NASA SP-7085 (02)
May 1991

LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA

A BIBLIOGRAPHY WITH INDEXES

NASA STI PROGRAM
SCIENTIFIC & TECHNICAL INFORMATION

NASA SP-7085 (02)
May 1991

LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA

A BIBLIOGRAPHY WITH INDEXES

National Aeronautics and Space Administration
Office of Management
Scientific and Technical Information Program
Washington, DC 1991

NOTE TO AUTHORS OF PROSPECTIVE ENTRIES:

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

INTRODUCTION

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

This literature survey lists 1219 reports, articles, and other documents announced between July 1, 1990 and December 31, 1990 in *Scientific and Technical Aerospace Reports (STAR)*, and *International Aerospace Abstracts (IAA)*.

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

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

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

References appear in each category in this order:

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

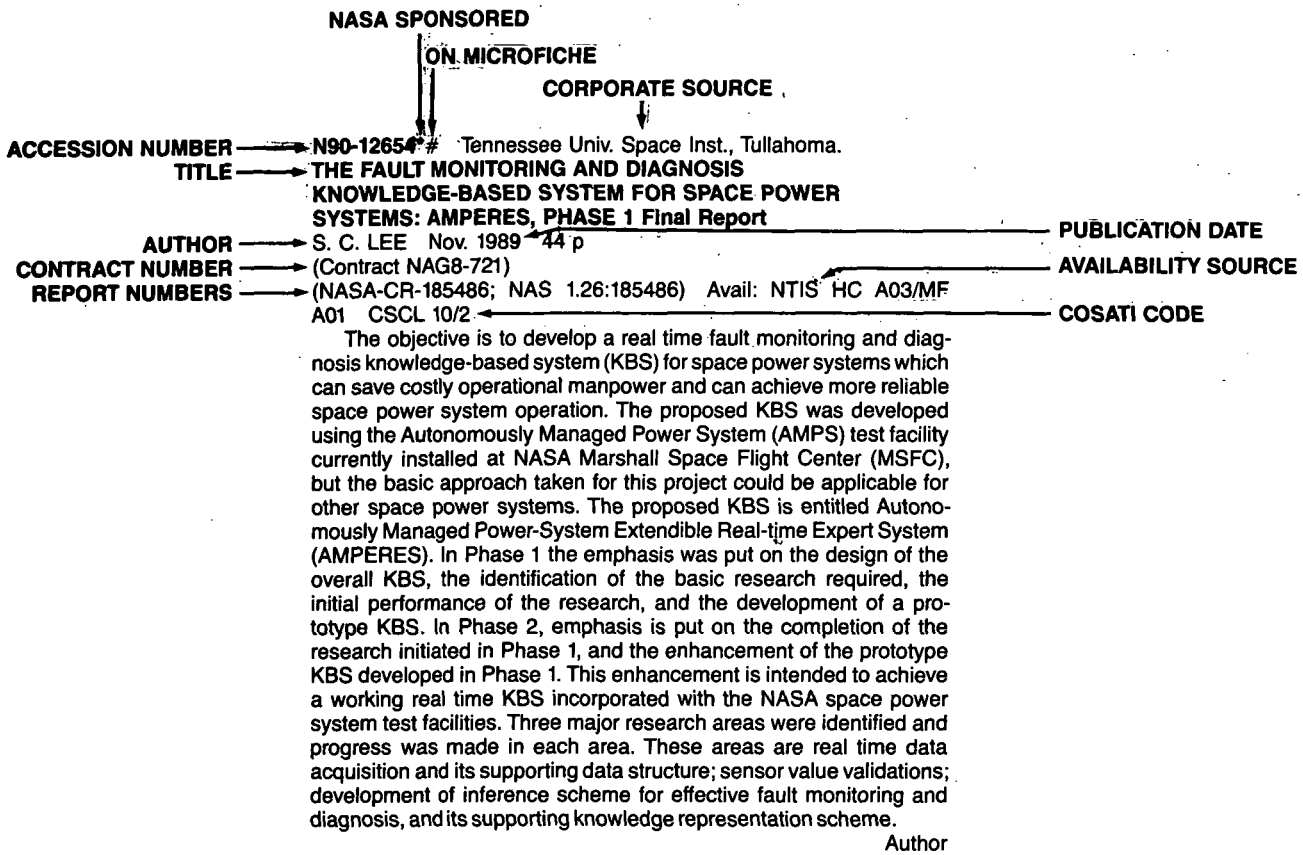
(2) *STAR* entries in ascending accession number order with the form N90-10000.

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

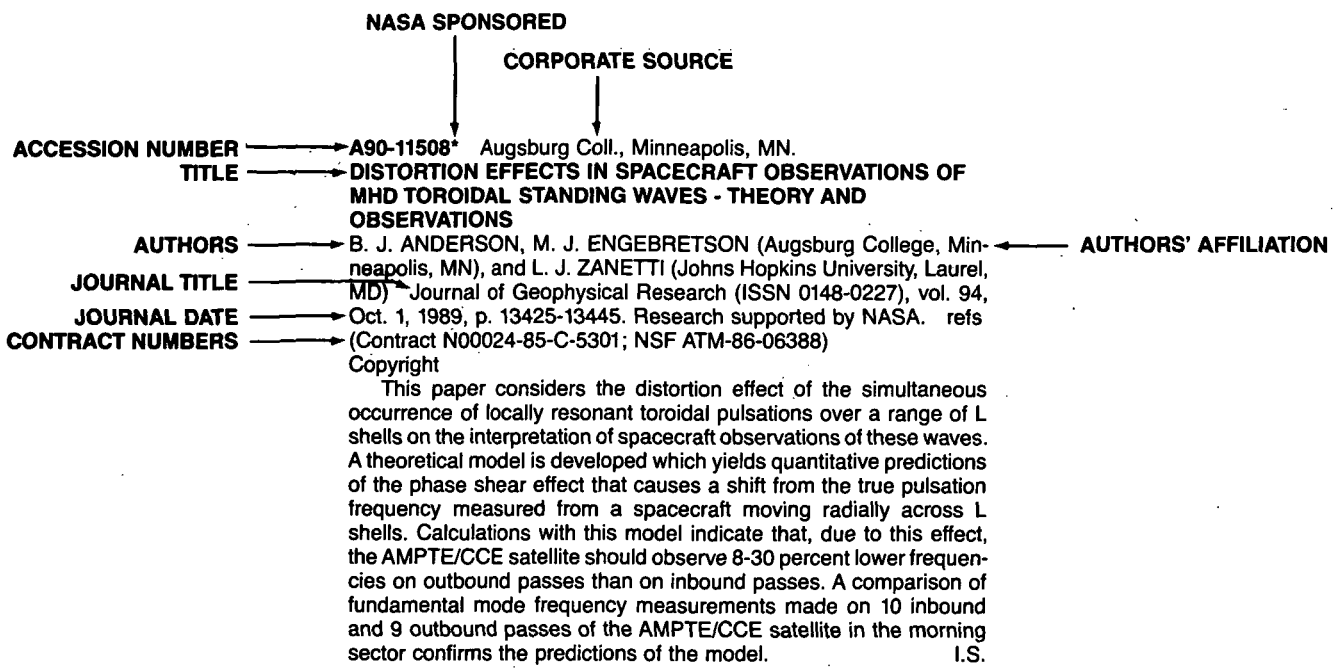
George F. Lawrence, *Space Station Office*
John J. Ferrainolo, *Technical Library Branch*

TABLE OF CONTENTS

TYPICAL REPORT CITATION AND ABSTRACT



TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA

A Bibliography (Suppl. 02)

MAY 1991

01

OVERALL DESIGN AND EVOLUTIONARY GROWTH

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

A90-33627
COLUMBUS V SYMPOSIUM ON SPACE STATION UTILIZATION; PROCEEDINGS OF THE FIFTH COLUMBUS SYMPOSIUM, CAPRI, ITALY, JULY 3-7, 1989
Symposium organized by ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al.; Supported by ASI, Aeritalia S.p.A., and Universita di Napoli. Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, 139 p. For individual items see A90-33628 to A90-33643.
Copyright

Various papers on the industrial and commercial applications of space technology are presented. Individual topics addressed include: status of the U.S. segment of Space Station Freedom, Columbus in the framework of Space Station Freedom, Canada's Mobile Servicing System, the European Data Relay System, Columbus decentralized operations: the Manned Space Laboratories Control Center (MSCC), Columbus Free Flyer Center for support of missions of the Columbus Free Flying Laboratory, small and rapid response payloads for space science with Columbus, the ESA Microgravity Program and its use of the Columbus infrastructure, Fluid Science Laboratory scientific study for Columbus, status of Biolab, the Anthrolab: human physiological research on Columbus Attached Laboratory, attached payloads support systems study, automation and robotics onboard, experience and concepts in microgravity user support, telescience: a test bed for operations, telescience concept: from TEXUS to Space Station, Teletexus experiment: preliminary experience for the Columbus program. National research programs in support of Columbus from the User Support Organization, the FRG, Italy, France, Spain, Belgium, the Netherlands, Denmark, and Norway are also addressed. C.D.

A90-36009*# NASA Space Station Program Office, Reston, VA.
SENSITIVITY STUDY OF SPACE STATION FREEDOM OPERATIONS COST AND SELECTED USER RESOURCES
ANNE ACCOLA, H. J. FINCANNON, GREGORY J. WILLIAMS (NASA, Space Station Freedom Program Office, Reston, VA), and R. TIMOTHY MEIER (Grumman Corp., Space Station Program Support Div., Reston, VA) IAA, Symposium on Space Systems Cost Estimation Methodologies and Applications, San Diego, CA, May 10, 11, 1990, Paper. 10 p.

