individual sections be capable of rotating 180 degrees about the hinge point. This can only be accomplished by offsetting the hinges from the longeron axes. Since offset hinges introduce bending moments in the truss members, an analysis of the effect of hinge offsets on the load-carrying capacity of the structure is required. The objective of the static finite element analysis described is to determine the effect of various offset lengths on the overall bending stiffness of the crane and on the maximum stresses. Author

N89-13889*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DON/DOFF SUPPORT STAND FOR USE WITH REAR ENTRY SPACE SUITS Patent Application
JOSEPH J. KOSMO, inventor (to NASA), TERRY O. TRI, inventor (to NASA), WILLIAM E. SPENNY, inventor (to NASA), and PHILIP R. WEST, inventor (to NASA) 19 Jul. 1988 22 p
(NASA-CASE-MSC-21364-1; NAS 1.71:MSC-21364-1; US-PATENT-APPL-SN-221472) Avail: NTIS HC A03/MF A01 CSCL 06/11

A don/doff support stand for use with rear entry space suits is disclosed. The support stand is designed for use in one-g environments; however, certain features of the stand can be used on future spacecraft, lunar, or planetary bases. The present invention has a retainer which receives a protrucing lug fixed on the torso section of the space suit. When the lug is locked in the retainer, the space suit is held in a generally upright position. In a one-g environment a portable ladder is positioned adjacent to the rear entry of the space suit supported by the stand. The astronaut climbs up the ladder and grasps a hand bar assembly positioned above the rear entry. The astronaut then slips his legs through the open rear entry and down into the abdominal portion of the suite. The astronaut then lowers himself fully into the suit. The portable ladder is then removed and the astronaut can close the rear entry door. The lug is then disengaged from the retainer and the astronaut is free to engage in training exercises in the suit. When suit use is over, the astronaut returns to the stand and inserts the lug into the retainer. A technician repositions the ladder. The astronaut opens the rear entry door, grasps the hand bar assembly and does a chin-up to extricate himself from the suit. The astronaut climbs down the movable ladder while the suit is supported by the stand. NASA

N89-13896*# Hamilton Standard Div., United Aircraft Corp., Windsor Locks, CT.
APPENDICES TO THE USER'S MANUAL FOR A COMPUTER PROGRAM FOR THE EMULATION/SIMULATION OF A SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM
JAMES L. YANOSY Sep. 1988 208 p
(Contract NAS1-17397)
(NASA-CR-181736; NAS 1.26:181736; SVHSER-10639) Avail: NTIS HC A10/MF A01 CSCL 05/8

A user's Manual for the Emulation Simulation Computer Model was published previously. The model consisted of a detailed model (emulation) of a SAWD CO2 removal subsystem which operated with much less detailed (simulation) models of a cabin, crew, and condensing and sensible heat exchangers. The purpose was to explore the utility of such an emulation/simulation combination in the design, development, and test of a piece of ARS hardware - SAWD. Extensions to this original effort are presented. The first extension is an update of the model to reflect changes in the SAWD control logic which resulted from the test. In addition, slight changes were also made to the SAWD model to permit restarting and to improve the iteration technique. The second extension is the development of simulation models for more pieces of air and water processing equipment. Models are presented for: EDC, Molecular Sieve, Bosch, Sabatier, a new condensing heat exchanger, SPE, SFWES, Catalytic Oxidizer, and multifiltration. The third extension is to create two system simulations using these models. The first system presented consists of one air and one water processing system, the second a potential Space Station air revitalization system. Author

N89-14156*# Iowa State Univ. of Science and Technology, Ames.
THREE DEGREE-OF-FREEDOM FORCE FEEDBACK CONTROL FOR ROBOTIC MATING OF UMBILICAL LINES
R. REES FULLMER *In* NASA, John F. Kennedy Space Center, NASA/ASEE Summer Faculty Fellowship Program: 1988 Research Reports p 19-41 Oct. 1988
Avail: NTIS HC A24/MF A01 CSCL 13/9

The use of robotic manipulators for the mating and demating of umbilical fuel lines to the Space Shuttle Vehicle prior to launch is investigated. Force feedback control is necessary to minimize the contact forces which develop during mating. The objective is to develop and demonstrate a working robotic force control system. Initial experimental force control tests with an ASEA IRB-90 industrial robot using the system's Adaptive Control capabilities indicated that control stability would by a primary problem. An investigation of the ASEA system showed a 0.280 second software delay between force input commands and the output of command voltages to the servo system. This computational delay was identified as the primary cause of the instability. Tests on a second path into the ASEA's control computer using the MicroVax II supervisory computer show that time delay would be comparable, offering no stability improvement. An alternative approach was developed where the digital control system of the robot was disconnected and an analog electronic force controller was used to control the robot's servosystem directly, allowing the robot to use force feedback control while in rigid contact with a moving three-degree-of-freedom target. An alternative approach was developed where the digital control system of the robot was disconnected and an analog electronic force controller was used to control the robot's servo system directly. This method allowed the robot to use force feedback control while in rigid contact with moving three degree-of-freedom target. Tests on this approach indicated adequate force feedback control even under worst case conditions. A strategy to digitally-controlled vision system was developed. This requires switching between the digital controller when using vision control and the analog controller when using force control, depending on whether or not the mating plates are in contact. Author

N89-14898*# Jackson State Univ., MS.MS. Dept. of Technology.
END-EFFECTOR - JOINT CONJUGATES FOR ROBOTIC ASSEMBLY OF LARGE TRUSS STRUCTURES IN SPACE: A SECOND GENERATION Abstract Only
W. V. BREWER *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 38-43 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

Current designs, a first generation intended for robotic assembly, have given priority to the ease and certainty of the assembly process under less than ideal conditions with a minimum of sensory feedback. As a consequence they are either heavy or expensive and all exhibit a relatively low packaging density. Low packaging density is caused by extensive scars applied to the node, increasing its envelope diameter by as much as 150 percent. Strut envelopes are violated to a lessor extent with diameters increased by 25 percent or more. This smaller percentage is still a significant problem owing to a much higher fraction of the packaged volume represented by struts. As structures in space become larger, packaging density becomes an important consideration. The objective is to develop end-effector-joint conjugates that do not violate the envelopes of a 2.5 inch diameter node or a 1.0 inch diameter strut. Author

N89-15004*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN OVERVIEW OF THE PROGRAM TO PLACE ADVANCED AUTOMATION AND ROBOTICS ON THE SPACE STATION

RICHARD P. HEYDORN *In its* Experiments in Planetary and Related Sciences and the Space Station 6 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 22/2

The preliminary design phase of the Space Station has uncovered a large number of potential uses of automation and robotics, most of which deal with the assembly and operation of the Station. If NASA were to vigorously push automation and robotics concepts in the design, the Station crew would probably be free to spend a substantial portion of time on payload activities. However, at this point NASA has taken a conservative attitude toward automation and robotics. For example, the belief is that robotics should evolve through telerobotics and that uses of artificial intelligence should be initially used in an advisory capacity. This conservativeness is in part due to the new and untested nature of automation and robotics; but, it is also due to emphases plased on designing the Station to the so-called upfront cost without thoroughly understanding the life cycle cost. Presumably automation and robotics has a tendency to increase the initial cost of the Space Station but could substantially reduce the life cycle cost. To insure that NASA will include some form of robotic capability, Congress directed to set aside funding. While this stimulates the development of robotics, it does not necessarily stimulate uses of artificial intelligence. However, since the initial development costs of some forms of artificial intelligence, such as expert systems, are in general lower than they are for robotics one is likely to see several expert systems being used on the Station. Author

N89-15410# National Aerospace Lab., Amsterdam (Netherlands). Space Div.
FLEXIBLE ROBOTIC MANIPULATOR IN SPACE: TOWARDS A MATHEMATICAL DYNAMICS TRUTH MODEL
P. TH. L. M. VANWOERKOM 15 Sep. 1987 49 p
(Contract NIVR-02506-N)
(NLR-TR-87129-U; ETN-89-93889) Avail: NTIS HC A03/MF A01

A mathematical truth model for the dynamics of a robotic manipulator which is attached to an orbiting spacecraft-manipulator system consisting of structurally flexible bodies is discussed. The dynamics equations for a single constituent body in the spacecraft-manipulator system are developed, using the method of hybrid coordinate modeling. The equations obtained are to form the basis for the development of the dynamics equations of the entire spacecraft manipulator system. ESA

N89-16896*# Sterling Federal Systems, Inc., Palo Alto, CA.
MODIFICATIONS TO THE NASA AMES SPACE STATION PROXIMITY OPERATIONS (PROX OPS) SIMULATOR
ADAM BRODY Oct. 1988 10 p
(Contract NAS2-11555)
(NASA-CR-177510; NAS 1.26:177510) Avail: NTIS HC A02/MF A01 CSCL 14/2

As the United States is approaching an operational space station era, flight simulators are required to investigate human design and performance aspects associated with orbital operations. Among these are proximity operations (PROX OPS), those activities occurring within a 1-km sphere of Space Station including rendezvous, docking, rescue, and repair. The Space Station Proximity Operations Simulator at NASA Ames Research Center was modified to provide the capability for investigations into human performance aspects of proximity operations. Accurate flight equations of motion were installed to provide the appropriate visual scene to test subjects performing simulated missions. Also, the flight control system was enhanced by enabling pilot control over thruster acceleration values. Currently, research is under way to examine human performance in a variety of mission scenarios. Author

N89-17392*# Grumman Aerospace Corp., Bethpage, NY. Space Systems.
EXTRAVEHICULAR ACTIVITIES LIMITATIONS STUDY. VOLUME 1: PHYSIOLOGICAL LIMITATIONS TO EXTRAVEHICULAR ACTIVITY IN SPACE Final Report
PAUL A. FURR, CONRAD B. MONSON, ROBERT L. SANTORO, WILLIAM J. SEARS, DONALD H. PETERSON, and MALCOLM SMITH (ILC Space Systems, Dover, DE.) 1988 269 p
(Contract NAS9-17702)
(NASA-CR-172098; NAS 1.26:172098; AS-EVALS-FR-8701-VOL-1) Avail: NTIS HC A12/MF A01 CSCL 06/19

This report contains the results of a comprehensive literature search on physiological aspects of EVA. Specifically, the topics covered are: (1) Oxygen levels; (2) Optimum EVA work; (3) Food and Water; (4) Carbon dioxide levels; (5) Repetitive decompressions; (6) Thermal, and (7) Urine collection. The literature was assessed on each of these topics, followed by statements on conclusions and recommended future research needs. Author

N89-17393*# Grumman Aerospace Corp., Bethpage, NY. Space Systems.
EXTRAVEHICULAR ACTIVITIES LIMITATIONS STUDY. VOLUME 2: ESTABLISHMENT OF PHYSIOLOGICAL AND PERFORMANCE CRITERIA FOR EVA GLOVES Final Report
JOHN M. OHARA, MICHAEL BRIGANTI, JOHN CLELAND, and DAN WINFIELD (Research Triangle Inst., Research Triangle Park, NC.) 1988 175 p
(Contract NAS9-17702)
(NASA-CR-172099; NAS 1.26:172099; AS-EVALS-FR-8701-VOL-2) Avail: NTIS HC A08/MF A01 CSCL 06/19

One of the major probelms 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. This report describes the development of a standardized set of tests designed to assess EVA-gloved hand capabilities in six measurement domains: Range of Motion, Strength, Tactile Perception, Dexterity, Fatigue, and Comfort. Based on an assessment of general human hand functioning and EVA task requirements several tests within each measurement domain were developed to provide a comprehensive evaluation. All tests were designed to be conducted in a glove box with the bare hand as a baseline and the EVA glove at operating pressure. A test program was conducted to evaluate the tests using a representative EVA glove. Eleven test subjects participated in a repeated-measures design. The report presents the results of the tests in each capability domain. Author

N89-18398*# National Aeronautics and Space Administration, Washington, DC.
AUTOMATION AND ROBOTICS
MELVIN MONTEMERLO *In its* NASA Information Sciences and Human Factors Program p 1-28 Sep. 1988
Avail: NTIS HC A10/MF A01 CSCL 13/9

The Autonomous Systems focus on the automation of control systems for the Space Station and mission operations. Telerobotics focuses on automation for in-space servicing, assembly, and repair. The Autonomous Systems and Telerobotics each have a planned sequence of integrated demonstrations showing the evolutionary advance of the state-of-the-art. Progress is briefly described for each area of concern. B.G.