The results of sensitivity studies performed to estimate probable ranges for four key Space Station parameters using the Space Station Freedom's Model for Estimating Space Station Operations Cost (MESSOC) are discussed. The variables examined are grouped into five main categories: logistics, crew, design, space transportation system, and training. The modification of these variables implies programmatic decisions in areas such as orbital replacement unit (ORU) design, investment in repair capabilities, and crew operations policies. The model utilizes a wide range of algorithms and an extensive trial logistics data base to represent Space Station operations. The trial logistics data base consists largely of a collection of the ORUs that comprise the mature station, and their characteristics based on current engineering understanding of the Space Station. A nondimensional approach is used to examine the relative importance of variables on parameters. N.B.

A90-42824*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
POTENTIAL ORBITAL USE OF THE SPACE SHUTTLE EXTERNAL TANKS
MAX E. NEIN and JOHN C. FIKES (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. (AIAA PAPER 90-2747) Copyright

The Space Shuttle was designed so that major components would be reusable; however, it has been shown that it would not be cost-effective to reuse the external tanks in the same manner as the solid rocket boosters. Studies have been conducted to investigate using the external tanks on orbit. Utilizing an external tank on-orbit appears simple enough, since the tank obtains 98 percent of orbital velocity during the Space Shuttle's ascent phase. However, there are many requirements, issues, and difficulties that users must be aware of and satisfy. Studies for converting an external tank into a gamma-ray imaging telescope (GRIT), conducted at NASA Marshall, have identified many of these specific issues. Results of the GRIT studies and other considerations for the potential conversion of external tanks into useful space resources are summarized. R.E.P.

A90-43366
THE SPACE STATION PROGRAMME - DEFINING THE PROBLEM
RONALD D. BRUNNER and RADFORD BYERLY, JR. (Colorado, University, Boulder) Space Policy (ISSN 0265-9646), vol. 6, May 1990, p. 131-145. refs
Copyright

The Space Station program has come under increasing pressure in the USA since its inception in 1984, to the extent that its survival is now seriously questioned. This article locates the underlying problem in a lack of resilience in the program's initial concept. It was conceived as large scale, long term and interdependent with nearly all other space programs, and hence has been vulnerable to unforeseen developments. It has also been difficult to manage effectively. The elements of the program should now be decoupled and made subject to separate evaluation in terms of a more modest, evolutionary space strategy. Author

A90-43460
THE 21ST CENTURY IN SPACE; PROCEEDINGS OF THE THIRTY-FIFTH ANNUAL AAS CONFERENCE, SAINT LOUIS, MO, OCT. 24-26, 1988
GEORGE V. BUTLER, ED. (McDonnell Douglas Astronautics Co., Huntington Beach, CA) Conference supported by McDonnell Douglas Corp. San Diego, CA, Univelt, Inc., 1990, 445 p. For

individual items see A90-43461 to A90-43485.
Copyright

Attention is given to such topics as the Space Station in the 21st century, large space structures, space utilization and applications, automation/robotics, and aerodynamics for manned Mars missions and hypervelocity flight. Consideration is also given to tracking/data, space sciences, life sciences, structures/materials, and rocket propulsion. B.J.

A90-43461* National Aeronautics and Space Administration, Washington, DC.
SPACE STATION IN THE 21ST CENTURY - INTRODUCTION
THOMAS L. MOSER (NASA, Space Station Freedom Program Office, Washington, DC) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 13-35.
(AAS PAPER 88-161) Copyright

The benefits of the Space Station Freedom (SSF) are described, and implementation paths are considered. Particular attention is given to the SSF infrastructure, option study comparisons, the program integration challenge, the Space Station assembly sequence, increment definition, supportability, Space Station R&D evolution, and the human-expedition-to-Mars concept. B.J.

A90-43462* NASA Space Station Program Office, Reston, VA.
USER'S VIEW OF SPACE STATION
ALAN C. HOLT (NASA, Space Station Freedom Program Office, Reston, VA) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 37-55.
(AAS PAPER 88-162) Copyright

It is pointed out that the current Space Station Freedom (SSF) design is the minimum station capable of satisfying the top-level user requirements, effectively incorporating the international partners, and providing the 'hooks' and 'scars' required to cost-effectively evolve the capabilites of the SSF. Research requirements have resulted in very important design drivers on the SS: three labs, three crewmembers per shift, low microgravity in the labs, minimum disturbances, high power for users, high data rates, multiple external attach points, and clean induced environment. Also addressed are the design capabilities that allow the SSF to support the development of technologies and the operations to expand the human presence in the solar system. B.J.

A90-52753
CONCEPT OF ADAPTABILITY IN SPACE MODULES
MIGUEL COOPER Journal of Aerospace Engineering (ISSN 0893-1321), vol. 3, Oct. 1990, p. 235-240.
Copyright

The space program is aiming towards the permanent use of space; to build and establish an orbital space station, a moon base and depart to Mars and beyond. The need for the total independency from the earth's natural resources and work in the design of a modular space base is emphasized. This modular concept will lead to other space goals as extensions of the primary project. The basic technology has to be defined, then relatively minor adjustments will make it possible to reach new objectives such as a first approach for a lunar base and for a Mars manned mission. This concept aims towards an open technology in which standards and recommendations will be created to assemble huge space bases and spaceships from specific modules that perform certain functions, that in combination will make it possible to reach the status of permanent use and exploration of space. Author

N90-21050*# National Aeronautics and Space Administration, Washington, DC.
THE PARTNERSHIP: SPACE SHUTTLE, SPACE SCIENCE, AND SPACE STATION
PHILIP E. CULBERTSON and ROBERT F. FREITAG 1989 15 p
(NASA-TM-102900; NAS 1.15:102900) Avail: NTIS HC A03/MF A01 CSCL 22/1

An overview of the NASA Space Station Program functions, design, and planned implementation is presented. The discussed functions for the permanently manned space facility include: (1) development of new technologies and related commercial products; (2) observations of the Earth and the universe; (3) provision of service facilities for resupply, maintenance, upgrade and repair of payloads and spacecraft; (4) provision of a transportation node for stationing, processing and dispatching payloads and vehicles; (5) provision of manufacturing and assembly facilities; (6) provision of a storage depot for parts and payloads; and (7) provision of a staging base for future space endeavors. The fundamental concept for the Space Station, as given, is that it be designed, operated, and evolved in response to a broad variety of scientific, technological, and commercial user interests. The Space Shuttle's role as the principal transportation system for the construction and maintenance of the Space Station and the servicing and support of the station crew is also discussed. Author

N90-23460*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION FREEDOM MEDIA HANDBOOK
Apr. 1989 113 p
(NASA-TM-102901; NAS 1.15:102901) Avail: NTIS HC A06/MF A01 CSCL 22/2

This handbook explains in lay terms, the work that is going on at the NASA Centers and contractors' plants in designing and developing the Space Station Freedom. It discusses the roles, responsibilities, and tasks required to build the Space Station Freedom's elements, systems, and components. New, required ground facilities are described, organized by NASA Center in order to provide a local angle for the media. Included are information on the historical perspective, international aspects, the utilization of the Space Station Freedom, a look at future possibilities, a description of the program, its management, program phases and milestones, and considerable information on the role of various NASA Centers, contractors and international partners. A list of abbreviations, a four-page glossary, and a list of NASA contacts are contained in the appendices. J.P.S.

N90-23470*# Ohio State Univ., Columbus. Dept. of Aeronautical and Astronautical Engineering.
PROJECT WISH: THE EMERALD CITY
HAYRANI OZ, LINDA SLONKSNES, ed., JAMES W. ROGERS, ed., SCOTT E. SHERER, ed., MICHELLE A. STROSKY, ed., ANDREW G. SZMEREKOVSKY, ed., and G. JOSEPH KLUPAR, ed. Jun. 1990 177 p
(Contract NASW-4435)
(NASA-CR-186692; NAS 1.26:186692) Avail: NTIS HC A09/MF A01 CSCL 22/2

The preliminary design of a permanently manned autonomous space oasis (PEMASO), including its pertinent subsystems, was performed during the 1990 Winter and Spring quarters. The purpose for the space oasis was defined and the preliminary design work was started with emphasis placed on the study of orbital mechanics, power systems and propulsion systems. A rotating torus was selected as the preliminary configuration, and overall size, mass and location of some subsystems within the station were addressed. Computer software packages were utilized to determine station transfer parameters and thus the preliminary propulsion requirements. Power and propulsion systems were researched to determine feasible configurations and many conventional schemes were ruled out. Vehicle dynamics and control, mechanical and life support systems were also studied. For each subsystem studied, the next step in the design process to be performed during the continuation of the project was also addressed. Author

N90-24176# Lockheed Missiles and Space Co., Sunnyvale, CA.
SPACE STATION FREEDOM: LIST OF ACRONYMS
1989 58 p
Avail: NTIS HC A04/MF A01

This is a pocket-type reference guide that contains, primarily,

an alphabetized list of acronyms related to NASA's Space Station program. It also contains a brief Hardware Development Dictionary; an International System of Units (SI) list of prefixes and their numerical values and symbols; a list of SI unit names and symbols; the chemical elements and their symbols; metric conversion formulas for area, length, power, temperature and velocity/speed; and a list of NASA's official national and foreign offices. J.P.S.

N90-25154*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A STUDY OF CONCEPT OPTIONS FOR THE EVOLUTION OF SPACE STATION FREEDOM
HERBERT R. KOWITZ, KAREN D. BRENDER, WILLIAM M. CIRILLO, LISA COLLIER, GEORGE G. GANOE, MARSTON J. GOULD, MARTIN KASZUBOWSKI, GEORGE F. LAWRENCE, CHARLES P. LLEWELLYN, and RAY REAUX (Computer Technology Associates, Inc., Rockville, MD.) May 1990 77 p
(NASA-TM-102675; NAS 1.15:102675) Avail: NTIS HC A05/MF A01 CSCL 22/1

Two conceptual evolution configurations for Space Station Freedom, a research and development configuration, and a transportation node configuration are described and analyzed. Results of pertinent analyses of mass properties, attitude control, microgravity, orbit lifetime, and reboost requirements are provided along with a description of these analyses. Also provided are brief descriptions of the elements and systems that comprise these conceptual configurations. Author

N90-25175*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A DESIGN OPTIMIZATION PROCESS FOR SPACE STATION FREEDOM
ROBERT G. CHAMBERLAIN, GEORGE FOX, and WILLIAM H. DUQUETTE 15 Jun. 1990 46 p
(Contract NAS7-918)
(NASA-CR-186851; NAS 1.26:186851; JPL-PUBL-90-23) Avail: NTIS HC A03/MF A01 CSCL 22/2

The Space Station Freedom Program is used to develop and implement a process for design optimization. Because the relative worth of arbitrary design concepts cannot be assessed directly, comparisons must be based on designs that provide the same performance from the point of view of station users; such designs can be compared in terms of life cycle cost. Since the technology required to produce a space station is widely dispersed, a decentralized optimization process is essential. A formulation of the optimization process is provided and the mathematical models designed to facilitate its implementation are described. Author

N90-25189# Deutsche Gesellschaft fuer Luft- und Raumfahrt, Bonn (Germany, F.R.).
THE JET ENGINE: 1932 [DER STRAHLMOTOR: 1932]
JOHANNES WINKLER 1989 180 p In GERMAN
(ISBN-3-922010-49-0; ETN-90-96784) Avail: NTIS HC A09/MF A01

A first publication of a 1932 manuscript about motors is presented. Several topics are addressed: thermodynamics of booster motors, Ziolkouski equations, space vehicles, flight stability, aerodynamic braking, space stations and intercontinental rockets. For mean powers, solid fuels were advisable. In the case of liquid fuels, methane and hydrogen are recommended because of their high potential energy. ESA

N90-26712# European Space Agency, Paris (France).
TECHNICAL CHARACTERISTICS AND FUNCTIONS OF DIFFERENT TYPES OF SPACE STATIONS [LES CARACTERISTIQUES TECHNIQUES ET LES FONCTIONS DES DIVERS TYPES DE STATIONS SPATIALES]
J.-J. DORDAIN . *In its* Manned Space Station: Legal Aspects p 19-26 Jan. 1990 In FRENCH
Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

Skylab, MIR, and the International Space Station Freedom are described. The Columbus program involved in the Freedom Space Station is given particular attention. Reduced gravity effects, operational characteristics, and access by different categories of users are described. Possible uses of space stations are described. Physiological aspects of reduced gravity are discussed especially as concerns circulation. An operations scenario for the use of a space station is reviewed. The complexities involved in combining a huge number of participants and users are described. ESA

N90-29422# National Aerospace Lab., Tokyo (Japan). Space Station Working Group.
UTILIZATION OF SPACE STATION, PART 3 [UCHU SUTE-SHON NO RIYOU NITSUITE (SONO SAN)]
YASUTOSHI INOUE, YASUO WATANABE, SEISHIROU KIBE, KOTARO MATSUMOTO, MASAO NAKA, HIROMICHI YAMAMOTO, KEIJI NITTA, TOSHIHARU TANEMURA, YOSHINORI FUJIMORI, KOJI OHTSUBO et al. Oct. 1988 86 p In JAPANESE
(NAL-TM-597-PT-3; ISSN-0452-2982; JTN-90-80187) Avail: NTIS HC A05/MF A01

Research on the utilization of the space environment has been performed since 1985. This research is very important because the international space station becomes available in 1994. In the space development committee, the policy of space development in Japan is under discussion and the development of space structure in orbit and aerospace planes is likely to be planned. This research is thought to become more important under such circumstances. The members of the working group on the space station in National Aerospace Laboratory Japan discussed the utilization of the space environment in 1987. Topics offered in the discussion are examined. Included items are: (1) Deployable Truss Beam; (2) Regeneration and Circulation System for Water and Gas; (3) Utilization of Catalyst for the Treatment of Excrement; (4) Payload-Tether System; (5) Boomerang Payload; (6) Expert System for Space Experiment; (7) Solar Rocket; (8) Collector Type Solar Power System; and (9) Mirror Segment for Solar Collector. NASDA

N90-30158*# Virginia Univ., Charlottesville.
A LUNAR SPACE STATION
LU TRINH, MARK MERROW, RUSS COONS, GABRIELLE IEZZI, HOWARD M. PALARZ, MARC H. NGUYEN, MIKE SPITZER, and SAM CUBBAGE 1989 115 p
(Contract NASW-4435)
(NASA-CR-186223; NAS 1.26:186223) Avail: NTIS HC A06/MF A01 CSCL 13/2

A concept for a space station to be placed in low lunar orbit in support of the eventual establishment of a permanent moon base is proposed. This space station would have several functions: (1) a complete support facility for the maintenance of the permanent moon base and its population; (2) an orbital docking area to facilitate the ferrying of materials and personnel to and from Earth; (3) a zero gravity factory using lunar raw materials to grow superior GaAs crystals for use in semiconductors and mass produce inexpensive fiber glass; and (4) a space garden for the benefit of the air food cycles. The mission scenario, design requirements, and technology needs and developments are included as part of the proposal. B.G.

02

POLICIES AND INTERNATIONAL COOPERATION

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

A90-32950
SPACE - JAPAN'S NEW FRONTIER

MICHAEL CROSS New Scientist (ISSN 0262-4079), vol. 126, April 21, 1990, p. 53-57.
Copyright

Japan's two institutions concerned with space exploration and development, namely the National Space Development Agency (NASDA) and the much smaller Institute for Space and Astronautical Science, divide their responsibilities in such a way that the former develops space-exploitation technology, while the latter conducts observations; in practice, overlapping of responsibilities has been unavoidable. In June of 1989, Japan's coordinating Space Activities Commission announced a 10-year plan which for the first time emphasized manned space missions, using the next-generation H II launch vehicle that is scheduled to begin operating in 1993. For NASDA's engineers, the most important H II launcher cargo will be the HOPE manned reusable spacecraft. O.C.

A90-33075* NASA Space Station Program Office, Reston, VA.
SPACE STATION FREEDOM - A PROGRAM UPDATE
WILLIAM B. RANEY (NASA, Space Station Freedom Program Office, Reston, VA) (IAF, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989) Acta Astronautica (ISSN 0094-5765), vol. 22, 1990, p. 49-56.
Copyright

A conceptual and programatic development status evaluation is presented for the NASA Space Station Freedom. A first Freedom-element launch by the Space Shuttle is planned for 1995, with completion of the assembly process by 1998. Man-tended capability is expected to be established by one of the early Space Shuttle assembly flights; a permanently manned capability is expected to be in place by 1996. This construction schedule fundamentally depends, however, on the availability of a replacement Space Shuttle Orbiter whose delivery is expected to occur in May 1991. Attention is given to the international-cooperation aspects of the program. O.C.

A90-33628* National Aeronautics and Space Administration, Washington, DC.
SPACE STATION FREEDOM - STATUS OF THE U.S. SEGMENT
JOHN DAVID F. BARTOE (NASA, Office of Space Station, Washington, DC) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 5-8.
Copyright

An overview of the Space Station Freedom program is given. The results of a technical audit of the U.S. program, and the reorganization taking place at NASA HQ are discussed. Some areas resolved in the past year such as the type of power to be delivered to each pressurized module and the definition of common payload interfaces within all modules are reviewed. The utility of the Space Station Freedom is emphasized. N.B.

A90-36023#
THE ROLE OF COST MODELS IN MAJOR SPACE PROGRAMMES
R. P. ROGERS, H. C. LEESON (Logica Space and Defence Systems, Ltd., London, England), and A. P. FOURNIER-SICRE (ESA, Noordwjik, Netherlands) IAA, Symposium on Space Systems Cost Estimation Methodologies and Applications, San Diego, CA, May 10, 11, 1990, Paper. 12 p.

The use of modeling techniques applied to operations costs in the European Columbus program is discussed. Some of the key attributes of the cost modeling technique when applied to complex space programs are identified, and the main characteristics required in such models are examined. Two concrete examples of the use of purpose-built cost models, including COLUCOU (Columbus costs of operation and utilization), in the early stages of a project, for two different purposes (trade-offs of different technical options and the examination of the consequences of different cost sharing alternatives for a given option) are presented. It is concluded that such models can play an important role at the early phases of a large project, particularly in performing simple parametric evaluations and identifying the true cost drivers. N.B.

A90-36124#
THE INTERNATIONAL SPACE PROJECT 'PRIRODA' [MEZHDUNARODEN TSELEVI KOSMICHESKI PROEKT 'PRIRODA']
DIMIT'R MISHEV and TODOR NAZ'RSKI B'lgarska Akademiia na Naukite, Spisanie (ISSN 0007-3989), vol. 36, no. 1, 1990, p. 35-40. In Bulgarian.

The main objectives of the Priroda project are outlined. The Priroda project, which is part of the Intercosmos program, is a remote sensing project intended to study the characteristics of the earth's land masses, oceans, and atmosphere. Consideration is given to the instrumentation for the Priroda project and the installation of the Priroda instruments on a special module of the Mir space station. Specific emphasis is placed on the role of Bulgaria in the Priroda project, focusing on a dual-polarization radiometric system constructed in Bulgaria. R.B.