N89-18405*# National Aeronautics and Space Administration, Washington, DC.
HUMAN FACTORS: SPACE
JAMES P. JENKINS *In its* NASA Information Sciences and Human Factors Program p 179-201 Sep. 1988
Avail: NTIS HC A10/MF A01 CSCL 05/8

The objectives are to provide a technology base for intelligent operator interfaces, especially with autonomous subsystems, and to develop a new generation of high performance space suits, gloves, and tools/end effectors to meet the requirements of advanced space missions. The technology base is intended to meet the requirements of productivity, efficiency, and safety in complex manned operations within automated onboard systems and extravehicular activities (EVA) environments. Crew station research is the first of two major areas. Development of methods for the astronaut to supervise, monitor, and evaluate the performance of robotic systems, other space subsystems, and orbital vehicles are key areas of research. The second major area is development of an EVA space suit and gloves. Emphasis in the space human factors research program is placed on technology baseline studies and development of methods, techniques, and data to support productive and safe operations by the astronaut and crew as they interface with complex systems, advance automation, and robotic assistants. Author

N89-18516*# Little (Arthur D.), Inc., Cambridge, MA.
ADVANCED EXTRAVEHICULAR ACTIVITY SYSTEMS REQUIREMENTS DEFINITION STUDY Final Report
Aug. 1988 131 p
(Contract NAS9-17894)
(NASA-CR-172111; NAS 1.26:172111) Avail: NTIS HC A07/MF A01 CSCL 22/2

A study to define the requirements for advanced extravehicular activities (AEVA) was conducted. The purpose of the study was to develop an understanding of the EVA technology requirements and to map a pathway from existing or developing technologies to an AEVA system capable of supporting long-duration missions on the lunar surface. The parameters of an AEVA system which must sustain the crewmembers and permit productive work for long periods in the lunar environment were examined. A design reference mission (DRM) was formulated and used as a tool to develop and analyze the EVA systems technology aspects. Many operational and infrastructure design issues which have a significant influence on the EVA system are identified. NASA

N89-18517*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
BERTHING MECHANISM FINAL TEST REPORT AND PROGRAM ASSESSMENT
Oct. 1988 90 p Prepared in cooperation with Control Dynamics Co., Huntsville, AL
(Contract NAS8-36417)
(NASA-CR-183554; NAS 1.26:183554; MDAC-H3913; CDRL-13; CDRL-14) Avail: NTIS HC A05/MF A01 CSCL 22/2

The purpose is to document the testing performed on both hardware and software developed under the Space Station Berthing Mechanisms Program. Testing of the mechanism occurred at three locations. Several system components, e.g., actuators and computer systems, were functionally tested before assembly. A series of post assembly tests were performed. The post assembly tests, as well as the dynamic testing of the mechanism, are presented. Author

N89-19128# British Aerospace Public Ltd. Co., Bristol (England). Space and Communications Div.
EVA SYSTEM REQUIREMENTS AND DESIGN CONCEPTS STUDY, PHASE 2 Final Report
T. J. CARTWRIGHT, J. TAILHADES, and M. SCHEID Paris, France ESA Jun. 1988 225 p Prepared in cooperation with Matra Espace, Paris-Velizy, France, Sener S.A., Madrid, Spain, and McDonnell Douglas, Long Beach, CA
(Contract ESA-7324/87-NL-MA(SC))
(BAE-TP-9035; ESA-CR(P)-2676; ETN-89-93930) Avail: NTIS HC A10/MF A01

A European extravehicular activity (EVA) system baseline similar to the STS baseline was derived from analysis of Hermes/Columbus and other ESA manned missions. The ESA suit, however, uses single walled laminate materials. Equipment heat dissipations are collected via cold plates. The sublimator is augmented by a heat storage unit. Primary oxygen storage uses a high pressure nonrechargeable system. The prime mover consists of a separate axial fan, paristaltic pump, and high speed rotary separator. The EVA information/communication module (EICM) uses a digital communications system. The EICM offers a more sophisticated automatic checkout and data display capability than the STS system. The technology assessment indicates that the development of the defined European EVA system lies within the capabilities of European industry although potentially technology transfer from the USA could have substantial benefits. ESA

N89-19575# Technische Univ., Delft (Netherlands).
A FINITE ELEMENT DYNAMIC ANALYSIS OF FLEXIBLE SPATIAL MECHANISMS AND MANIPULATORS Ph.D. Thesis
BEN JONKER 1988 162 p
(ETN-89-93901) Avail: NTIS HC A08/MF A01

A finite-element based method for the dynamic analysis of spatial mechanisms and manipulators with flexible links is presented. Finite element types, appropriate for modeling spatial mechanisms are presented. For each element, expressions for the deformation modes as analytical functions of the element nodal coordinates are defined. The angular orientations are described in terms of four Euler parameters; in contrast to Euler angles or any set of three angular generalized coordinates, these parameters display no singular behavior of the rotational transformations. The constraint condition for the Euler parameters can easily be incorporated in the theory as it is a condition similar to the constraint condition for undeformable finite elements. The kinematic description of multi degree of freedom mechanisms based on the geometric transfer function formalism is considered. The list of derivatives of the geometric transfer functions is extended up to the third order. The associated computation scheme for the kinematic analysis is described. The choice of the degrees of freedom is discussed. ESA

N89-19809*# Essex Corp., Huntsville, AL.
ADVANCED EXTRAVEHICULAR ACTIVITY SYSTEMS REQUIREMENTS DEFINITION STUDY. PHASE 2: EXTRAVEHICULAR ACTIVITY AT A LUNAR BASE Final Report
VALERIE NEAL, NICHOLAS SHIELDS, JR., GERALD P. CARR, WILLIAM POGUE, HARRISON H. SCHMITT, and ARTHUR E. SCHULZE (Lovelace Scientific Resources, Inc., Albuquerque, NM.) Sep. 1988 160 p
(Contract NAS9-17779)
(NASA-CR-172117; NAS 1.26:172117) Avail: NTIS HC A08/MF A01 CSCL 06/11

The focus is on Extravehicular Activity (EVA) systems requirements definition for an advanced space mission: remote-from-main base EVA on the Moon. The lunar environment, biomedical considerations, appropriate hardware design criteria, hardware and interface requirements, and key technical issues for advanced lunar EVA were examined. Six remote EVA scenarios (three nominal operations and three contingency situations) were developed in considerable detail. B.G.

N89-19816# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
STUDY ON CHECKOUT OF FLIGHT UNITS AND SUBSYSTEMS Final Report
W. BERGHOFER and S. Y. OVADYA Paris, France ESA Jun. 1988 130 p
(Contract ESA-5974/84)
(ESA-CR(P)-2693; ETN-89-93937) Avail: NTIS HC A07/MF A01

Tradeoffs were performed to derive the ground support requirements of TV-SAT. The interfaces between checkout equipment, onboard data handling, and test facilities were defined. The European Test Operation Langage and AS-BASIC were compared in terms of utilization, support, and performance. Remote checkout for extravehicular activity (EVA) was studied. It is shown that it is not possible to perform EVA without local monitoring, control of the acquired data and their transmission. Thus, as a windfall product remote checkout becomes available for the whole life of the EVA space suit system, and should be used to reduce cost and improve efficiency of the whole system. ESA

N89-19861*# Lockheed Engineering and Sciences Co., Houston, TX.
SIMULATION OF THE HUMAN-TELEROBOT INTERFACE
MARK A. STUART and RANDY L. SMITH *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations

Automation and Robotics (SOAR 1988) p 321-326 Nov. 1988
(Contract NAS9-17900)
Avail: NTIS HC A22/MF A01 CSCL 05/8

A part of NASA's Space Station will be a Flight Telerobotic Servicer (FTS) used to help assemble, service, and maintain the Space Station. Since the human operator will be required to control the FTS, the design of the human-telerobot interface must be optimized from a human factors perspective. Simulation has been used as an aid in the development of complex systems. Simulation has been especially useful when it has been applied to the development of complex systems. Simulation should ensure that the hardware and software components of the human-telerobot interface have been designed and selected so that the operator's capabilities and limitations have been accommodated for since this is a complex system where few direct comparisons to existent systems can be made. Three broad areas of the human-telerobot interface where simulation can be of assistance are described. The use of simulation not only can result in a well-designed human-telerobot interface, but also can be used to ensure that components have been selected to best meet system's goals, and for operator training. Author

N89-19862*# CAMUS, Inc., Huntsville, AL.
MAN-SYSTEMS REQUIREMENTS FOR THE CONTROL OF TELEOPERATORS IN SPACE
NICHOLAS L. SHIELDS, JR. *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 329-334 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/8

The microgravity of the space environment has profound effects on humans and, consequently, on the design requirements for subsystems and components with which humans interact. There are changes in the anthropometry, vision, the perception of orientation, posture, and the ways in which we exert energy. The design requirements for proper human engineering must reflect each of the changes that results, and this is especially true in the exercise of control over remote and teleoperated systems where the operator is removed from any direct sense of control. The National Aeronautics and Space Administration has recently completed the first NASA-wide human factors standard for microgravity. The Man-Systems Integration Standard, NASA-STD-3000, contains considerable information on the appropriate design criteria for microgravity, and there is information that is useful in the design for teleoperated systems. There is not, however, a dedicated collection of data which pertains directly to the special cases of remote and robotic operations. The design considerations for human-system interaction in the control of remote systems in space are discussed, with brief details on the information to be found in the NASA-STD-3000, and arguments for a dedicated section within the Standard which deals with robotic, teleoperated and remote systems and the design requirements for effective human control of these systems in the space environment, and from the space environment. Author

N89-19870*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
DESIGN CONCEPT FOR THE FLIGHT TELEROBOTIC SERVICER (FITS)
J. F. ANDARY, S. W. HINKAI, and J. G. WATZIN *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 391-396 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/8

NASA has just completed an in-house Phase B Study (one of three studies) for the preliminary definition of a teleoperated robotic device that will be used on the National Space Transportation System (NSTS) and the Space Station to assist the astronauts in the performance of assembly, maintenance, servicing, and inspection tasks. This device, the Flight Telerobotic Servicer (FTS), will become a permanent element on the Space Station. Although it is primarily a teleoperated device, the FTS is being designed to grow and evolve to higher states of autonomy. Eventually, it will be capable of working from the Orbital Maneuvering Vehicle (OMV) to service free-flying spacecraft at great distances from the Space Station. A version of the FTS could also be resident on the large space platforms that are part of the Space Station Program. Author

N89-19879*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MACHINE VISION FOR SPACE TELEROBOTICS AND PLANETARY ROVERS
BRIAN H. WILCOX *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 457-460 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/8

Machine vision allows a non-contact means of determining the three-dimensional shape of objects in the environment, enabling the control of contact forces when manipulation by a telerobot or traversal by a vehicle is desired. Telerobotic manipulation in Earth orbit requires a system that can recognize known objects in spite of harsh lighting conditions and highly specular or absorptive surfaces. Planetary surface traversal requires a system that can recognize the surface shape and properties of an unknown and arbitrary terrain. Research on these two rather disparate types of vision systems is described. Author

N89-19881*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
A MULTI-SENSOR SYSTEM FOR ROBOTICS PROXIMITY OPERATIONS
J. B. CHEATHAM, C. K. WU, P. L. WEILAND (Rice Univ., Houston, TX.), and T. F. CLEGHORN *In its* 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 467-470 Nov. 1988
(Contract NCC9-16; NAG9-208)
Avail: NTIS HC A22/MF A01 CSCL 05/8

Robots without sensors can perform only simple repetitive tasks and cannot cope with unplanned events. A multi-sensor system is needed for a robot to locate a target, move into its neighborhood and perform operations in contact with the object. Systems that can be used for such tasks are described. Author

N89-19882*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A METHODOLOGY FOR AUTOMATION AND ROBOTICS EVALUATION APPLIED TO THE SPACE STATION TELEROBOTIC SERVICER
JEFFREY H. SMITH, MAX GYANFI, KENT VOLKMER, and WAYNE ZIMMERMAN *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 471-479 Nov. 1988
(Contract NAS7-918)
Avail: NTIS HC A22/MF A01 CSCL 05/8

The efforts of a recent study aimed at identifying key issues and trade-offs associated with using a Flight Telerobotic Servicer (FTS) to aid in Space Station assembly-phase tasks is described. The use of automation and robotic (A and R) technologies for large space systems would involve a substitution of automation capabilities for human extravehicular or intravehicular activities (EVA, IVA). A methodology is presented that incorporates assessment of candidate assembly-phase tasks, telerobotic performance capabilities, development costs, and effect of operational constraints (space transportation system (STS), attached payload, and proximity operations). Changes in the region of cost-effectiveness are examined under a variety of systems design assumptions. A discussion of issues is presented with focus on three roles the FTS might serve: (1) as a research-oriented testbed to learn more about space usage of telerobotics; (2) as a research based testbed having an experimental demonstration orientation with limited assembly and servicing applications; or (3) as an operational system to augment EVA and to aid the construction of the Space Station and to reduce the programmatic (schedule) risk by increasing the flexibility of mission operations. Author

N89-19885*# Rockwell International Corp., Downey, CA.
DESIGN GUIDELINES FOR REMOTELY MAINTAINABLE EQUIPMENT
MARGARET M. CLARKE and DAVOUD MANOUCHEHRI *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 495-497 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/8

The quantity and complexity of on-orbit assets will increase significantly over the next decade. Maintaining and servicing these costly assets represent a difficult challenge. Three general methods are proposed to maintain equipment while it is still in orbit: an extravehicular activity (EVA) crew can perform the task in an unpressurized maintenance area outside any space vehicle; an intravehicular activity (IVA) crew can perform the maintenance in a shirt sleeve environment, perhaps at a special maintenance work station in a space vehicle; or a telerobotic manipulator can perform the maintenance in an unpressurized maintenance area at a distance from the crew (who may be EVA, IVA, or on the ground). However, crew EVA may not always be possible; the crew may have other demands on their time that take precedence. In addition, the orbit of the tasks themselves may be impossible for crew entry. Also crew IVA may not always be possible as option for equipment maintenance. For example, the equipment may be too large to fit through the vehicle airlock. Therefore, in some circumstances, the third option, telerobotic manipulation, may be the only feasible option. Telerobotic manipulation has, therefore, an important role for on-orbit maintenance. It is not only used for the reasons outlined above, but also used in some cases as backup to the EVA crew in an orbit that they can reach. Author

N89-20072*# Michigan Technological Univ., Houghton. Dept. of Mechanical Engineering.
MODEL EVALUATION, RECOMMENDATION AND PRIORITIZING OF FUTURE WORK FOR THE MANIPULATOR EMULATOR TESTBED Final Report
FREDERICK A. KELLY *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 1 10 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 13/9

The Manipulator Emulator Testbed (MET) is to provide a facility capable of hosting the simulation of various manipulator configurations to support concept studies, evaluation, and other engineering development activities. Specifically, the testbed is intended to support development of the Space Station Remote Manipulator System (SSRMS) and related systems. The objective of this study is to evaluate the math models developed for the MET simulation of a manipulator's rigid body dynamics and the servo systems for each of the driven manipulator joints. Specifically, the math models are examined with regard to their amenability to pipeline and parallel processing. Based on this evaluation and the project objectives, a set of prioritized recommendations are offered for future work. Author

N89-20075*# Texas A&I Univ., Kingsville. Dept. of Civil and Mechanical Engineering.
INTELLIGENT CONTROL OF ROBOTIC ARM/HAND SYSTEMS FOR THE NASA EVA RETRIEVER USING NEURAL NETWORKS Final Report
ROBERT A. MCLAUCHLAN *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 2 15 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 09/2

Adaptive/general learning algorithms using varying neural network models are considered for the intelligent control of robotic arm plus dextrous hand/manipulator systems. Results are summarized and discussed for the use of the Barto/Sutton/Anderson neuronlike, unsupervised learning controller as applied to the stabilization of an inverted pendulum on a cart system. Recommendations are made for the application of the controller and a kinematic analysis for trajectory planning to simple object retrieval (chase/approach and capture/grasp) scenarios in two dimensions. Author

N89-20082*# East Texas State Univ., Commerce. Dept. of Computer Science.
VISUAL PERCEPTION AND GRASPING FOR THE EXTRAVEHICULAR ACTIVITY ROBOT Final Report
SCOTT A. STARKS *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 2 14 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 13/9

The development of an approach to the visual perception of object surface information using laser range data in support of robotic grasping is discussed. This is a very important problem area in that a robot such as the EVAR must be able to formulate a grasping strategy on the basis of its knowledge of the surface structure of the object. A description of the problem domain is given as well as a formulation of an algorithm which derives an object surface description adequate to support robotic grasping. The algorithm is based upon concepts of differential geometry namely, Gaussian and mean curvature. Author

09

PROPULSION

Includes propulsion concepts and designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.

A89-10487
PLANNING FRAMEWORK FOR HIGH TECHNOLOGY AND SPACE FLIGHT - PROPULSION SYSTEMS [ORIENTIERUNGSRAHMEN HOCHTECHNOLOGIE RAUMFAHRT - ANTRIEBE]
H. KREBS (MBB-ERNO Raumfahrttechnik GmbH, Munich, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 15-22. In German.
(DGLR PAPER 87-073)

Plans for the development of space propulsion systems in the FRG are outlined, with reference to the Planning Framework for High Technology and Space Flight (OHR). The engines considered primary goals in the OHR are 350-400-kN air-breathing or hybrid main engines; high-performance 500-700-kN upper-stage main engines; 20-80-kN chemical or cryogenic engines for OTVs; and small chemical, cryogenic, or electric propulsion systems for AOCS and fine-maneuver applications. The capabilities required of these systems are listed and briefly characterized, and six specific technology-development programs are recommended, focusing on component technology, internal aerodynamics and thermodynamics, new materials and structures, subsystems with variable configurations, engine control and sensor technology, and integrated engine-diagnostics and life-monitoring systems. Also discussed are the new research and test facilities called for by the OHR. T.K.

A89-10496
MODELLING, ANALYSIS AND CONTROL OF SLOSHING EFFECTS FOR SPACECRAFT UNDER ACCELERATION CONDITIONS
K. EBERT, CHR. ROCHE, and M. SURAUER (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 78-82.
(DGLR PAPER 87-093)

The analysis and control of sloshing in liquid-propellant tanks during spacecraft acceleration are discussed, with a focus on the fuel and oxidizer tanks of the DFS direct-broadcast and communication satellite. The DFS platform configuration and the z-axis acceleration involved in its apogee boost maneuver are characterized; the sloshing dynamics and equations of motion are analyzed; and a controller which is insensitive to system-parameter variations is derived on the basis of the state-observer principle for the body and sloshing, disturbance torque estimation/compensation, and panel attenuation filtering. Gain phase diagrams are presented for the plant open loop and the pitch control loop. T.K.

A89-10638* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
NEAR TERM SPACE TRANSPORTATION SYSTEMS FOR EARTH ORBIT AND PLANETARY APPLICATIONS
SIDNEY SAUCIER (NASA, Marshall Space Flight Center, Huntsville, AL) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 149-165. refs
(SAE PAPER 872414)
With the resumption of Space Shuttle flights in mid-1988, many of the initial flights will include a mix of upper stage propulsion systems for geosynchronous orbit and planetary mission applications. This paper presents a system definition and the modifications required to the Inertial Upper Stage and the Transfer Orbit Stage for the near term Space Shuttle missions, namely the Tracking and Data Relay Satellite, Magellan, Galileo, Ulysses, Mars Observer, and the Advanced Communications Technology Satellite. The definition and capabilities of the Orbital Maneuvering Vehicle, currently being developed by NASA to perform a wide range of on-orbit missions and services in support of orbiting spacecraft, are also included. Author

A89-12651* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A LOW EARTH ORBIT SKYHOOK TETHER TRANSPORTATION SYSTEM
PAUL A. PENZO (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 455-468. refs
(AAS PAPER 87-436)
This paper discusses the design concept of a structure, called the Skyhook Tether Transportation System (STTS) which may be used to transport mass to higher or lower orbits or to capture objects from higher or lower orbits. An analysis is presented for the possibility of the STTS to perform the function of transporting masses suborbitally, capturing the objects, and then releasing them to a higher orbit, the GEO, the moon, or for an escape. It is shown that, although the possibility of such a system is limited by the tether strength, even a modest system can yield considerable benefits in propellant savings if it is used in combination with chemical propulsion. I.S.

A89-12694
MINIMUM DELTA-V CONTROL OF RELATIVE MOTION UNDER OPERATIONAL AND SAFETY CONSTRAINTS
FRIEDHELM HECHLER and JUERGEN FERTIG (ESA, Operations Control Centre, Darmstadt, Federal Republic of Germany) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 1279-1302. refs
(AAS PAPER 87-520)
Delta-v minimum orbit control strategies are studied for a rendezvous between two spacecraft. Particular attention is given to safety considerations in the design of the control. It is found that a combination of analytic considerations and convex-linear optimization methods makes it possible to compute the control strategies that protect the target from plume impingement and collision even if the chaser is running out of control. K.K.

A89-17711#
SPACE TRANSFER SYSTEM EVOLUTION TO SUPPORT LUNAR AND MARS MISSIONS
MARK WILLIAM HENLEY (General Dynamics Corp., Space Systems Div., San Diego, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. refs
(IAF PAPER 88-184)
Space transfer vehicles and supporting orbital facilities, to be developed for initial application in earth orbit, can be adaptable for use in manned exploration of the moon and Mars. An initial system with modular construction will allow easy modification to meet additional requirements of future missions. System modifications for early missions to the moon and Mars include man-rating, increased mission duration and velocity, and vehicle derivatives for landing. Continuing system evolution may involve adaptation for new propulsion systems and use of extraterrestrial resources. Near-term development of an initial system is necessary to allow time for the system to mature for manned exploration of the moon and Mars early in the next century. Author

A89-17726#
ORBITAL CRYOGENIC DEPOT FOR SUPPORT OF SPACE TRANSFER VEHICLE OPERATIONS
JOHN R. SCHUSTER (General Dynamics Corp., Space Systems Div., San Diego, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p. refs
(IAF PAPER 88-205)
An ongoing study has examined the requirements for a low-earth-orbit (LEO) cryogenic propellant storage depot to support projected future space transportation missions. A reusable space transportation vehicle (STV) based in LEO will require a depot with a 90,000-kg storage capacity for LO2/LH2, which can best be met with two tank sets of 45,000 kg capacity. The tank sets employ many advanced features to provide for microgravity fluid management and to limit cryogen boiloff. Basing the depot on a coorbiting platform is attractive compared with basing it at the manned Space Station due to concerns over Space Station crew safety, contamination, and microgravity environment. A platform should permit venting of boiloff, while basing on the Space Station may require the use of active cryogenic refrigeration to reliquefy boiloff. Depot on-orbit buildup and maintenance estimates are modest, but there could be a substantial need for robotics. An earth-to-orbit propellant resupply tanker capacity of 73,000 kg provides the best match for the depot, thus defining a mission for a future heavy-lift launch vehicle. Author

A89-17748#
A REAPPRAISAL OF SATELLITE ORBIT RAISING BY ELECTRIC PROPULSION
R. HOLDAWAY, Y. S. WONG (SERC, Rutherford Appleton Laboratory, Didcot, England), A. R. MARTIN, and P. M. LATHAM (U.K. Atomic Energy Authority, Culham Laboratory, Abingdon, England) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 5 p. refs
(IAF PAPER 88-261)
This paper makes an updated assessment of the technical and economic feasibility of transferring satellites from LEO to GEO using low thrust propulsion. In particular, the concept of a solar electric tug is discussed, whereby the main propulsion unit is returned from GEO to LEO for reuse. Author

A89-24495* RCA Aerospace and Defense, East Windsor, NJ.
ALL RESISTOJET CONTROL OF THE NASA DUAL KEEL SPACE STATION
M. A. PALUSZEK (RCA, Astro-Space Div., East Windsor, NJ) IN: Automatic control; Proceedings of the Tenth Triennial World Congress of IFAC, Munich, Federal Republic of Germany, July 27-31, 1987. Volume 6. Oxford, England and Elmsford, NY, Pergamon Press, 1988, p. 167-173. refs
(Contract NAS9-16023)

This paper describes a control system that uses small (0.1-N) hydrogen-fueled, high-expansion-ratio resistojets to control a Space Station's position and attitude. The number and size of the resistojets is calculated based on requirements for stationkeeping, compensation for steady-state gravity-gradient and aerodynamic torques, momentum loading due to mobile remote manipulator motion, Shuttle Orbiter docking, and translational evasive maneuvering. The all-resistojet control system performs continuous orbit maintenance while keeping the linear accelerations on the spacecraft lower than they would be without any control system operating. Author

A89-25296#
DISTURBANCE ON GSTAR SATELLITES DUE TO THRUSTER PLUME IMPINGEMENT ON SOLAR ARRAY
S. A. PARVEZ (GTE Spacenet, McLean, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p.
(AIAA PAPER 89-0351)

Data available from an operational GSTAR satellite are used to compute the actual disturbance torques experienced during north/south maneuvers due to plume impingement on solar arrays as a function of the array position. It is shown that roll and yaw disturbance torques go through a complete cycle as the array position during north/south burns goes through one complete rotation, while the pitch disturbance torque goes through two cycles. The maximum roll and yaw disturbance torque has an approximate magnitude of 0.10 in-lbf, while the maximum pitch disturbance torque has a magnitude of 0.04 in-lbf. The analysis shows that the solar arrays may be bent in the direction of the sun. K.K.