A90-36742
CAN NASA STILL DO THE JOB?
DAVID F. SALISBURY (California, University, Santa Barbara) Planetary Report (ISSN 0736-3680), vol. 10, May-June 1990, p. 18-23.
Copyright

This paper reports on an interview with six former officials of NASA, concerning the future of this agency. Most of these NASA veterans profess at least cautious optimism about the future of the space program. When asked what they considered NASA's major strength, the group members cited the ability of NASA to tackle very large and tough system problems; the willingness to take on the 'impossible' assignments and the persistence to carry them out; and the ability to excite the imagination of its employees and industry associates. A view was expressed that the plan that President Bush put forward on the 20th anniversary of Apollo 11 flight has laid the 'exactly right' stepping stones for NASA: first a space station, then a lunar outpost, and, finally, a human mission to Mars. However, some of the NASA veterans expressed reservations on several fronts (e.g, the increased age of the NASA people, the growing risk aversion by the agency, and the increased external oversight). I.S.

A90-38815
THE UNITED STATES PROPOSED PATENT IN SPACE LEGISLATION - AN INTERNATIONAL PERSPECTIVE
G. LAFFERRANDERIE (ESA, Paris, France) Journal of Space Law (ISSN 1012-3431), vol. 18, no. 1, 1990, p. 1-10. refs
Copyright

Consideration is given to the impact of a U.S. Congressional bill to amend Section 105 of the Patent Act (1982) stating that an invention made, used, or sold on a space object under U.S. jurisdiction shall be deemed to have been made for use in the U.S. It is suggested that the proposed bill may not be compatible with the International Space Station Agreement and other U.S. treaty obligations, such as the UN Outer Space Treaty. The relationship between 'jurisdiction and control' and 'registration' detailed in the Outer Space Treaty is discussed in relation to the proposed bill. R.B.

A90-38848* George Washington Univ., Washington, DC.
TOWARDS A COHERENT REMOTE SENSING DATA POLICY
LISA R. SHAFFER (George Washington University, Washington, DC) and PETER BACKLUND (SM Systems and Research Corp., Washington, DC) Space Policy (ISSN 0265-9646), vol. 6, Feb. 1990, p. 45-52. Research supported by NASA.
Copyright

Access to space-based remote sensing data is critical for earth science and the study of global change. This article summarizes a variety of U.S. government earth science data policies and problems. The authors examine current efforts to develop data policies for the next generation of U.S. remote sensing programs,

noting likely problems based on past experiences. They argue that the goal of U.S. earth science data policy should be to provide the widest possible dissemination of data. Setting such a goal permits the development of a simple, coherent data policy that serves scientific, commercial, and U.S. government interests.
Author

A90-38849
CANADA'S SPACE PROGRAMME
JOCELYN MALLETT (Canadian Space Agency, Ottawa, Canada) Space Policy (ISSN 0265-9646), vol. 6, Feb. 1990, p. 53-59.
Copyright

This article provides an overview from a government perspective of Canada's space-related activities and projects since the 1950s. The development of the national space program is outlined, and its main characteristics are described, such as the emphasis on the use of space to develop the country's industrial base, encouragement of commercialization, the centrality of international cooperation, and a concern to spread the benefits of the program equitably across the regions of Canada. Author

A90-38850
CANADIAN SPACE POLICY
JOHN KIRTON (Toronto, University, Canada) Space Policy (ISSN 0265-9646), vol. 6, Feb. 1990, p. 61-71. refs
Copyright

Canada's geography made it an early leader in the development of space technology, and generated a civilian-oriented, terrestrially focused space program with a strong focus on communications and an increasing emphasis on transferring space technology and activity from the government to the private sector. During the 1980s Canada's space program has strengthened and broadened measurably; it now contains major projects in earth observation and robotics, as well as communications, and has diversified its international partnership from the U.S. to Europe. However, persisting weaknesses in launch capability, space science, and military space programs, and the dependence of all three current major projects (Msat, Radarsat, and the International Space Station's Mobile Servicing System) on the U.S. represent potential vulnerabilities which require national investments and expanded international affiliations if they are to be offset. Author

A90-38930
EAST-WEST COOPERATION IN MANNED SPACEFLIGHTS - WHY?
J.-L. CHRETIEN (CNES, Toulouse, France) (IAA, International Astronautical Congress, 40th, Malaga, Spain, Oct. 7-13, 1989) Acta Astronautica (ISSN 0094-5765), vol. 21, April 1990, p. 281, 282.
Copyright

The advantages of cooperation in east-west manned space missions are briefly discussed. The exchange of technical and scientific experiences and of crew experiences have considerable significance. Most important is the resultant increased efficiency of safety and rescue abilities. Active cooperation would bring both U.S. and Soviet space stations into close cooperation and would prepare for the realization of an international space station. C.D.

A90-41151
MIR MISSION REPORT - COSMONAUTS FLY THEIR 'SPACE MOTORCYCLE'
NEVILLE KIDGER Spaceflight (ISSN 0038-6340), vol. 32, July 1990, p. 228-233.
Copyright

Activities on the Soviet Mir space station during the period January-May 1990 are reviewed and illustrated with diagrams and photographs. Particular attention is given to the installation and apparently successful testing of the SPK-1 manned maneuvering unit during three EVAs in late January and early February. Also described are the undocking of the Progress M-2 cargo spacecraft, the preparation and launch of Soyuz TM-9 (bearing two replacement cosmonauts) on February 11, the return to earth of Soyuz TM-8 on February 18, the docking and undocking of Progress M-3, the hatching and later death of quail chicks, delays in the launch of the Kristall material-science module, the arrival of Progress 42, and preparations to receive Kristall at the end of May. T.K.

A90-43364
EUROPEAN-US SPACE COOPERATION AT THE CROSSROADS
PETER CREOLA (Eidgenoessisches Departement fuer auswaertige Angelegenheiten, Bern, Switzerland) Space Policy (ISSN 0265-9646), vol. 6, May 1990, p. 97-106.
Copyright

The changing geopolitical situation offers unparalleled opportunities for space cooperation. However, thanks to U.S.insistence on retaining control, the history of past U.S.-European cooperation in space has been fraught with difficulties and disappointments, not least of which is the current debacle over the international Space Station. This and other cooperative ventures are analyzed, and the need for truly equitable partnerships is argued. In conclusion, a model for an expedition to Mars which could form the basis for real global cooperation in space is presented. Author

A90-43804#
SPACE ACTIVITIES IN THE NETHERLANDS
Ruimtevaart, June 1990, p. 5-12.

An overview of space programs in the Netherlands is presented. The strong points of the Dutch space system design and engineering are solar arrays, robotics, thermal subsystems, sensors, data handling and workstations. More than fifty scientific institutes and universities are involved in space research projects. Space technology items such as robotics, multimedia systems, and workstations can be applied in both civil and space projects, possibly providing useful spinoffs. Examples of Dutch space technology are briefly discussed, including robotics for Hermes and Columbus, and workstations and multimedia systems for Columbus. L.K.S.

A90-43806#
SPACE PROJECTS IN THE NETHERLANDS
Ruimtevaart, June 1990, p. 25-29.

Dutch space activities concentrate on participation in ESA programs, but also include some national projects such as cooperative projects with one or two other countries, and space technology and space science programs. The technology program supports developments in the Dutch industry including space structures, thermal control, robotics, telescience, simulation and, to a larger extent, solar array developments. Participation in mandatory ESA programs includes contributions to Hipparcos and the Infrared Space Observatory, while work on optional ESA programs centers on telecommunications; remote sensing or earth observation; and Columbus studies on solar arrays, thermal control subsystems, and crew work stations. Over 20 microgravity experiments dealing with fluid science, metallurgy, biology, physiology, chemistry, and physics are also discussed. L.K.S.

A90-45696
JAPAN'S SPACE PROGRAM - BUILDING FOR THE 21ST CENTURY
CRAIG COVAULT (Tanegashima Space Center, Japan) Aviation Week and Space Technology (ISSN 0005-2175), vol. 133, Aug. 13, 1990, p. 36-43, 62-67, 70-72.
Copyright

Japan is gearing its space program toward space station operations, development of an infrastructure for manned flight, and the launch of spacecraft to the moon, Venus, and Mars. The National Space Development Agency (NASDA) is responsible for handling large boosters and applications satellites. The Institute of Space and Astronautical Science (ISAS) develops medium boosters and science spacecraft. Japan's Ministry of Trade and Industry along with ISAS and NASDA is developing the 3.8-ton Space Flyer, the nation's first large retrievable satellite. The new H-2 launch facilities rival the largest U.S. or European sites. In addition, a large new rocket engine test stand has been constructed

to test fire the oxygen/hydrogen LE-7 main engine that powers the first stage of the H-2 heavy booster. Initial space flight missions include the OREX orbiting reentry experiment, which is part of the HOPE spaceplane development. Launching of the ETS-6 is planned to demonstrate advanced geosynchronous satellite technologies. The Japanese Space Flyer, a 3.8-ton reusable spacecraft to carry various payloads, is scheduled for launch into a low earth orbit in late 1994. Additional details are provided for the HOPE unmanned spaceplane, the Marine Observation Satellites, the Earth Resources Satellite, and the Advanced Earth Observing Satellite. R.E.P.

A90-47526
JUNO AND THE BUSINESS-SPACE GAP
PATRICK COLLINS (Imperial College of Science, Technology, and Medicine, London, England) Space Policy (ISSN 0265-9646), vol. 6, Aug. 1990, p. 184-186. refs
Copyright

The problem of reconciliation between the scientific and commercial aspects of the Juno mission to send the UK's first astronaut to conduct microgravity experiments on board Mir and subsequent loss of funding for the mission are discussed. An analysis is presented of what went wrong with the project and it is argued that the scientific community can potentially benefit from popular interest in space travel. L.K.S.