N89-11803*# Textron Bell Aerospace Co., Buffalo, NY.
SPACE STATION AUXILIARY THRUST CHAMBER TECHNOLOGY Final Report
J. M. SENNEFF Feb. 1987 44 p
(Contract NAS3-24883)
(NASA-CR-179650; NAS 1.26:179650; BELL-REPT-8911-950003) Avail: NTIS HC A03/MF A01 CSCL 20/8

A program to design, fabricate, and test a 50 lb sub f (222 N) thruster was undertaken to demonstrate the applicability of the reverse flow concept as an item of auxillary propulsion for the Space Station. The thruster was to operate at a mixture ratio (O/F) of 4, be capable of operating for 2 million lb sub f-seconds (8.896 million N-seconds) impulse with a chamber pressure of 75 psia (52N/sq cm) and a nozzle area ratio of 40. A successful demonstration of an (0/F) of 4 thruster, was followed by the design objective of operating at (O/F) of 8. The demonstration of this thruster resulted in the order of and additional (O/F) of 8 thruster chamber under the present NAS 3-24883 contract. The effort to fabricate and test the second (0/F) of 8 thruster is documented. Author

N89-13786* National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
QUICK-DISCONNECT INFLATABLE SEAL ASSEMBLY Patent
KURT D. BUEHLER, inventor (to NASA) and JAMES E. FESMIRE, inventor (to NASA) 20 Sep. 1988 9 p Filed 22 May 1987 Supersedes N87-25583 (25 - 19, p 2616)
(NASA-CASE-KSC-11368-1; US-PATENT-4,772,050; US-PATENT-APPL-SN-052940; US-PATENT-CLASS-285-39; US-PATENT-CLASS-285-97; US-PATENT-CLASS-285-107; US-PATENT-CLASS-285-108; US-PATENT-CLASS-285-109; US-PATENT-CLASS-285-133.1; US-PATENT-CLASS-285-351) Avail: US Patent and Trademark Office CSCL 13/11

This invention concerns an inflatable seal assembly adapted for use with a bayonet quick-disconnect system particularly useful for the insulated transfer of cryogenic consumables in orbit (such as between a space station and a re-supply vehicle). The zero-leak cryogenic coupling includes a polymeric seal clamped to a male bayonet member with two pairs of tightening rings. The tightening rings threadably engage each other in respective pairs around tapered ends of the inflatable seal member so that a wedging action tightens the seal member about the male bayonet. Once in place, the seal may be inflated via an inflation port so that its expansion provides pressure contact with the inside surface of a coaxial female member.
Official Gazette of the U.S. Patent and Trademark Office

N89-15969*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.
SPACE-BASED LASER-POWERED ORBITAL TRANSFER VEHICLE (PROJECT SLICK)
Jun. 1988 225 p
(Contract NGT-21-002-080; NGT-80001)
(NASA-CR-184716; NAS 1.26:184716) Avail: NTIS HC A10/MF A01 CSCL 22/2

A conceptual design study of a laser-powered orbital transfer vehicle (LOTV) is presented. The LOTV, nicknamed SLICK (Space Laser Interorbital Cargo Kite), will be utilized for the transfer of 16000 kg of cargo between Low Earth Orbit (LEO) and either Geosynchronous Earth Orbit (GEO) or Low Lunar Orbit (LLO). This design concentrates primarily on the LEO/GEO scenario, which will have typical LEO-to-GEO trip time of 6 days and two return versions. One version uses an all propulsive return while the other utilizes a ballute aerobrake for the return trip. Furthermore, three return cargo options of 16000 kg, 5000 kg (standard option), and 1600 kg are considered for this scenario. The LEO/LLO scenario uses only a standard, aerobraked version. The basic concept behind the LOTV is that the power for the propulsion system is supplied by a source separate from the LOTV itself. For the LEO/GEO scenario the LOTV utilizes a direct solar-pumped iodide laser and possibly two relay stations, all orbiting at an altitude of one Earth radius and zero inclination. An additional nuclear-powered laser is placed on the Moon for the LEO/LLO scenario. The propulsion system of the LOTV consists of a single engine fueled with liquid hydrogen. The laser beam is captured and directed by a four mirror optical system through a window in the thrust chamber of the engine. There, seven plasmas are created to convert the laser beam energy into thermal energy at an efficiency of at least 50 percent. For the LEO/LLO scenario the laser propulsion is supplemented by LH2/LOX chemical thrusters. Author

N89-17613*# Martin Marietta Aerospace, Denver, CO. Astronautics Group.
SPACE STATION INTEGRATED PROPULSION AND FLUID SYSTEMS STUDY. SPACE STATION PROGRAM FLUID MANAGEMENT SYSTEMS DATABOOK
B. BICKNELL, S. WILSON, M. DENNIS, and M. LYDON 26 Apr. 1988 231 p
(Contract NAS8-36438)
(NASA-CR-183583; NAS 1.26:183583; MCR-88-557) Avail: NTIS HC A11/MF A01 CSCL 22/2

Commonality and integration of propulsion and fluid systems associated with the Space Station elements are being evaluated. The Space Station elements consist of the core station, which includes habitation and laboratory modules, nodes, airlocks, and trusswork; and associated vehicles, platforms, experiments, and payloads. The program is being performed as two discrete tasks. Task 1 investigated the components of the Space Station architecture to determine the feasibility and practicality of commonality and integration among the various propulsion elements. This task was completed. Task 2 is examining integration and commonality among fluid systems which were identified by the Phase B Space Station contractors as being part of the initial operating capability (IOC) and growth Space Station architectures. Requirements and descriptions for reference fluid systems were compiled from Space Station documentation and other sources. The fluid systems being examined are: an experiment gas supply system, an oxygen/hydrogen supply system, an integrated water system, the integrated nitrogen system, and the integrated waste fluids system. Definitions and descriptions of alternate systems were developed, along with analyses and discussions of their benefits and detriments. This databook includes fluid systems descriptions, requirements, schematic diagrams, component lists, and discussions of the fluid systems. In addition, cost comparison are used in some cases to determine the optimum system for a specific task. Author

N89-18503# Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).
STUDY OF IN-ORBIT SERVICING OF COLUMBUS ELEMENTS BY ALV, EXECUTIVE SUMMARY
Paris, France ESA Mar. 1988 86 p
(Contract ESTEC-7343/87-NL-MA(SC))
(ESA-CR(P)-2675; ETN-89-93929) Avail: NTIS HC A05/MF A01

An orbital servicing concept, especially for Columbus, based on an Ariane 5 logistics vehicle (ALV) is shown to be feasible. The ALV concept meets all the performance requirements, including safety for transporting logistics resupplies to the space station elements. Deletion of the ALV capability to perform active proximity maneuvers greatly reduces system complexity. Replacement of a large mono tank by separate tanks increases overall safety, deletes tank emptying operation, and the need for additional tanks. The separate tank concept reduces overall height of stage with associated mass savings on the interstage. The propulsion stage proposed can be used as basic stage for all Ariane 5 applications using 20 kN engine together with 2, 4, or 6 tanks for LEO-GTO missions. Attached pressurized module downloads must be returned by STS. The ALV offers very large free capacity for accommodating all types of expendable equipment, trash, waste products for atmospheric burn-up. Pressurized cargo modules were designed for worst case docking to the space station (180 days) offering pressurized storage capability, or umpressurized CM operating as tank farm. ESA

N89-18518*# Ball Aerospace Systems Div., Boulder, CO.
SUPERFLUID HELIUM TANKER (SFHT) STUDY
1 Oct. 1988 157 p
(Contract NAS9-17852)
(NASA-CR-172116; NAS 1.26:172116; F88-04) Avail: NTIS HC A08/MF A01 CSCL 22/2

The accomplishments and recommendations of the two-phase Superfluid Helium Tanker (SFHT) study are presented. During the first phase of the study, the emphasis was on defining a comprehensive set of user requirements, establishing SFHT interface parameters and design requirements, and selecting a fluid subsystem design concept. During the second phase, an overall system design concept was constructed based on appropriate analyses and more detailed definition of requirements. Modifications needed to extend the baseline for use with cryogens other than SFHT have been determined, and technology development needs related to the recommended design have been assessed. NASA

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GENERAL

Includes either state-of-the-art or advanced technology which may apply to Large Space Systems and does not fit within the previous categories. Publications of conferences, seminars, and workshops are covered in this area.

A89-10452
SAFE ASSOCIATION, ANNUAL SYMPOSIUM, 25TH, LAS VEGAS, NV, NOV. 16-19, 1987, PROCEEDINGS
Symposium sponsored by the SAFE Association. Newhall, CA, SAFE Association, 1987, 289 p. For individual items see A89-10453 to A89-10483.
(AD-A199276)

The conference presents papers on the attrition of a molecular sieve in on-board oxygen generating systems, Space Station emergency egress and EVA lighting considerations and candidate Koch hardware, performance criteria for the MSOGS, and an altered control position for simulating fluid shifts during Shuttle launch. Other topics include cognitive workload and symptoms of hypoxia, development of an oxygen mask integrated arterial oxygen saturation (SaO2) monitoring system for pilot protection in advanced fighter aircraft, and eyeblink monitoring as a means of measuring pilot psychological state. Consideration is also given to a new approach to head and neck support, the prediction of Hybrid II manikin head-neck kinematics and dynamics, pyrolaser and optical initiator development, safety in man-machine interfaces, and a passive thermal protection system. K.K.

A89-10627
INTERNATIONAL PACIFIC AIR AND SPACE TECHNOLOGY CONFERENCE, MELBOURNE, AUSTRALIA, NOV. 13-17, 1987, PROCEEDINGS
Conference sponsored by SAE. Warrendale, PA, Society of Automotive Engineers, Inc. (SAE Proceedings P-208), 1988, 563 p. For individual items see A89-10628 to A89-10673.
(SAE P-208)

Papers are presented on such topics as a conceptual study of the H-II Orbiting Plane, V/STOL aircraft configurations and opportunities in the Pacific basin, Boeing 7J7 technology and design, space transportation systems for the future, propulsion-airframe integration for commercial and military aircraft, and X-29A forward-swept-wing flight research. Consideration is also given to the mission-adaptive wing, large space structures, boundary layer control for drag reduction, the interoperability of military and civil air-cargo systems, maintenance and airline safety, forward error correction techniques for mobile satellite communications, spacecraft mechanisms technology, modern techniques for the control of RPVs, and Space Station utilization. B.J.

A89-10716
PHYSICAL/TECHNICAL PRINCIPLES BEHIND THE DEVELOPMENT AND APPLICATION OF SPACECRAFT [FIZIKO/TEKHNICHESKIE OSNOVY SOZDANIIA I PRIMENENIIA KOSMICHESKIKH APPARATOV]
GENNADII PETROVICH DEMENT'EV, ALEKSANDR GRIGOR'EVI ZAKHAROV, and IURII KONSTANTINOVIC KAZAROV Moscow, Izdatel'stvo Mashinostroenie, 1987, 264 p. In Russian. refs

Various aspects of spacecraft design, development, and application are discussed, with some projections made concerning space programs up to the year 2000. Particular consideration is given to the functional design of spacecraft, the structural design and application of orbital complexes, the development of spacecraft with two-mode liquid rocket engines and low-thrust engines, the features of onboard computers, and advanced spacecraft construction materials. B.J.

A89-10719
PROBLEMS IN SPACE EXPLORATION [PROBLEMY OSVOENIIA KOSMOSA]
SERGEI DMITRIEVICH GRISHIN and SERGEI VASIL'EVICH CHEKALIN Moscow, Izdatel'stvo Znanie (Novoe v Zhizni, Nauke i Tekhnike. Seriia Kosmonavtika, Astronomiia, No. 1), 1988, 64 p. In Russian. refs

Articles are presented on various aspects of the Soviet space program. Particular attention is given to the development of space transportation systems, space energy supplies, construction in weightlessness, in-orbit repair and servicing, and ecological aspects of space exploration. B.J.

A89-11651
DYNAMICS AND CONTROL OF LARGE STRUCTURES; PROCEEDINGS OF THE SIXTH VPI&SU/AIAA SYMPOSIUM, BLACKSBURG, VA, JUNE 29-JULY 1, 1987
L. MEIROVITCH, ED. (Virginia Polytechnic Institute and State University, Blacksburg) Symposium sponsored by the Virginia Polytechnic Institute and State University and AIAA. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, 731 p. For individual items see A89-11652 to A89-11693.

Papers are presented on such topics as robustness optimization for the control of flexible structures, square-root filtering for continuous-time models of large space structures, a survey of decentralized control techniques for large space structures, the evaluation of two identification methods for damage detection in large space trusses, a laboratory facility for flexible structure control experiments, and the stability analysis of large space structure control systems with delayed input. Consideration is also given to the optimal control of large flexible space structures, a modified independent modal space control method for the active control of flexible systems, robots for manipulation in a microgravity environment, and the analysis and test of a space truss foldable hinge. B.J.

A89-11803
SPACE STATION AUTOMATION III; PROCEEDINGS OF THE MEETING, CAMBRIDGE, MA, NOV. 2-4, 1987
WUN C. CHIOU, SR., ED. Meeting sponsored by SPIE, IEEE, NASA, et al. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 851), 1987, 192 p. For individual items see A89-11804 to A89-11828.
(SPIE-851)

The conference presents papers on the application of artificial intelligence technology to national space programs, system and subsystem autonomy, telerobotic technology for space applications, and remote servicing platforms. Topics include testing and validation in artificial intelligence programming, common sense knowledge framework for subsystem autonomy, mission planning and simulation via intelligent agents, and system autonomy hooks and scars for Space Station. Consideration is also given to sensor integration by system and operator, intelligent training system for payload-assist module deploys, telerobot experiment concepts in space, common sense planning applied to grasping and manipulating, and Space Station flight telerobotic servicer functional requirements development. K.K.

A89-12111#
CURRENT U.S. INITIATIVES TO CONTROL SPACE DEBRIS
F. KENNETH SCHWETJE (USAF, International Law Div., Washington, DC) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 163-171. refs

The potential dangers posed by man-made space debris are reviewed, and U.S. efforts to limit debris are described. It is pointed out that the number of tracked and untracked objects is increasing rapidly and will continue to do so, with serious implications for manned missions in LEO; operation at high risk levels or redesign of spacecraft to withstand debris impact are considered unacceptable options. Accelerated decay, disposal orbits, or spacecraft retrieval are discussed as methods for reducing debris; the international legislation applying to such operations is outlined; DOD, USAF, and SDIO policy statements indicating an interest in limiting debris are cited; and the NORAD debris tracking and cataloging program and the NASA 10-year debris-assessment plan are briefly characterized. T.K.

A89-12626
ASTRODYNAMICS 1987; PROCEEDINGS OF THE AAS/AIAA ASTRODYNAMICS CONFERENCE, KALISPELL, MT, AUG. 10-13, 1987. PARTS 1 & 2
JOHN K. SOLDNER, ED. (Science Applications International Corp., Schaumburg, IL), ARUN K. MISRA, ED. (McGill University, Montreal, Canada), ROBERT E. LINDBERG, ED. (Orbital Sciences Corp., Fairfax, VA), and WALTON WILLIAMSON, ED. (Sandia National Laboratories, Albuquerque, NM) Conference sponsored by AAS and AIAA. San Diego, CA, Univelt, Inc., 1988, p. Pt. 1, 870 p.; pt. 2, 919 p. For individual items see A89-12627 to A89-12715.

Papers on astrodynamics are presented, concerning space transportation, LEO orbit determination, optimal control, gravity assist missions, precise orbit determination, multibody dynamics and tethered satellite, the NASA Mars exploration program, semianalytic satellite theory. NORAD programs, structural identification and control, planetary mission and payload analysis, celestial mechanics, satellite debris and orbit decay, the dynamics and control of rotating structures, outer planetary exploration, and attitude dynamics are also discussed. Other topics include satellite constellations and the GPS system, inner planetary exploration, attitude control, orbit analysis and synthesis, future mission studies, tracking and orbit determination, orbital dynamics, geosynchronous and high altitude orbit analysis, satellite drag coefficients, and rendezvous, intercept, and evasive maneuvers. R.B.

A89-12659
SPACE SURVEILLANCE - THE SMART CATALOG
DAVID G. COOKE (USAF, Space Surveillance Div., Peterson AFB, CO) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 569-575.
(AAS PAPER 87-450)

The current satellite population includes about 6800 objects in both near earth and deep space, much of which is satellite debris or rocket bodies left in orbit after the deployment of a payload or an operational satellite. This paper discusses the concept of a facility (termed 'SMART Catalog') which would be tasked with the job of characterizing the space debris environment and would share data with the Space Surveillance Center. The SMART Catalog will be a hybrid data base unlike any in existence today; it will include such types of data as orbital elements, uncorrelated observations, and unknown objects. Data will be sampled from both optical and radar sensors of the Space Surveillance Network, a system of sensors which make an average of 40,000 satellite observations every day and which have the capacity to catalog three or four times more data than is the level of the current catalog. I.S.

A89-12670
MODELLING UNTRACKABLE ORBITAL DEBRIS ASSOCIATED WITH A TRACKED SPACE DEBRIS CLOUD
ROBERT D. CULP and RONALD A. MADLER (Colorado, University, Boulder) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 775-790. refs
(AAS PAPER 87-472)

Untrackable satellite fragments in the 1-10 cm range associated with an individual tracked debris cloud are modeled using a computer in an attempt to obtain a more accurate estimate of their number and the hazard they represent for space operations. A sample application of the model to the calculation of the collision hazard for a typical Space Station orbit is used to illustrate the importance of accounting for the untrackable debris in evaluating the threat to large space structures. V.L.

A89-12671
THE EFFECTS OF ECCENTRICITY ON THE EVOLUTION OF AN ORBITING DEBRIS CLOUD
DAVID B. SPENCER (Aerospace Corp., Los Angeles, CA) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 791-807. refs
(Contract F04701-85-C-0086)
(AAS PAPER 87-473)

Following an orbital break-up of a spacecraft, a cloud of debris is formed, and evolves into unique orbits with respect to the parent body. A formulation of the debris cloud motion and evolutionary characteristics are described for a disintegrating body that is in an initially elliptical orbit. Results for different values of eccentricity and event time of periapsis passage are presented, and are compared to the results for the circular orbit case. Additionally, the consequences of assuming a circular orbit instead of an elliptical orbit for the object breaking up are discussed. The actual cloud size and collision hazard posed by the cloud on other spacecraft passing through it are also discussed. Author

A89-14751
MECHANICS AND SCIENTIFIC-TECHNOLOGICAL PROGRESS. VOLUME 1 - GENERAL AND APPLIED MECHANICS [MEKHANIKA I NAUCHNO-TEKHNICHESKII PROGRESS. VOLUME 1 - OBSHCHAIA I PRIKLADNAIA MEKHANIKA]
A. IU. ISHLINSKII, ED., N. N. KRASOVSKII, ED., V. V. RUMIANTSEV, ED., and V. N. RUBANOVSKII, ED. Moscow, Izdatel'stvo Nauka, 1987, 296 p. In Russian. For individual items see A89-14752 to A89-14763.

The papers presented in this volume provide an overview of recent research related to a variety of problems in theoretical and applied mechanics. Topics discussed include asymptotic methods in nonlinear mechanics, absolute stability of nonlinear periodic systems, computer algebra methods in mechanics problems, and inverse problems in the dynamics of controlled systems. The discussion also covers game theory problems concerned with the estimation of motion parameters in the presence of nonmodeled accelerations, dynamics of tethered space systems, and trajectory control problems. V.L.

A89-15501
INTERNATIONAL MODAL ANALYSIS CONFERENCE, 6TH, KISSIMMEE, FL, FEB. 1-4, 1988, PROCEEDINGS. VOLUMES 1 & 2
Conference sponsored by Union College and SEM. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. Vol. 1, 874 p.; vol. 2, 915 p. For individual items see A89-15502 to A89-15645.

Topics considered include analytical methods, structural dynamic modification, seismic topics, modal test methods, noise/acoustics, experimental techniques, finite element analysis, transducers and instrumentation, linking analysis and test, and processing modal data. Consideration is also given to space structures, machinery diagnostics, design methods, substructuring, nonlinear structures, system identification and control, and damping. B.J.

A89-15793
FREE-SPACE LASER COMMUNICATION TECHNOLOGIES; PROCEEDINGS OF THE MEETING, LOS ANGELES, CA, JAN. 11, 12, 1988
GERHARD A. KOEPF, ED. (Ball Corp., Ball Aerospace Systems Div., Boulder, CO) and DAVID L. BEGLEY, ED. (McDonnell Douglas Astronautics Co., Saint Louis, MO) Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 885), 1988, 216 p. For individual items see A89-15794 to A89-15818.
(SPIE-885)

The present conference discusses topics in free-space laser communications, laser link characteristics, satellite laser communication systems, optoelectronic components for laser communications, and space laser subsystem technologies. Attention is given to Space Station-based deep-space communication experiments, the application of intersatellite links to operational satellite systems, high-power 0.87 micron channel substrate planar lasers for spaceborne communications, a ground experiment using a CO2 laser transceiver for free-space communications, studies of laser ranging to the TOPEX satellite, diffraction-limited tracking for space communications, and the compact implementation of a real-time, acoustooptic SAR processor. O.C.

A89-15854
DOCKING/BERTHING SENSOR USING A LASER DIODE RANGEFINDER, CCD AND VIDEO TRACKER
G. STEPHEN MECHERLE (Hughes Aircraft Co., El Segundo, CA) IN: Acquisition, tracking, and pointing II; Proceedings of the Meeting, Los Angeles, CA, Jan. 14, 15, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 88-95. Research supported by the Hughes Aircraft Co.

A laser docking sensor for STS orbiter satellite retrieval, Space Station rendezvous with the OMV and STS orbiter, and orbiter/lander docking for interplanetary missions is discussed. A laser docking sensor design is presented using a laser diode rangefinder, CCD array with active laser diode illumination and multitarget video tracker. Author

A89-17670#
MOBILE SERVICING SYSTEM FLIGHT OPERATIONS AND SUPPORT
D. A. BASSETT (National Research Council of Canada, Ottawa), J. A. MIDDLETON, W. J. G. BRIMLEY, and T. W. YOUNG (SPAR Aerospace, Ltd., Toronto, Canada) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 33 p.
(IAF PAPER 88-086)

The Mobile Servicing System (MSS), Canada's contribution to the International Space Station Program will perform a vital role in the on-orbit operations of the Space Station. This role will include activities in Assembly, Maintenance, Attached Payload Servicing, and Berthing/deberthing operations. This paper provides a description of the operations role of the MSS in the Assembly Sequence of the International Space Station. The launch sequence and on-orbit checkout and integration of the early elements of the MSS will be described in detail. Berthing and cargo transfer operations between the MSS and the STS Orbiter will be discussed as will operations scenarios during the early assembly sequence. The support and training efforts in support of early operations are discussed, and a description of the Canadian Operations support facilities are provided. Author

A89-17846#
THE ORBITAL DEBRIS ISSUE - A STATUS REPORT
DARREN MCKNIGHT (U.S. Air Force Academy, Colorado Springs, CO), MALCOLM WOLFE, VLADIMIR CHOBOTOV (Aerospace Corp., El Segundo, CA), DAVID COOKE (Canadian Forces, Canada), ROBERT CULP (Colorado, University, Boulder) et al. IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 11 p. refs
(IAF PAPER 88-519)

New analytical tools, computer models, and data-gathering modes have been developed to address the expanding menace to spacecraft that is posed by the growth of orbital debris. The legal aspects of orbital debris have been discussed at international forums on space law since an international orbital debris workshop was held at NASA's Johnson Space Center in 1982; in addition, a USAF study was conducted in 1986-1987 that led to a DOD debris policy statement. Attention is given to the status of debris hazards in LEO and GEO. A Presidential Directive On Space Policy promulgated on February 11, 1988 has mandated the minimization of debris creation by future operations in orbit. O.C.

A89-17847#
COLLISION PROBABILITY OF SPACECRAFT WITH MAN-MADE DEBRIS
A. S. GANESHAN, S. C. RATHNAKARA, N. S. GOPINATH, and P. PADMANABHAN (ISRO, Flight Dynamics Div., Bangalore, India) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. refs
(IAF PAPER 88-522)

A probabilistic modeling has been conducted of the collision hazard probabilities faced by the Indian Remote Sensing (IRS) satellite due to man-made debris. This Monte Carlo approach assumes collision to occur when both the operational spacecraft and the debris come within an a priori specified volume in orbital space. This approach is also applied to the collision probabilities between two collocated geostationary satellites. The IRS's probability of debris collision is about 7.34 x 10 to the -5th impacts/year; collocated geostationary satellites' collision probability is 6.3 x 10 to the -7th. O.C.

A89-17860*# Arizona Univ., Tucson.
ECONOMICAL IN-SITU PROCESSING FOR ORBITAL DEBRIS REMOVAL
KUMAR RAMOHALLI (Arizona, University, Tucson) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct.

8-15, 1988. 8 p. NASA-supported research. refs
(IAF PAPER 88-576)

This paper proposes and develops the first description of a concept for the removal of large pieces of orbital debris. After a brief discussion of the growing importance of the general problem of orbital debris, the idea of utilizing local resources for clearing the debris is introduced. A description of the initial terrestrially working hardware and future projections for this Autonomous Space Processor for Orbital Debris concludes this paper. Author

A89-17939*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

THE EFFECT OF THE NEAR EARTH MICROMETEOROID ENVIRONMENT ON A HIGHLY REFLECTIVE MIRROR SURFACE

MICHAEL J. MIRTICH, HERMAN MARK, and WILLIAM R. KERSLAKE (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 26th, Reno, NE, Jan. 11-14, 1988. 39 p. Previously announced in STAR as N88-29833. refs
(AIAA PAPER 88-0026)

A resurgence of interest in placing large solar concentrator solar dynamic systems in space for power generation has brought up again a concern for maintaining the integrity of the optical properties of highly specular reflecting surfaces in the near earth space environment. One of the environmental hazards needing evaluation is the micrometeoroid environment. It has been shown that highly reflective polished metals and thin film coatings degrade when exposed to simulated micrometeoroids in the lab. At NASA-Lewis, a shock tube was used to simulate the phenomenon of micrometeoroid impact by accelerating micron sized particles to hypervelocities. Any changes in the optical properties of surfaces exposed to this impact were then evaluated. The degradation of optical properties of polished metals and thin metallic films after exposure to simulated micrometeoroids was determined as a function of impacting kinetic energy area of the particles. A calibrated sensor was developed to not only detect the micrometeoroid environment, but also to evaluate the degradation of the optical properties of thin aluminum films in space. Results of the simulation are presented and discussed. Author

A89-18289

AIAA/SOLE SPACE LOGISTICS SYMPOSIUM, 2ND, COSTA MESA, CA, OCT. 3-5, 1988, PROCEEDINGS

Symposium sponsored by the Society of Logistics Engineers and AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 316 p. For individual items see A89-18290 to A89-18331.