A90-47912
THE SOVIET YEAR IN SPACE 1989
NICHOLAS L. JOHNSON Colorado Springs, CO, Teledyne Brown Engineering, 1990, 186 p. refs
Copyright

Soviet space activities during 1989 are characterized on the basis of press reports, articles in scientific journals, and unclassified satellite tracking data. Sections are devoted to support systems (launch facilities, launch vehicles, and infrastructure), photographic reconnaissance satellites, communication satellites, navigation and geodetic satellites, meteorological and remote-sensing satellites, scientific satellites, dedicated military satellite systems, manned space programs (the Mir space station and the Buran space shuttle), and solar-system exploration (especially the Phobos mission). Extensive diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

A90-48419*# National Aeronautics and Space Administration, Washington, DC.
FREEDOM IS AN INTERNATIONAL PARTNERSHIP
RICHARD H. KOHRS (NASA, Washington, DC) Aerospace America (ISSN 0740-722X), vol. 28, Sept. 1990, p. 20-22.
Copyright

The NASA Space Station Freedom (SSF) project initiated in 1984 is a collaborative one among the U.S., Japan, Canada, and the 10 nations participating in ESA. The SSF partners have over the last six years defined user requirements, decided on the hardware to be manufactured, and constructed a framework for long-term cooperation. SSF will be composed of user elements furnished by the foreign partners and a U.S.-supplied infrastructure encompassing the truss assembly, electrical power system, and crew living quarters. The U.S. will also furnish a lab and a polar-orbit platform; ESA, a second lab and the coorbiting Free-Flying Laboratory, as well as a second polar platform. Japan's Japanese Experiment Module shall include an Exposed Facility and an Experimental Logistics module. Canada will contribute the Mobile Servicing System robotic assembler/maintainer for the whole of SFF. O.C.

A90-48420#
INTERNATIONAL ANTECEDENTS
RICHARD BARNES Aerospace America (ISSN 0740-722X), vol. 28, Sept. 1990, p. 23-25.
Copyright

A history is presented for the emergence of space research-oriented foreign agencies, their growing cooperation, and ultimately comprehensive collaboration in the Space Station Freedom development effort in which NASA, ESA, and the space establishments of Japan and Canada are engaged. ESA/NASA cooperation has already accomplished Spacelab construction and orbital operations. The prospects for the drawing of the USSR into a Mars exploration partnership with NASA, ESA, etc, are noted. O.C.

A90-48421#
CANADA'S CRITICAL ROLE IN FREEDOM
KARL H. DOETSCH (Canadian Space Agency, Ottawa, Canada) Aerospace America (ISSN 0740-722X), vol. 28, Sept. 1990, p. 25, 26, 28, 30.
Copyright

Canada has chosen to participate in the Space Station Freedom (SSF) through the development and operation of the Mobile Servicing System (MSS); the MSS program will be managed by the Canadian Space Agency formed in 1989, and has as its basic aim the minimization of SSF crews' EVA requirements and general dependence on earth-based support resources. The MSS component of the SSF will encompass a Mobile Servicing Center (MSC), a Maintenance Depot, and the Special Purpose Dexterous Manipulator (SPDM). The MSC will be controlled by the SSF crew from internal work stations. The Maintenance Depot will be attached to the truss structure for MSS servicing and large structure assembly. The SPDM will give the MSS a dexterous capability for SSF assembly, self-maintenance, and in situ attached-payload servicing. O.C.

A90-48422#
THE COLUMBUS PROGRAM AND FREEDON
FRANK LONGHURST (ESA, Paris, France) Aerospace America (ISSN 0740-722X), vol. 28, Sept. 1990, p. 31, 32, 34, 35.
Copyright

The ESA Columbus Development Program (CDP) associated with NASA's Space Station Freedom will cover the development, manufacture, and delivery to orbit of the Columbus Attached Laboratory, the Polar Platform, and the Free Flying Laboratory. CDP will accomplish these goals with the further intention of optimizing the technical, operational, and programmatic coherence of Freedom with three other ESA programs: the manned Hermes project, the Ariane 5 launch vehicle, and the European Data Relay Satellite. As part of a second developmental phase from the late 1990s onward, Columbus will furnish a comprehensive infrastructure that can not only fulfil Freedom's cooperative requirements but also form the basis of an autonomous ESA capability for manned flights. O.C.

A90-48423#
JAPAN GETS MANNED SPACE EXPERIENCE
NEIL W. DAVIS Aerospace America (ISSN 0740-722X), vol. 28, Sept. 1990, p. 36-38.
Copyright

NASDA's Japanese Experimental Module (JEM) for the NASA Space Station Freedom will give Japan's space industry the opportunity to develop and test manned hardware and its requisite software at a far earlier date than would otherwise be possible, and at substatially lower cost than an independent program. JEM will be a lab of 4 m diameter and 10 m length, weighing almost 10 tonnes; it will be equipped with an Experiment Logistics Module above its main frame, a robot arm, and an 8-m long 'exposed' facility extending from its aft section. Japanese, Canadian, and U.S. weightlessness experimentation will be conducted within the JEM. O.C.

A90-48523
JAPAN'S SPACE PROGRAM. II
Aviation Week and Space Technology (ISSN 0005-2175), vol. 133, Aug. 20, 1990, p. 70, 71, 74, 79, 82.
Copyright

The Space Flyer Unit (SFU), a 3.8-ton reusable spacecraft, is being developed to carry diverse space technology experiments for Japanese companies and government agencies to be launched on the third H-2 booster mission in 1994. A U.S. Space Shuttle is programmed to recover the SFU some six months after the launch

of the satellite. The program is aimed at providing the agencies and companies frequent access to space for experiments, in particular, advanced materials research, which is best suited for a free-flying satellite. With three furnaces on board, the satellite will process multiple materials samples including some involved in the development of advanced semiconductors. Japan is also developing facilities that will lead to the launch in 1998 of an experiment module and its space exposure platform to the U.S./international Space Station Freedom. Plans are also being formulated to fly an aerospace plane research aircraft and to later develop a scramjet powered prototype vehicle as part of an international project. R.E.P.

A90-48525
JAPAN'S SPACE PROGRAM. III
CRAIG COVAULT Aviation Week and Space Technology (ISSN 0005-2175), vol. 133, Aug. 27, 1990, p. 72-83.
Copyright

The Spacelab J mission scheduled for launching on the orbiter Atlantis in 1991 will lay the foundation for an autonomous Japanese manned space-flight capability. Japanese contributions to the mission include 35 experiments and a number of Spacelab materials processing and life sciences devices that will be mounted in the European-constructed Spacelab pressurized module. The crew will consist of six U.S. astronauts and a Japanese payload specialist. Japan's part of the flight is called the first materials processing test (FMPT) and will carry several semiconductor and other materials experiments sponsored by Japanese industry. Materials facilities on the FMPT will include a continuous heating furnace, a gradient heating furnace, and a large isothermal furnace. Japan is also building two new spacecraft to image violent solar flares on the sun and evaluate the effects of the solar wind on earth. Also under development is an advanced spacecraft for deep space X-ray astronomy and radio astronomy. Additional studies will focus on stations, lunar bases, and launchers. R.E.P.

A90-49773
LET THE CONSTRUCTION BEGIN
A. ROYCE DALBY Ad Astra (ISSN 1041-102X), vol. 2, July-Aug. 1990, p. 15-22.
Copyright

The construction of Space Station Freedom, scheduled to begin in December 1990, and its intended purposes are described. The contributions of various components by the four major partners on the project, the U.S., Japan, ESA, and Canada are outlined, and it is noted that Italy may soon participate by adding a pressurized attached logistics module to the Space Station. A schedule for development and assembly is presented, giving assembly complete date to be August 1999. Freedom will provide a crew of eight permanent members with a habitation module of 13.5 x 4.3 m for their 6-month stay. Other components include a U.S. laboratory, an ESA laboratory, ESA's Man-Tended Free Flyer, the Japanese Experiment Module and Attached Logistics Module, and the Canadian Mobile Servicing System. Political and budgetary issues which have developed concerning the construction and operation of Space Station Freedom are examined, and international decision-making is discussed. L.K.S.

A90-51503
COMMENTS ON THE GERMAN SPACE STRATEGY - TASKS AND GOALS OF DARA (LECTURE) [ANMERKUNGEN ZUR DEUTSCHEN RAUMFAHRTSTRATEGIE - AUFGABEN UND ZIELSETZUNGEN DER DARA /VORTRAG/]
W. WILD (Deutsche Agentur fuer Raumfahrtangelegenheiten GmbH, Bonn, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 14, Aug. 1990, p. 209-214. In German.
Copyright

The current planning status of the FRG space program under the aegis of DARA, the newly reorganized German Agency for Space Affairs, is surveyed. The overall strategy is to continue active participation in international cooperative programs (within ESA and through bilateral and multilateral agreements with other nations) while building the support structures and technology base needed for a healthy German space industry. Topics addressed include manned space projects (operation and maintenance of space platforms, science and exploration, and space medicine), the desirable relative funding levels for space flight vs space science and for ESA vs national projects, practical applications of space technology (primarily in remote sensing and communication), and astronomy and planetary-science projects. It is suggested that microgravity work in the future may focus on biological rather than physical and material-science experiments. The importance of long-term planning beyond the year 2000 is stressed. T.K.

A90-52585
EUROPEAN MANNED IN-ORBIT INFRASTRUCTURE - AN ALTERNATIVE VIEWPOINT
C. M. HEMPSELL (British Aerospace /Space Systems/, Ltd., Stevenage, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Oct. 1990, p. 459-472.
Copyright

Europe has three major manned in-orbit programs, the Columbus Attached laboratory, the Columbus Free Flyer, and the European Space Station. As currently baselined, these are independent systems with little commonality. This paper explores the potential of commonality to improve program costs and timescales. It introduces a feasibility design for a standard module and then shows how this can be used to meet the Columbus and European Space Station objectives. It then integrates the three systems into a single program showing timescale and cost improvements. Author

N90-22462# Executive Office of the President, Washington, DC.
AERONAUTICS AND SPACE REPORT OF THE PRESIDENT: 1987 ACTIVITIES
1989 183 p
Avail: NTIS HC A09/MF A01

United States aeronautics and space activities for the calender year 1987 are summarized in the areas of space science and applications; communications; space transportation; safety, reliability, and quality assurance; commercial use of space; the Space Station; space operations; aeronautics; and space research and technology. The activities of each of the following organizations are described: National Aeronautics and Space Administration, Department of Defense, Department of Commerce, Department of Energy, Department of the Interior, Department of Agriculture, Federal Communications Commission, Department of Transportation, Environmental Protection Agency, National Science Foundation, Smithsonian Institution, Department of State, Arms Control and Disarmament Agency, and the United States Information Agency. M.G.

N90-24188# Committee on Science, Space and Technology (U.S. House).
THE 1991 NASA AUTHORIZATION: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION FISCAL YEAR 1991 AUTHORIZATION REQUEST AND BUDGET ESTIMATES
Summary Report
Washington GPO 1990 249 p Presented to the Committee on Science, Space, and Technology, 101st Congress, 2d Session, Mar. 1990
(GPO-27-291) Avail: Subcommittee on Space Science and Applications, House of Representatives, Washington, D.C. 20515 HC free; SOD HC $8.00 as 552-070-07978-5

The fiscal year 1991 budget request is examined for the National Aeronautics and Space Administration programs which include: space station development; space transportation; materials processing in space; commercial use of space; space research and technology; exploration mission studies; academic programs; propulsion systems; launching and landing operations; and communications. This report was prepared by the Subcommittee on Space Science and Applications for the U.S. House of Representatives Committee on Science, Space, and Technology. J.P.S.

N90-24220*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TECHNICAL ACCOMPLISHMENTS OF THE NASA LEWIS RESEARCH CENTER, 1989 Annual Report, 1989
1990 252 p Original contains color illustrations
(NASA-TM-102296; NAS 1.15:102296) Avail: NTIS HC A12/MF A02; 13 functional color pages CSCL 05/1

Topics addressed include: high-temperature composite materials; structural mechanics; fatigue life prediction for composite materials; internal computational fluid mechanics; instrumentation and controls; electronics; stirling engines; aeropropulsion and space propulsion programs, including a study of slush hydrogen; space power for use in the space station, in the Mars rover, and other applications; thermal management; plasma and radiation; cryogenic fluid management in space; microgravity physics; combustion in reduced gravity; test facilities and resources. J.P.S.

N90-24290# Centre National d'Etudes Spatiales, Toulouse (France). Space Center.
IN-ORBIT OPERATIONS RESEARCH AND DEVELOPMENT PROGRAM OF THE TOULOUSE SPACE CENTER
J.-J. RUNAVOT *In* ESA, Second European In-Orbit Operations Technology Symposium p 51-56 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Research and development activities organized round the space robotic activities, and the manned extravehicular experimentation through the development and in-flight test of a truss deployable structure (ERA) on the Soviet Space Station MIR, are discussed. The ERA experiment had three objectives: in-flight validation of modal prediction methods; in-flight qualification of the concept; development of know-how in EVA methods and procedures. The milestones of the development have been: the 0 g test in parabolic flights in Airbus A 300; the EVA rehearsal and training in pool at COMEX in France and Star City in USSR; and the Flat-Floor deployments in Aerospatiale Les Mureaux. A final synthesis gives the main lessons drawn from these developments and from the problems encountered in flight on ERA. ESA

N90-25017# Committee on Appropriations (U.S. Senate).
DEPARTMENTS OF VETERANS AFFAIRS AND HOUSING AND URBAN DEVELOPMENT, AND INDEPENDENT AGENCIES APPROPRIATIONS FOR FISCAL YEAR 1990, PART 2
GPO 1990 684 p Hearings on H.R. 2916 before the Committee on Appropriations, 101st Congress, 1st Session, 3-4 Apr., 2-3 May, and 15-16 May 1989
(S-HRG-101-345-PT-2; GPO-92-982) Avail: Committee on Appropriations, Senate, Washington, DC 20515 HC free; SOD HC $20.00 as 552-070-07648-4

Hearings before a subcommittee of the Senate Committee on Appropriations are presented. Included are the verbal and written testimony and the budget estimates for the National Aeronautics and Space Administration for fiscal year 1990. The testimony outlines budgetary information and justifications for expenditures, primarily to continue programs previously approved by the Congress.

N90-25018# Committee on Appropriations (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, 2 MAY 1989
In its Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations for Fiscal Year 1990, Part 2 p 261-307 1990
Avail: Committee on Appropriations, Senate, Washington, DC 20515 HC free; SOD HC $20.00 as 552-070-07648-4

Following the opening statements of the Subcommittee members of the Committee on Appropriations, the National Aeronautics and Space Administration presented its fiscal year 1990 budget. Comments on the various budget items included justifications for space flight, Space Station Freedom, university research programs, space commercialization, space operations, employee training, safety programs and devices, and senior executive pay. Budget cuts, should they occur, will probably result in eliminating the space station which is considered to be the cornerstone of the U.S. program. The U.S.S.R.'s and Japan's space research and development programs were also discussed. J.P.S.

N90-25019# Committee on Appropriations (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, 3 MAY 1989
In its Departments of Veterans Affairs and Housing and Urban Development, and Independent Agencies Appropriations for Fiscal Year 1990, Part 2 p 309-434 1990
Avail: Committee on Appropriations, Senate, Washington, DC 20515 HC free; SOD HC $20.00 as 552-070-07648-4

The second day's hearings for NASA by the Senate Committee on Appropriations, covered the following topics: NASA's cooperation with the space program of the Department of Defense; NASA's educational programs at all levels; Jet Propulsion Laboratory- produced NASA programs on cable TV, available to schools and museums; the status of the Challenger crew memorial trust fund established by Congress to create and operate the Challenger Center for Space Science Education; international agreements for space missions, two of which are the space station and CRAF-Cassini (which will study Saturn and other outer giant planets, and a comet); supersonic transports, including investigations into ways of reducing sonic booms and ozone depletion; deep space missions; cost overruns; structural spares; space station power requirements; tilt rotor technology; shuttle operations; the mission to planet earth, expected to be a new start for 1991; NASA cooperation with the Environmental Agency, the National Science Foundation and other agencies concerned with the environment; and finally, NASA's employment of women and minorities in positions of grade GS-12 or higher. All written testimony and submittals for the record are also included. J.P.S.

N90-26711# European Space Agency, Paris (France).
MANNED SPACE STATIONS: LEGAL ISSUES
T. DUC GUYENNE, ed. Jan. 1990 216 p In ENGLISH and FRENCH International colloquium held in Paris, France, 7-8 Nov. 1989; sponsored by CNES
(ESA-SP-305; ISBN-92-9092-062-9; ISSN-0379-6566; ETN-90-96979) Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The technical characteristics and functions of different space stations are reviewed. The legal aspects of the U.S./International Space Station are reviewed. Damage responsability in the case of space stations is discussed. The legal aspects of international cooperation on the MIR Space Station are reviewed. The partnership concept and international management are reviewed. Astronaut legal status and rights are discussed. Crossborder movements of personnel, goods, or technologies, are discussed. Intellectual property rights and U.S. patent law as applied to Space Stations is reviewed. The legal protection of inventions or innovations is discussed.

N90-26713# Mississippi Univ., University. Law Center.
THE US/INTERNATIONAL SPACE STATION: LEGAL ASPECTS OF SPACE OBJECTS AND JURISDICTION AND CONTROL
S. GOROVE *In* ESA, Manned Space Stations: Legal Aspects p 27-33 Jan. 1990
Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The intergovernmental agreement to establish and operate an international joint venture in the development of increasing outer space utilization is discussed. Various legal aspects of the agreement are analyzed. Jurisdiction and control aspects are discussed. Provisions added to the Outer Space Treaty are described. General, as well as, criminal jurisdiction is discussed. Issues of registration, liability, and property rights concerning non-Earth materials launched from a celestial body into outer space are discussed. ESA

N90-26714# Societe Francaise de Droit Aerien et Spatial, *Blere.*

DAMAGE RESPONSIBILITY AND LIABILITY IN SPACE STATIONS [LA RESPONSABILITE POUR DOMMAGES DANS LE CAS DES STATIONS SPATIALES]

M. BOURELY *In* ESA, Manned Space Stations: Legal Aspects p 35-42 Jan. 1990 In FRENCH

Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The legal system developed to handle damage responsibility problems in the framework of the International Space Station program is described. An assessment of the system is made to assess its capability of handling all possible situations that may arise in space station liability. Details of the intergovernmental agreement drawn up on 29 Sep. 1988 are presented. The areas not covered in this agreement are listed and discussed. The agreement is concluded to be satisfactory on the whole, but still incomplete. Urgency in addressing these incomplete points is stressed. ESA

N90-26715# Academy of Sciences (USSR), Moscow. Inst. of Space Law.

MIR: A SOVIET SPACE STATION. SOME LEGAL ASPECTS OF INTERNATIONAL COOPERATION

V. S. VERESHCHETIN *In* ESA, Manned Space Stations: Legal Aspects p 51-54 Jan. 1990

Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The history of the MIR Space Station is reviewed. Various operational aspects and characteristics of the Space Sation are described. The legal regime for foreign or joint experiments in the Space Station are reviewed. Examples of agreements between the USSR and Austria are presented to illustrate the type of intergovernmental cooperation possible. The need for development of a special agreement on manned space flights to supplement provisions within universal international space law is stressed. ESA

N90-26716# Bundesministerium fuer Forschung und Technologie, Bonn (Germany, F.R.).

THE INTERNATIONAL SPACE STATION: THE LEGAL FRAMEWORK

REINHARD LOOSCH *In* ESA, Manned Space Stations: Legal Aspects p 55 -58 Jan. 1990

Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The history of the international Space Station negotiations is summarized. The overall setup of the Space Station agreements is presented. The hierarchy among them and in relation to other international instruments is outlined. Key features in the agreements are given special attention. The issue of peaceful purposes versus national security is given particular attention. The European position in the framework of the agreements is discussed. Letters between the German Ministry for Research and Technology and the U.S. Department of State regarding signing of the final agreements are presented. ESA

N90-26717# European Space Agency, Paris (France). Legal Service.