The present conference discusses topics in SDI space logistics concepts and challenges, the influence of logistical considerations on space hardware design, logistical support of ground operations, Space Shuttle logistics concepts, logistical support of orbital systems, and the AI, system-modeling, and computer aids developed for orbital system support. Attention is given to an integrated effectiveness/supportability analysis capability for SDI, new avenues in space logistics, Space Station organization, future civil space systems logistics, the Columbus logistics program, Space Station maintenance concepts, increased autonomy through satellite expert system scheduling, and applications of queuing theory to on-orbit logistics modeling. O.C.

A89-18319*# Grand Valley State Coll., Allendale, MI.

EVALUATION OF THE BENEFITS AND FEASIBILITY OF ON-ORBIT REPAIR BY COMPARISON WITH OPERATIONS IN AN ANALOGOUS ENVIRONMENT - HOW IS THE FREEDOM SPACE STATION LIKE AN OCEANOGRAPHIC EXPEDITION?

WILLIAM C. LEWIS (Grand Valley State University, Allendale; Research and Technology Institute, Grand Rapids, MI) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 8 p. NASA-supported research.
(AIAA PAPER 88-4743)

Equipment maintenance and logistics strategies followed on the R/S Thompson, an oceanographic research vessel, are described, and parallels are drawn between the problems and solutions of an oceanographic expedition and those of a space station mission. Presumably oceanic expeditions, which have been conducted for over 150 years, have developed effective methods of equipment maintenance. Similarities are found in relative budget and equipment maintenance problems, but few similarities are found in solutions to these problems. It is speculated that the high relative cost of on-orbit work is responsible, and that development of significantly more effective component level fault diagnosis equipment and repair equipment could enable application of oceanographic equipment maintenance strategies, enhancing safety and speeding laboratory work while giving significant cost reduction. Author

A89-20601

ROBOTICS AND FACTORIES OF THE FUTURE '87; PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE, SAN DIEGO, CA, JULY 28-31, 1987

R. RADHARAMANAN, ED. (San Diego State University, CA) Conference sponsored by the International Society for Productivity Enhancement, San Diego State University, U.S. Navy, et al. Berlin and New York, Springer-Verlag, 1988, 862 p. For individual items see A89-20602 to A89-20610.

The conference presents papers on planning of automation, CAD/CAM, CIM/FMS, kinematic analysis, dynamics and control, trajectory planning, and sensors and vision systems. Other topics include AI and expert systems, mobile robots/robotic devices, robot applications, automation and innovation in mining, and CAD/CAM and robotics education/training. Particular attention is given to the use of CAD systems in the design of Space Station and space robots, a kinematic model of flexible robot arms, and a state-of-the-art survey of robot programming languages. K.K.

A89-20830

GUIDANCE AND CONTROL 1988; PROCEEDINGS OF THE ANNUAL ROCKY MOUNTAIN GUIDANCE AND CONTROL CONFERENCE, KEYSTONE, CO, JAN. 30-FEB. 3, 1988

ROBERT D. CULP, ED. (Colorado, University, Boulder) and PAUL L. SHATTUCK, ED. (Martin Marietta Astronautics Co., Denver, CO) Conference sponsored by AAS. San Diego, CA, Univelt, Inc., 1988, 576 p. For individual items see A89-20831 to A89-20857.

Spacecraft attitude control and autonomy are discussed as well as guidance and control storyboard displays, offboard navigation and attitude systems, Space Station system control techniques, and recent experiences. Topics include an EOS integrated payload articulation and identification, automated low-thrust guidance for the orbital maneuvering vehicle, dithered ring laser gyros for angular rate stabilization of tracking systems, and attitude determination using GPS measurement techniques. Consideration is also given to quiet structures for precision pointing, on-orbit guidance for the Delta 180 mission, and Titan 34D-9 failure investigation and recovery. K.K.

A89-22623#

COES - AN APPROACH TO OPERATIONS AND CHECK-OUT STANDARDS

R. F. WORRON (ESA, Automation and Informatics Dept., Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 56, Nov. 1988, p. 58-65.

The accumulated costs of testing and operating a spacecraft form one of the major cost elements of any space project. As the complexity of projects increases, so do the associated costs of testing and mission control. To limit these cost factors, more account must be taken of testability and operability during the design phases of new projects. Author

A89-22891#

PROTECTION OF MANNED MODULES AGAINST MICROMETEORITES AND SPACE DEBRIS [ABSCHIRMUNG BEMANNTER MODULE GEGEN MIKROMETEORITEN UND SPACE DEBRIS]

ERNST BAUER (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) Hermann Oberth Gesellschaft, Raumfahrtkongress, 37th, Hanover, Federal Republic of Germany, May 7, 1988, Paper. 32 p. In German. refs
(MBB-UO-0004/88-PUB)

The protective measures being taken for the Columbus space vehicle to protect it against micrometeorites and space debris are discussed. The meteorites and debris environment is described, and the resulting safety requirements are examined. The design of the protective structures for Columbus is addressed, and the results of damage studies on those structures are reviewed. C.D.

A89-23448
IS THE SPACE ENVIRONMENT AT RISK?
G. B. FIELD (Harvard University, Cambridge, MA), M. J. REES (Cambridge University, England), and D. N. SPERGEL (Princeton University, NJ) Nature (ISSN 0028-0836), vol. 336, Dec. 29, 1988, p. 725, 726.

The problems posed by pollution of near-earth space are reviewed, and possible solutions are considered. Measures that need to be taken to monitor the space environment, restrict the growth of space debris and the use of nuclear reactors in space, and emphasize peaceful pursuits in space are discussed. The use of space to verify arms control treaties and the need to ban the development, testing, and deployment of ASAT systems is addressed. C.D.

A89-24476
AUTOMATIC CONTROL; PROCEEDINGS OF THE TENTH TRIENNIAL WORLD CONGRESS OF IFAC, MUNICH, FEDERAL REPUBLIC OF GERMANY, JULY 27-31, 1987. VOLUME 6
ROLF ISERMANN, ED. (Darmstadt, Technische Hochschule, Federal Republic of Germany) Congress sponsored by IFAC, International Association for Mathematics and Computer Simulation, International Federation for Information Processing, et al . Oxford, England and Elmsford, NY, Pergamon Press, (IFAC Proceedings Series, No. 11), 1988, 463 p. For individual items see A89-24477 to A89-24506.

Recent advances in control theory and applications are discussed in reviews and reports. Topics addressed include satellite control, satellite attitude control, flight control of airborne vehicles, space stations and platforms, space experiments and control of active optics, and the evolution of simulators for airborne vehicles. Consideration is given to control of ship operations, control of air and ground transportation, expert systems in on-line control, expert systems for diagnosis and performance monitoring, and the use of AI methods for control. T.K.

A89-24845
RISK ASSESSMENT FOR SAFETY
CHARLES R. HADLOCK and PETER E. GLASER (Arthur D. Little, Inc., Cambridge, MA) IN: Space safety and rescue 1986-1987. San Diego, CA, Univelt, Inc., 1988, p. 11-16. refs
(IAF PAPER 86-59B)

The application of probabilistic risk-assessment techniques to space missions is discussed, with a focus on the International Space Station. The types of hazards likely to be caused by random events; design, operational, and management errors; and intentional intervention are examined along with their secondary effects; and the top-level safety requirements defined by NASA are considered. It is suggested that such qualitative stipulations be supplemented with more quantitative measures such as used in the nuclear-power industry; the major features of such quantitative methods are reviewed. T.K.

A89-25404*# TRW, Inc., Redondo Beach, CA.
METEOROID AND ORBITAL DEBRIS SHIELDING ON THE ORBITAL MANEUVERING VEHICLE
MARC E. KIRKPATRICK (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(Contract NAS8-36800)
(AIAA PAPER 89-0495)

NASA's Orbital Maneuvering Vehicle (OMV) is being designed to withstand a 10-year lifetime in polar and low earth orbits. A large percentage of OMV's lifetime will be spent operating in the vicinity of the Space Shuttle and Space Station or in storage at these manned locations. An extensive analysis has been performed to determine the effects of the meteoroid and orbital debris environments on OMV's external fuel tanks. A finite element model of OMV was constructed using NASTRAN and analyzed with the meteoroid and debris design analysis code BUMPER. The results show that the long design lifetime, and the ever increasing man-made orbital debris environment, will require the use of shielding over the external fuel tanks. Author

A89-25868* National Science Foundation, Washington, DC.
INTERNATIONAL CONFERENCE ON ADVANCES IN COMMUNICATION AND CONTROL SYSTEMS, 1ST, WASHINGTON, DC, JUNE 18-20, 1987, PROCEEDINGS
NICHOLAS DECLARIS, ED. (NSF, Technologies Div., Washington, DC) Conference sponsored by the International Federation of Information Processing Societies and NASA. New York, Optimization Software, Inc., 1988, 224 p. For individual items see A89-25869 to A89-25875.

Theoretical models of communication and control systems are discussed in reviews and reports. Topics addressed include smoothing and identification for random fields, the information and coding capacities of mismatched Gaussian channels, recursive least-squares estimation and Kalman filtering by systolic arrays, Kemp echo digital filters, a periodic test-scheduling scheme for communication and queuing processes, and receivers for direct-sequence systems. Consideration is given to a distributed-parameter model for detecting cracks in rotors, active control of aeroelastic systems governed by functional differential equations, robust multivariable control of large space structures, finite-rank relatively bounded perturbations of semigroup generators, and sensitivity analysis of convex optimal-control problems. T.K.

A89-29111
SOLAR ENGINEERING - 1988; PROCEEDINGS OF THE TENTH ANNUAL ASME SOLAR ENERGY CONFERENCE, DENVER, CO, APR. 10-14, 1988
L. M. MURPHY, ED. (Solar Energy Research Institute, Golden, CO) and T. R. MANCINI, ED. (Sandia National Laboratories, Albuquerque, NM) Conference sponsored by ASME. New York, American Society of Mechanical Engineers, 1988, 560 p. For individual items see A89-29112 to A89-29123.

Various papers on solar engineering are presented. The general topics addressed include: testing and measurements; fundamentals of solar energy systems; solar ponds; alternative heating and cooling technologies; utility-oriented conceptual design studies for central receivers. Also discussed are: testing and advanced concepts for central receivers; distributed receiver systems; components: concentrators, receivers, and engines; solar dynamic space power; energy conversion in buildings; photovoltaic components and systems; and simulation, modeling, and optimization. C.D.

A89-30651
AIAA, ASME, ASCE, AHS, AND ASC, STRUCTURES, STRUCTURAL DYNAMICS AND MATERIALS CONFERENCE, 30TH, MOBILE, AL, APR. 3-5, 1989, TECHNICAL PAPERS. PARTS 1, 2, 3, & 4
Conference sponsored by AIAA, ASME, ASCE, AHS, and ASC. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. Pt. 1, 593 p.; pt. 2, 529 p.; pt. 3, 500 p.; pt. 4, 721 p. For individual items see A89-30652 to A89-30891.

Recent analytical and experimental investigations of structural dynamics and material behavior in aerospace applications are discussed in reviews and reports. Topics addressed include panel flutter, active control, the buckling of composite structures, FEM techniques, optimization methods, the vibration of cyclic structures, composites and laminated plates and shells, aeroelasticity, dynamics and damping, nonlinear vibrations, dynamic stability, and control and synthesis. Consideration is given to thermal structures, rotor elasticity, structural-system identification, damage/failure analysis and testing of composites, dynamic modeling, aerodynamic loading, adaptive structures, modal testing and correlation, buckling and postbuckling, space structures, acoustics and random vibration, probabilistic methods, eigenvector solution methods, impact analysis, and the accuracy of FEM solutions. T.K.

A89-30820*# Southwest Research Inst., San Antonio, TX.
A HYPERVELOCITY LAUNCHER FOR SIMULATED LARGE FRAGMENT SPACE DEBRIS IMPACTS AT 10 KM/S
R. J. TULLOS, W. M. GRAY, S. A. MULLIN (Southwest Research Institute, San Antonio, TX), and B. G. COUR-PALAIS (NASA, Johnson Space Center, Houston, TX) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1623-1628. refs
(AIAA PAPER 89-1345)

The background, design, and testing of two explosive launchers for simulating large fragment space debris impacts are presented. The objective was to develop a launcher capable of launching one gram aluminum fragments at velocities of 10 km/s. The two launchers developed are based on modified versions of an explosive shaped charge, common in many military weapons. One launcher design has yielded a stable fragment launch of approximately one gram of aluminum at 8.93 km/s velocity. The other design yielded velocities in excess of 10 km/s, but failed to produce a cohesive fragment launch. This work is ongoing, and future plans are given. Author

A89-30884*# Alabama Univ., Huntsville.
DESIGN OF A SECONDARY DEBRIS CONTAINMENT SHIELD FOR LARGE SPACE STRUCTURES
WILLIAM P. SCHONBERG (Alabama, University, Huntsville) and ROY A. TAYLOR (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 2193-2198. refs
(AIAA PAPER 89-1412)

All long-duration spacecraft are susceptible to impacts by meteoroids and pieces of orbiting space debris. Such impacts are expected to occur at extremely high speeds and can damage internal and external flight-critical systems of spacecraft. An effective mechanism is developed to protect external spacecraft subsystems against damage by ricochet particles formed during such impacts. Equations and design procedures for protective shield panels are developed based on observed ricochet phenomena and calculated ricochet particle sizes and speeds. Panel dimensions are shown to be strongly dependent on their inclination and on their distribution around a spacecraft module. It is concluded that obliquity effects of high-speed impacts must be considered in the design of any structure exposed to the meteoroid and space debris environment. Author

A89-31601
HUMAN FACTORS SOCIETY, ANNUAL MEETING, 32ND, ANAHEIM, CA, OCT. 24-28, 1988. PROCEEDINGS. VOLUMES 1 & 2
Meeting sponsored by the Human Factors Society. Santa Monica, CA, Human Factors Society, 1988, p. Vol. 1, 768 p.; vol. 2, 784 p. For individual items see A89-31602 to A89-31678.

Papers dealing with human factors in transportation are presented, covering topics such as pilot performance and simulation, Space Station design and performance, human factors design in special-purpose workstations for the Space Station, auditory spatial information and head-coupled display systems, situation awareness in aircraft systems, control and display issues, human factors in maintenance, aging, telephony and video teleconferencing, auditory and vocal communication, and aircrew station workload, design, and automation. Other subjects include approaches to user interface design, speech recognition systems, hypermedia and interfaces, the development of documentation in real time, computer screen and menu design, expert systems, human factors education, design of work environments, forensics issues, human factors and automobiles, industrial ergonomics, international technology transfer, organizational design and management, personality and human performance, mental models of complex performance, and gender, intelligence, and human performance. Additional topics include accident analysis, product safety, transportation safety, robotics/industrial safety, system development, the human-computer interface, human factors in navy systems, workload evaluation, training systems and data bases, skill aquisition, visual performance, information portrayal determinants of complex decision making, and advanced displays. R.B.

A89-31607
FORECASTING CREW ANTHROPOMETRY FOR SHUTTLE AND SPACE STATION
JOHN ROEBUCK (Roebuck Research and Consulting, Santa Monica, CA), KIM SMITH, and LOUIS RAGGIO (Rockwell International Corp., Downey, CA) IN: Human Factors Society, Annual Meeting, 32nd, Anaheim, CA, Oct. 24-28, 1988, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1988, p. 35-39. refs

Habitation module and Crew Emergency Rescue Vehicle (CERV) designs for the International Space Station to be built by the United States are expected to accommodate a wide range of persons, according to body dimensions predicted for the year 2000. This prediction was aided by the opportunity, which arose in 1985, to check actual Space Shuttle male crew anthropometry, particularly stature, against predictions made circa 1973 and by recently acquired Japanese data. Revised hypotheses discussed herein have been accepted by an Anthropometry Working Group as the bases for developing anthropometry requirements that appear in the Man-Systems Integration Standard (NASA-STD-3000), published in 1987. Pleas are made for further research in civilian anthropometry and wider use of anthropometric forecasting. Author

A89-32126
THE GAGARIN SCIENTIFIC LECTURES ON ASTRONAUTICS AND AVIATION 1987 [GAGARINSKIE NAUCHNYE CHTENIIA PO KOSMONAVTIKE I AVIATSII 1987 G.]
A. IU. ISHLINSKII, ED. Moscow, Izdatel'stvo Nauka, 1988, 168 p. In Russian. No individual items are abstracted in this volume.

Reports given at the 17th Gagarin Lectures (1987) and the 16th Lectures (1986) are presented. Works are presented on problems in flight mechanics, gas dynamics, and modern techniques for the automated design of flight vehicles. Attention is also given to space power systems, flight-vehicle structural strength, and flight-vehicle control systems. B.J.

N89-10063*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
PROCEEDINGS OF 1987 GODDARD CONFERENCE ON SPACE APPLICATIONS OF ARTIFICIAL INTELLIGENCE (AI) AND ROBOTICS
ELLEN G. STOLARIK, ed., RONALD G. LITTLEFIELD, ed., and DAVID S. BEYER, ed. 1987 718 p Conference held in Greenbelt, Md., 13-14 May 1987
(NASA-TM-89663; NAS 1.15:89663) Avail: NTIS HC A99/MF E03 CSCL 22A

Topics addressed include: planning/scheduling expert systems; fault isolation/diagnosis expert systems; data processing/analysis expert systems; expert system tools/techniques; and robotics.

N89-10838*# Joint Inst. for Advancement of Flight Sciences, Washington, DC.
PROGRAM OF RESEARCH IN STRUCTURES AND DYNAMICS Final Report
Sep. 1988 35 p

(Contract NGR-09-010-078)
(NASA-CR-183191; NAS 1.26:183191) Avail: NTIS HC A03/MF A01 CSCL 01B

The Structures and Dynamics Program was first initiated in 1972 with the following two major objectives: to provide a basic understanding and working knowledge of some key areas pertinent to structures, solid mechanics, and dynamics technology including computer aided design; and to provide a comprehensive educational and research program at the NASA Langley Research Center leading to advanced degrees in the structures and dynamics areas. During the operation of the program the research work was done in support of the activities of both the Structures and Dynamics Division and the Loads and Aeroelasticity Division. During the period of 1972 to 1986 the Program provided support for two full-time faculty members, one part-time faculty member, three postdoctoral fellows, one research engineer, eight programmers, and 28 graduate research assistants. The faculty and staff of the program have published 144 papers and reports, and made 70 presentations at national and international meetings, describing their research findings. In addition, they organized and helped in the organization of 10 workshops and national symposia in the structures and dynamics areas. The graduate research assistants and the students enrolled in the program have written 20 masters theses and 2 doctoral dissertations. The overall progress is summarized. Author

N89-10931*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE SCIENCE/SPACE STATION ATTACHED PAYLOAD POINTING ACCOMMODATION STUDY: TECHNOLOGY ASSESSMENT WHITE PAPER
RICHARD Y. LIN, KENNETH E. MANN, ROBERT A. LASKIN, and SAMUEL W. SIRLIN 15 Dec. 1987 82 p
(Contract NAS7-918)
(NASA-CR-182735; NAS 1.26:182735; JPL-PUBL-87-43) Avail: NTIS HC A05/MF A01 CSCL 22B

Technology assessment is performed for pointing systems that accommodate payloads of large mass and large dimensions. Related technology areas are also examined. These related areas include active thermal lines or power cables across gimbals, new materials for increased passive damping, tethered pointing, and inertially reacting pointing systems. Conclusions, issues and concerns, and recommendations regarding the status and development of large pointing systems for space applications are made based on the performed assessments. Author

N89-12575# Martin Marietta Corp., New Orleans, LA.
A TEACHER'S COMPANION TO THE SPACE STATION: A MULTI-DISCIPLINARY RESOURCE
LYNN P. HAGAN and LIZ ELSEN 1988 67 p Prepared in cooperation with Louisiana Nature and Science Center, New Orleans
Avail: NTIS HC A04/MF A01

The United States Space Station promises to be an adventure in enterprise and ingenuity. This collection of activities, geared for students from kindergarten through high school, promises to help them become aware of the potential of space. Within their lifetime, men and women will be living in space on a routine basis, carrying out activities once only dreamt of in books. Author

N89-12582*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
FIFTEENTH SPACE SIMULATION CONFERENCE: SUPPORT THE HIGHWAY TO SPACE THROUGH TESTING
JOSEPH STECHER, ed. 1988 492 p Conference held in Williamsburg, Va., 31 Oct. - 3 Nov. 1988; sponsored by NASA, Inst. of Environmental Sciences, AIAA, and the American Society for Testing and Materials
(NASA-CP-3015; REPT-88B0253; NAS 1.55:3015) Avail: NTIS HC A21/MF A01 CSCL 22/2

The Institute of Environmental Sciences Fifteenth Space Simulation Conference, Support the Highway to Space Through Testing, provided participants a forum to acquire and exchange information on the state-of-the-art in space simulation, test technology, thermal simulation and protection, contamination, and techniques of test measurements.

N89-12607*# Boeing Aerospace Co., Seattle, WA.
SIMULATION OF THE EFFECTS OF THE ORBITAL DEBRIS ENVIRONMENT ON SPACECRAFT Abstract Only
MICHAEL D. BJORKMAN *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 311 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

A remedy for the lack of a technique for testing the effects of orbital debris impacts has been sought along two paths at Boeing and elsewhere, firstly through the development of new launcher techniques capable of impact velocities between 8 and 16 km/s and secondly through the development of similitude techniques for modeling 8 to 16 km/s impacts using the present capabilities of projectile launchers. These two approaches are briefly discussed. Author

N89-13459* National Aeronautics and Space Administration, Washington, DC.
SPACE STATION SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 6)
Jul. 1988 294 p
(NASA-SP-7056(06); NAS 1.21:7056(06)) Avail: NTIS HC A13 CSCL 22/2

This bibliography lists 1,133 reports, articles, and other documents introduced into the NASA scientific and technical information system between July 1, 1987 and December 31, 1987. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design according to system, interactive analysis and design, structural and thermal analysis and design, structural concepts and control systems, electronics, advanced materials, assembly concepts, propulsion, and solar power satellite systems. The coverage includes documents that define major systems and subsystems, servicing and support requirements, procedures and operations, and missions for the current and future Space Station. Author

N89-13460*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PROCEEDINGS OF THE 4TH ANNUAL SCOLE WORKSHOP
LAWRENCE W. TAYLOR, JR., comp. Oct. 1988 383 p Workshop held in Colorado Springs, Colo., 16 Nov. 1987
(NASA-TM-101503; NAS 1.15:101503) Avail: NTIS HC A17/MF A01 CSCL 22/2

This publication is a collection of papers presented at the Fourth Annual Spacecraft Control Laboratory Experiment (SCOLE) Workshop held at the U.S.A.F. Academy, Colorado Springs, Colorado, November 16, 1987. The papers address the modeling, systems identification, and control synthesis for the Spacecraft Control Laboratory Experiment (SCOLE) configuration.