THE PARTNERSHIP CONCEPT AND INTERNATIONAL MANAGEMENT

K. J. MADDERS *In its* Manned Space Stations: Legal Aspects p 59-61 Jan. 1990

Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

Donations of authority and reservations of autonomy in international partnerships is discussed. The practical deployment of concessions in relation to management is shown to reveal that cooperation is not a one way street. The factor of complementarity is identified as critical to the understanding of a genuine partnership. The use of the space agreements drawn up in Sep. 1988 as a reference point in undertaking future large scale cooperative projects is discussed. Its possible application to better environmental management on Earth is suggested. ESA

N90-26718# *Paris Univ. (France). Inst. de Droit Compare.*

THE INTERNATIONAL SPACE STATION: CONDITIONS OF ACCESS AND USE [LA STATION INTERNATIONALE: CONDITIONS D'ACCES ET D'UTILISATION]

S. COURTEIX *In its* Manned Space Stations: Legal Aspects p 63-77 Jan. 1990 In FRENCH

Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

Aspects of the Intergovernmental Agreement (IGA) on space are discussed. The effect of specific aspects of the agreements on the agreements drawn up in relation to the International Space Station development are described. The concept of Freedom to develop, explore, and use extra-atmospheric space is examined more closely. The access of various partners to the Space Station is discussed. The space and utilities available to each partner aboard the Space Station is described in detail. The respective positions of each of the partners involved in the Space Station project are described in depth. ESA

N90-26719# International Inst. of Space Law, Eh Baarn (Netherlands).

HUMAN WORK IN SPACE: THE ASTRONAUT'S LEGAL STATUS. INTRODUCTION

I. H. PH. DIEDERICKS-VERSCHOOR *In* ESA, Manned Space Stations: Legal Aspects p 85-86 Jan. 1990 In FRENCH

Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The legal status of astronauts is discussed. Differences in the legal status of astronauts working in national versus international space stations are investigated. Movement of goods, personnel, or ideas across borders is discussed from a legal point of view. The issue of whether the laws governing human interaction on Earth are applicable to the conditions within a space station is addressed. Risks to astronauts in a space environment are assessed. ESA

N90-26720# Szczecin Univ., Lodz (Poland). Faculty of Law and Administration.

THE MANNED NATIONAL SPACE STATION: INTERNATIONAL LEGAL CONSIDERATIONS [LA STATION SPATIALE NATIONALE HABITEE: ASPECTS JURIDIQUES INTERNATIONAUX]

A. GORBIEL *In* ESA, Manned Space Stations: Legal Aspects p 87-88 Jan. 1990 In FRENCH

Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The lack of legislation capable of handling the legal problems which can arise with relation to a manned space station is criticized. Suggestions for a framework to be used in setting up such legislation are presented. The issue of international versus national missions is addressed in a legal context. The definition of what constitutes a manned space station is discussed. The opinions of various authorities in space law are quoted on this subject. The need to better organize the subcommittee of the United Nations concerned with drawing up space law legislation, is stressed. ESA

N90-26721# Bundesministerium fuer Forschung und Technologie, Bonn (Germany, F.R.).

THE ASTRONAUTS' LEGAL STATUS: THE INTERNATIONAL SPACE STATION

J. REIFARTH *In* ESA, Manned Space Stations: Legal Aspects p 89-92 Jan. 1990

Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

Aspects of astronaut legal status as derived from the Intergovernmental Space Station Agreement (IGA) are discussed. The personal status of the astronauts is defined. Patent law considerations pertaining to the work or discoveries carried out by an astronaut are discussed. Liability considerations are discussed.

Questions of criminal jurisdiction are addressed. It is concluded that the legal status of an astronaut will essentially be similar to his or her national status as regards public, private, patent, and usually also criminal law. ESA

N90-26722# Ministere des Affaires Exterieures du Canada, Ottawa (Ontario).
CROSSBORDER MOVEMENTS: GOODS, PERSONNEL AND TECHNOLOGIES [LES MOUVEMENTS TRANSFRONTIERES: BIENS, PERSONNES ET TECHNOLOGIES]
P. DUBOIS *In* ESA, Manned Space Station: Legal Aspects p 93-100 Jan. 1990 In FRENCH
Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

Aspects of the special import and export agreements made between the four main partners in the International Space Station programs are described. The legal framework of exchanges between the four partner countries is outlined. Property rights and transit status are discussed. Mutual renunciation to recourse in matters of shared responsibility and issue of authorizations and rights are addressed. The areas of competence of each of the four partner countries are identified. The legal role of the mission commander is given particular attention. ESA

N90-26723# Gantt (J. B.), Washington, DC.
SPACE STATION INTELLECTUAL PROPERTY RIGHTS AND US PATENT LAW
J. B. GANTT *In* ESA, Manned Space Stations: Legal Aspects p 107-114 Jan. 1990
Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The principles governing intellectual property rights associated with Space Station activity are investigated. The article 21 of the Intergovernmental Space Station Agreement (IGA) is given particular attention. The separate provisions required to apportion jurisdiction among the European partner states within ESA are discussed. The status of U.S. as it relates to inventions in outer space is examined and the provisions of pending legislation in implementation of the IGA and clarification of U.S. law are analyzed. ESA

N90-26725# Max-Planck-Inst. for Foreign and International Patent, Copyright and Competition Law, Munich (Germany, F.R.).
PRODUCTION ACTIVITIES IN SPACE: THE PROBLEMS OF PROTECTION
D. STAUDER *In* ESA, Manned Space Stations: Legal Aspects p 117-121 Jan. 1990
Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The issue of patent law in its role of protecting technical innovations or inventions made on space stations, objects, labs, or modules is addressed. The legal problems within patent law in protecting knowledge and inventions are described. The difficulties caused by the application of different national patent systems in the very confined area of a space station are discussed. The notions of unlawful misappropriation of knowledge are defined. Contracts of confidentiality are described. Contracts of co-inventorship are discussed. Territoriality and infringing acts are considered. ESA

N90-26726# Aerospatiale, Les Mureaux (France). Service Juridique.
POSSIBLE SOLUTIONS [LES SOLUTIONS POSSIBLES]
M. F. MURPHY *In* ESA, Manned Space Stations: Legal Aspects p 123-126 Jan. 1990 In FRENCH
Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The fact that national patent laws are applied to inventions made on a space vehicle under the legal control of a certain country is criticized. Difficulties which arise due to this practice are addressed. A series of solutions are proposed to resolve these problems. One solution is to maintain the status quo for inventions made on Earth. The second is to protect the inventions made in space by patent legislation by the organization which initiated the experiments leading to the inventions. An international code is proposed which would deliver special patent rights recognized by all countries and organizations. ESA

N90-26727# Groupe de Travail sur le Droit de l'Espace, Paris (France).
SPACE LAW PUT TO THE TEST BY THE INTERNATIONAL SPACE STATION [LE DROIT DE L'ESPACE A L'EPREUVE DE LA STATION SPATIALE]
C. A. COLLIARD *In its* Manned Space Stations: Legal Aspects p 133-136 Jan. 1990 In FRENCH
Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The relationship between the Intergovernmental Space Station Agreement (IGA) and the principles of space law drawn up in the 1967 treaty on satellite agreements is investigated. It is concluded that the two agreements have a great deal in common and that in fact the text of IGA is often taken directly from that of the previous agreement. Certain vague areas in the IGA are identified. The most important of these are the principle of politico in space activities and the definition of pacific or exclusively pacific operation of spacecraft. ESA

N90-27561# Committee on Appropriations (U.S. House).
DEPARTMENTS OF VETERANS AFFAIRS AND HOUSING AND URBAN DEVELOPMENT, AND INDEPENDENT AGENCIES APPROPRIATIONS FOR 1991. PART 4: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GPO 1990 1319 p Hearings before the Committee on Appropriations, 101st Congress, 2nd Session, 20 Mar. 1990
(GPO-30-861) Avail: Subcommittee on VA, HUD, and Independent Agencies, House of Representatives, Washington, DC 20510 HC free; also available SOD HC $31.00 as 552-070-08441-0

Hearings before a subcommittee of the House Committee on Appropriations are presented along with the budget estimates for the National Aeronautics and Space Administration for the fiscal year 1991. All written testimony and submittals for the record are also included. The budget estimates provide a detailed outline of budgetary information and justification for research and development, for construction of facilities, and for research and program management. J.P.S.

N90-30138# Committee on Science, Space and Technology (U.S. House).
NASA AUTHORIZATION, 1991, VOLUME 2
Washington GPO 1990 702 p Hearings before the Committee on Science, Space, and Technology, 101st Congress, 2d Session, no. 129, 6, 8, 21, and 27 Feb. 1990
(GPO-32-196) Avail: Subcommittee on Space Science and Applications, House of Representatives, Washington, DC 20515 HC free; also available SOD HC $20.00 as 552-070-08879-2

The hearing of the Subcommittee on Space Science and Applications of the Committee on Science, Space, and Technology of the 101st Congress is presented. It was held at the full committee because the nature of the proposed budget signifies some profound changes that will have far-reaching effects on the space program for the 21st century. It was noted that the budget request represents an increase of 23 to 24 percent over the previous year, but that the government's investment in civil space and aeronautics has been steadily reduced since the mid-1960's. Statements were made by NASA Administrator Richard H. Truly and a team of Associate Administrators, Deputy Associate Administrators, and others. Budget items discussed include the national aerospace plane, space transportation, the Space Station Freedom, global changes on earth, space exploration, tracking, facilities, research, technology, applications, and public outreach programs. J.P.S.