N89-13481* National Aeronautics and Space Administration, Washington, DC.
TECHNOLOGY FOR LARGE SPACE SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 19)
Nov. 1988 145 p
(NASA-SP-7046(19); NAS 1.21:7046(19)) Avail: NTIS HC A07 CSCL 22/2

This bibliography lists 526 reports, articles, and other documents introduced into the NASA scientific and technical information system between January 1, 1988 and June 30, 1988. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design according to system, interactive analysis and design, structural and thermal analysis and design, structural concepts and control systems, electronics, advanced materials, assembly concepts, propulsion, and solar power satellite systems. Author

N89-15149*# Battelle Columbus Labs., OH.
SPACE STATION LONG-TERM LUBRICATION ANALYSIS Monthly Progress Report, 1-30 Sep. 1985
K. F. DUFRANE and E. E. MONTGOMERY 15 Oct. 1985 7 p
Prepared in cooperation with Spectra Research Systems, Inc., Huntsville, AL
(Contract NAS8-36655)
(NASA-CR-178882; NAS 1.26:178882) Avail: NTIS HC A02/MF A01 CSCL 22/2

The objectives of this program are: (1) to perform a complete tribology survey of every point of contact in the space station subject to relative motion regarding the materials, environment, and operation characteristics, (2) to review each point of relative motion regarding the selected materials and lubricants from the standpoint of the required operating characteristics and environmental conditions, (3) to make recommendations for improvements where the lubricants and/or materials are not considered optimum, and (4) to perform or recommend simulated or full-scale tests on components where problems are possible or likely because of new designs, significant design extensions beyond current practice, or sensitivity of other components to problems with a particular point of contact. The project is to be conducted over a 3-year time frame in two phases. Phase 1 will be a preliminary analysis conducted during the preliminary design phases of the Space Station. Phase 2 will be a more detailed analysis conducted during the period when the design becomes more established. Author

N89-15159# Sandia National Labs., Albuquerque, NM.
EXPERIMENTAL OBSERVATIONS OF LOW AND ZERO GRAVITY NONLINEAR FLUID-SPACECRAFT INTERACTION
L. D. PETERSON 1988 24 p Presented at the 59th Shock and Vibration Symposium, Albuquerque, NM, 18 Oct. 1988
(Contract DE-AC04-76DP-00789)
(DE88-015263; SAND-88-1520C; CONF-881076-6) Avail: NTIS HC A03/MF A01

Low and zero gravity simulation experiments of the motion of a spacecraft coupled to the nonlinear slosh of a contained fluid are presented and discussed. A generic study model, in which a linear, spring-mass-damper spacecraft mode was coupled to the slosh of a fluid within an attached cylinder, has been studied experimentally using a unique, scale model apparatus. Low gravity was simulated in a 1 g laboratory using capillary (Bond number) scaled models, and zero gravity was simulated during experiments on the NASA KC-135 Reduced Gravity Test Facility. The mass fraction of fluid, the tuning ratio of the fluid and spacecraft vibrations, the spacecraft damping ratio, and the nondimensional gravity level were systematically varied. The nonlinear free decay response of the experimental systems exhibited system natural frequencies which varied in proportion to the square of the amplitude of the motion. The nonlinear resonance responses displayed harmonic, nonharmonic, planar, nonplanar, and spatially chaotic motions. These experimental responses can only be modeled by a nonlinear analytical model of the fluid coupled to the spacecraft model, and cannot be predicted by the simple linear slosh models now in use. DOE

N89-15572*# Oxford Univ. (England).
OBJECT ORIENTED STUDIES INTO ARTIFICIAL SPACE DEBRIS
J. M. ADAMSON and G. MARSHALL *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 163-171 Oct. 1988 Prepared in cooperation with Marshall (G.), Eastleigh (England)
Avail: NTIS HC A21/MF A01 CSCL 09/2

A prototype simulation is being developed under contract to the Royal Aerospace Establishment (RAE), Farnborough, England, to assist in the discrimination of artificial space objects/debris. The methodology undertaken has been to link Object Oriented programming, intelligent knowledge based system (IKBS) techniques and advanced computer technology with numeric analysis to provide a graphical, symbolic simulation. The objective is to provide an additional layer of understanding on top of conventional classification methods. Use is being made of object and rule based knowledge representation, multiple reasoning, truth maintenance and uncertainty. Software tools being used include Knowledge Engineering Environment (KEE) and SymTactics for knowledge representation. Hooks are being developed within the SymTactics framework to incorporate mathematical models describing orbital motion and fragmentation. Penetration and structural analysis can also be incorporated. SymTactics is an Object Oriented discrete event simulation tool built as a domain specific extension to the KEE environment. The tool provides facilities for building, debugging and monitoring dynamic (military) simulations. Author

N89-15790*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION INDUCED MONITORING
JAMES F. SPANN, ed. and MARSHA R. TORR, ed. Washington, DC Nov. 1988 85 p Conference held in Huntsville, AL, 10-11 May 1988 Sponsored by NASA, Washington
(NASA-CP-3021; M-602; NAS 1.55:3021) Avail: NTIS HC A05/MF A01 CSCL 22/2

This report contains the results of a conference convened May 10-11, 1988, to review plans for monitoring the Space Station induced environment, to recommend primary components of an induced environment monitoring package, and to make recommendations pertaining to suggested modifications of the Space Station External Contamination Control Requirements Document JSC 30426. The contents of this report are divided as Follows: Monitoring Induced Environment - Space Station Work Packages Requirements, Neutral Environment, Photon Emission Environment, Particulate Environment, Surface Deposition/Contamination; and Contamination Control Requirements.

N89-17614# Committee on Science, Space and Technology (U.S. House).
ORBITAL SPACE DEBRIS
1988 111 p Hearing before the Subcommittee on Space Science Applications of the Committee on Science, Space and Technology, 100th Congress, 2d Session, No. 112, 13 Jul. 1988
(GPO-88-188) Avail: Subcommittee on Space Science and Applications of the Committee on Science, Space and Technology, House of Representative, Washington, D.C. 20515 HC free; SOD SN 552-070-048-69-3 HC $3.00

A Hearing before the Subcommittee of Space Science Applications of the Committee on Science, Space and Technology, of the House of Representatives (100th Congress, second session), on 13 July 1988, discussed the problem of orbital space debris. Some 7000 spent spacecraft rockets, spent upper stages, separation devices, fragments of exploded systems are abandoned in Earth orbit at a rough altitude of 800 miles, where they are being tracked by radar. They present a clear danger to future space flight. In addition, there is other orbital debris too small to be tracked by present day radar. Steps are being taken by NASA and DOD to try to reduce the amount of space debris being created, and to improve the ability of radar to track the smaller bits and pieces. F.M.R.

N89-18522* National Aeronautics and Space Administration, Washington, DC.
SPACE STATION SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 7)
Dec. 1988 289 p
(NASA-SP-7056(07); NAS 1.21:7056(07)) Avail: NTIS HC A13 CSCL 22/2

This bibliography lists 1,158 reports, articles, and other documents introduced into the NASA scientific and technical information system between January 1, 1988 and June 30, 1988. Its purpose is to provide helpful information to researchers, designers and managers engaged in Space Station technology development and mission design. Coverage includes documents that define major systems and subsystems related to structures and dynamic control, electronics and power supplies, propulsion, and payload integration. In addition, orbital construction methods, servicing and support requirements, procedures and operations, and missions for the current and future Space Station are included. Author

N89-19333# Virginia Univ., Charlottesville. Dept. of Mechanical and Aerospace Engineering.

PROCEEDINGS OF THE FIFTH AFOSR FORUM ON SPACE STRUCTURES

WALTER D. PILKEY, ed. and ROBERT L. KOSUT, ed. (Integrated Systems, Inc., Palo Alto, CA.) 11 Dec. 1987 92 p Forum held at Monterey, Calif., 20-21 Aug. 1987
(Contract F49620-86-K-0009; AF PROJ. 2302)
(AD-A194761; AFOSR-88-0477TR; UVA/525673/MAE88/102)
Avail: NTIS HC A05/MF A01 CSCL 22/5

This is the Proceedings of the Fifth AFOSR Forum on Space Structures. The topics covered include modeling of spacecraft, wave propagation in large space structures, multiflexible body dynamic simulation, adaptive structures, electromechanical actuators for controlling flexible structures, system identification of suboptimal control parameters, integrated structural analysis and control, active control of elastic wave motion in structural networks, adaptive control of large space structures; analysis of performance degradation, optimal projection equations for fixed-order dynamic compensation, decentralized/relegated control for large space structures, Frobenius-Hankel norm framework for disturbance rejection and low order decentralized controller design, a method for truss structure vibration control, and robust eigenstructure assignment by a projection method.

N89-19350 Virginia Polytechnic Inst. and State Univ., Blacksburg.

DAMAGE DETECTION AND LOCATION IN LARGE SPACE TRUSSES Ph.D. Thesis

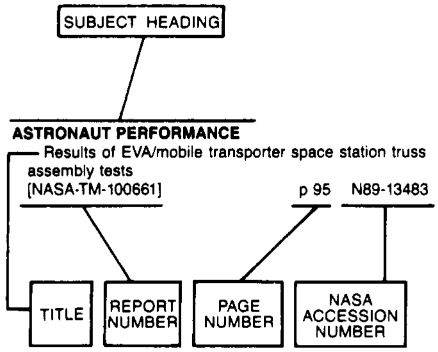
SUZANNE WEAVER SMITH 1988 139 p
Avail: Univ. Microfilm Order No. DA8817424

Researchers pursuing the goal to design and construct a large orbiting space structure are directing considerable effort toward many issues, including the ability to maneuver a flexible structure. In particular, basic research is underway into the technologies of control system design and structural modeling to support this effort. The thesis of this research is that structural damage can be detected and located with the control system of a large space structure. A concept for damage location was developed and demonstrated in simulated tests. The control system tests the structure and measures the response. The measurement are then used in a system identification algorithm to produce a model of the damaged structure. The model is compared to one for the undamaged structure to find regions of reduced stiffness which indicate the location of damage. Simulation studies were performed on two truss models. The members of both and the design of the second were borrowed form the concept design for the Space Station. Exact and inexact data simulated tests with the two structures indicated that damage can be located with this approach. Dissert. Abstr.

SUBJECT INDEX

S U B J E C T

Typical Subject Index Listing



The subject heading is a key to the subject content of the document. The title is used to provide a description of the subject matter. When the title is insufficiently descriptive of the document content, the title extension is added, separated from the title by three hyphens. The (NASA or AIAA) accession number and the page number are included in each entry to assist the user in locating the abstract in the abstract section. If applicable, a report number is also included as an aid in identifying the document. Under any one subject heading, the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

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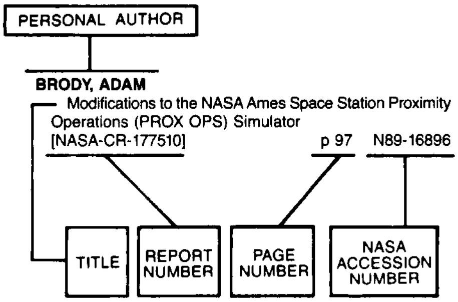
Typical Personal Author Index Listing



Listings in this index are arranged alphabetically by personal author. The title of the document provides the user with a brief description of the subject matter. The report number helps to indicate the type of document listed (e.g., NASA report, translation, NASA contractor report). The page and accession numbers are located beneath and to the right of the title. Under any one author's name the accession numbers are arranged in sequence with the AIAA accession numbers appearing first.

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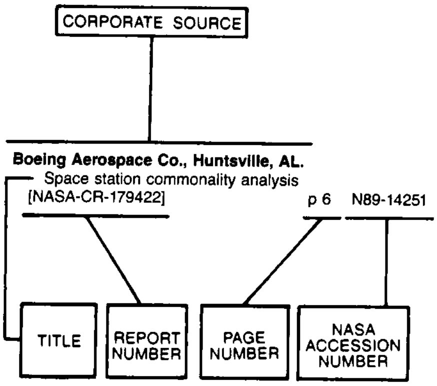
Typical Corporate Source Index Listing



Listings in this index are arranged alphabetically by corporate source. The title of the document is used to provide a brief description of the subject matter. The page number and the accession number are included in each entry to assist the user in locating the abstract in the abstract section. If applicable, a report number is also included as an aid in identifying the document.

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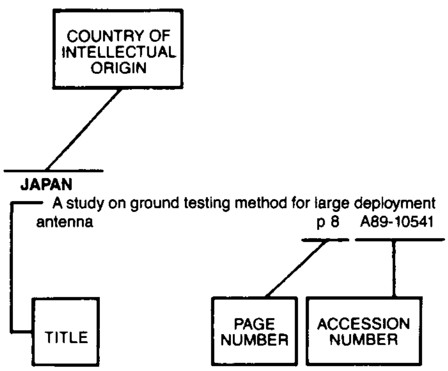
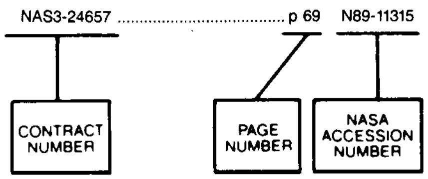
FOREIGN TECHNOLOGY INDEX

Typical Foreign Technology Index Listing



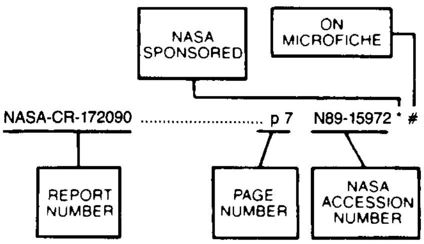
Listings in this index are arranged alphabetically by country of intellectual origin. The title of the document is used to provide a brief description of the subject matter. The page number and the accession number are included in each entry to assist the user in locating the citation in the abstract section.

Typical Contract Number Index Listing



Listings in this index are arranged alphanumerically by contract number. Under each contract number, the accession numbers denoting documents that have been produced as a result of research done under that contract are arranged in ascending order with the AIAA accession numbers appearing first. The accession number denotes the number by which the citation is identified in the abstract section. Preceding the accession number is the page number on which the citation may be found.

Typical Report Number Index Listing



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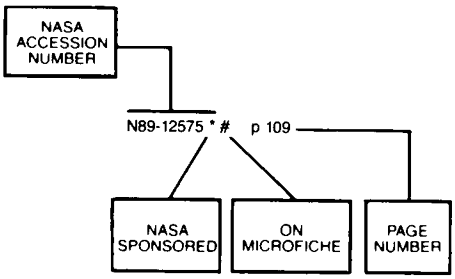

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