N90-30141# European Space Agency, Paris (France). Space Science Dept.
ESA'S REPORT TO THE 28TH COSPAR MEETING
A. CHICARRO, V. DOMINGO, U. O. FRISK, P. JAKOBSEN, K.

KNOTT, M. F. KESSLER, J. P. LEBRETON, R. MARSDEN, A. PEACOCK, M. A. C. PERRYMAN et al. Jun. 1990 137 p Meeting held in The Hague, The Netherlands, Jun. 1990 Original contains color illustrations
(ESA-SP-1124; ISSN-0379-6566; ETN-90-97588) Copyright Avail: NTIS HC A07/MF A01

Ongoing and complete missions, including IUE, EXOSAT, Hipparcos and Giotto, are discussed. Projects under development, including Ulysses, Hubble Space Telescope, ISO (Infrared Space Observatory), the Solar Terrestrial Science Programme (STSP), Cassini/Huygens and the high throughput X ray spectroscopy mission (XMM), are reported. Missions under study are reviewed; the submillimeter spectroscopy mission (FIRST); Rosetta CNSR (Comet Nucleus Sample Return); third millenium Mars exploration, interferometry from space and Vulcan missions. The Eureca A and Columbus Polar Platforms are included. ESA

N90-30169# European Space Agency, Paris (France).
ACTIVITIES REPORT OF THE EUROPEAN SPACE AGENCY Annual Report, 1989
NORMAN LONGDON, ed. and JAMES HUNT, ed. May 1990 236 p Original contains color illustrations
(ISSN-0258-025X; ETN-90-97599) Copyright Avail: NTIS HC A11/MF A02

The development program and basic activities, installations and administration are reviewed. Programs covered include: scientific, Earth observation, microgravity, telecommunications, space transportation and space stations and platforms. Activities relating to technological research and development, scientific research, satellite operations and data handling and archiving are covered. Installations include ground facilities for space systems, test facilities, and ESA establishments. The organization and structure, finance and contracts and commercialization, and external relations are discussed. ESA

03

MANAGEMENT SYSTEMS AND LOGISTICAL SUPPORT

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

A90-33632
COLUMBUS DECENTRALIZED OPERATIONS - THE MANNED SPACE LABORATORIES CONTROL CENTER (MSCC)
JOACHIM G. KEHR (DLR, Oberpfaffenhofen, Federal Republic of Germany) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 35-48.
Copyright

The concept for the decentralized operations activity for manned Columbus elements, the attached and free flying laboratories operations at the Manned Space Laboratories Control Center (MSCC), is presented. The operational management structure is examined, showing its compatibility with the NASA Space Station management structure. The MSCC responsibilities in the execution of tasks during the implementation, preparation, and operations phases of the APM and MTFF are described, and the MSCC operations concept is examined. The interfaces of the MSCC with users are discussed. C.D.

A90-33633
COLUMBUS FREE FLYER CENTER FOR SUPPORT OF MISSIONS OF THE COLUMBUS FREE FLYING LABORATORY
HANS M. KAPPLER, H. J. C. KOOPMANN, and H. MICHAELIS (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 49-56.
Copyright

An overview of the development of the Free Flyer Center concept, as a facility of the European ground infrastructure which will provide continuous operation support for the Columbus Free Flying Laboratory, is given. Structural and functional characteristics of the center are discussed. The functions of the center, including mission control support, payload integration support, and logistics support, are defined and analyzed. The conceptual approach to the implementation of these functions, and the resulting infrastructure and facility/tools requirements are identified based on this analysis. The implementation schedule is presented. N.B.

A90-36078* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LAUNCH PACKAGING OPTIONS FOR THE PV POWER MODULE CARGO ELEMENT
MARK A. HOBERECHT (NASA, Lewis Research Center, Cleveland, OH) and SCOTT T. VOGT (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 295-298. Previously announced in STAR as N89-25275.
Copyright

NASA recently embarked on the Space Station Freedom program, which will utilize the Shuttle Orbiter for transportation to orbit. Each flight is unique in terms of the hardware that is manifested and the method by which it is integrated to form viable cargo elements. Various constraints determine the packaging options for the three PV power module combined assemblies. Several packaging options for the PV power module cargo element are presented. These options are discussed in terms of their impact on the overall flight hardware manifest as determined by the various constraints. Author

A90-42312#
EXTERNAL SERVICING OF SPACECRAFT - THE HERMES CAPABILITY
A. THIRKETTLE (ESTEC, Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 62, May 1990, p. 40-48.
Copyright

The development and design of the Hermes EVA system and the Hermes Robot Arm (Hera) are described. The technical requirements for the Hera and the EVA system are discussed. It is proposed that Hera be in-orbit based and maintained with a lifetime of 10 years. The Hera has a symmetrical arm configuration and has fully automated, teleoperated, and operator manipulated modes of operation. The EVA system is designed for 30 flights with two sorties of 7 hr duration per flight. The suit has an operating pressure of 500 hpa and functions autonomously from the spaceplane. The main components of the suit are: the enclosure, the life-support equipment, and the information and communications package. Consideration is given to the design of gloves, joints and bearings, material, biomedical sensors, voice processing, and environmental control components. I.F.

A90-43463* National Aeronautics and Space Administration, Washington, DC.
OPERATIONS VIEW OF SPACE STATION IN THE 21ST CENTURY
KATHY CANNON (NASA, Space Station Freedom Program Office, Washington, DC) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 57-63.
(AAS PAPER 88-163) Copyright

Operations envisioned onboard the Space Station are described. The operations framework and functions are examined, and the need for implementing more automation is discussed. It is

concluded that increasing automation is the key to keeping operation costs down, while providing the flexibility needed to support the operations envisioned in the 21st century. B.J.

A90-43496
HERMES GUIDANCE AND NAVIGATION IN FLY-AROUND TRAJECTORIES FOR FREE FLYER EXTERNAL SERVICING
J. COSMEN SCHORTMANN, I. RAMOS GOROSTIOLA (Grupo de Mecanica del Vuelo, S.A., Madrid, Spain), and G. JANIN (ESA, European Space Operations Centre, Darmstadt, Federal Republic of Germany) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 125-138. refs
(Contract ESA-7049/87/D/MD)
(AAS PAPER 89-163) Copyright

Hermes guidance and navigation techniques for performing the servicing of the Free Flyer Resource Module after the attached phase to the Pressurized Module by using fly-around strategies are given in this paper. While earth pointing attitude of the Free Flyer is taken as baseline and investigated in full details, special features of the sun pointing attitude are also described. In a first step, a fly-around reference trajectory is constructed by using parametric optimization of the total delta v as cost function. Safety considerations for worst case of execution errors and total loss of orbital and attitude control, plume impingement, and visibility constraints are taken into account in this optimization process. Secondly, a control law for guiding the Hermes with respect to the reference trajectory and for grappling conditions keeping is designed. Finally, the relative orbit estimation scheme based on the use of sensors such as differential GPS, laser, and camera sensors is defined. A simulation was built to determine the performances of these techniques in a realistic scenario. Results show the feasibility of the fly-around scenario with the designed Hermes GN&C system. The time necessary to perform the fly-around is about one orbital revolution, and the total applied increment of velocity is less than 0.33 m/s. Author

A90-48845#
PRELIMINARY DESIGN OF A CARGO RETURN VEHICLE FOR SPACE STATION FREEDOM
STEPHEN COOK and ANDREW VANO (Minnesota, University, Minneapolis) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Conference, Dayton, OH, Sept. 17-19, 1990. 12 p.
(AIAA PAPER 90-3233) Copyright

The design of an unmanned, reusable cargo return vehicle (CRV) incorporated as a class project at the University of Minnesota under NASA auspices is presented. Two configurations are considered, a winged and a biconic with a parafoil advanced recovery system. Three inline liquid rocket boosters would propel the CRV into a low earth orbit with onboard orbital maneuvering system engines used to reach station orbit and dock to the station. The main objective of the courses was to develop the design skills of the students while allowing them to work together in teams with NASA and industry engineers on a specific NASA project. The final conclusion of the study was that the winged CRV was the best vehicle for space station resupply. R.E.P.

A90-50244
GROUND INFRASTRUCTURE FOR EXPERIMENTERS USING THE COLUMBUS APM AND MTFF [BODENINFRASTRUKTUR FUER EXPERIMENTATOREN ZUR NUTZUNG VON COLUMBUS APM UND MTFF]
CH. PUETZ and J. BURFEINDT (Kayser-Threde GmbH, Munich, Federal Republic of Germany) IN: Yearbook 1988 II; DGLR, Annual Meeting, Darmstadt, Federal Republic of Germany, Sept. 20-23, 1988, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 931-937. In German. refs
(DGLR PAPER 88-096) Copyright

A possible ground infrastructure for experimenters involved in the Columbus project, in particular the MTFF (Man-Tended Free Flyer) and the APM (Attached Pressurized Module) is described. Experimental scenarios for such an infrastructure are examined. The international division of usage of the infrastructure is addressed. C.D.

A90-52582
THE USE OF PALLETS IN THE SPACE STATION INFRASTRUCTURE
C. H. MARTIN and C. M. HEMPSELL (British Aerospace /Space Systems/, Ltd., Stevenage, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Oct. 1990, p. 426-430.
Copyright

The Spacelab Pallet was developed in the 1970s as an effective means of carrying payloads within the Space Shuttle payload bay. By introducing attachments that allow removal from the payload bay and mounting to the Freedom Space Station, the Pallet can be made an effective method of transporting and mounting Space Station external payloads and equipment. Modifications that allow the Pallet to attach to the truss structure or, alternatively, to the pressurized section have been considered. Both approaches have potentially valuable roles to play in developing the Space Station infrastructure. Potential missions include general experiment mounting, an exposed platform attached to the Columbus laboratory, a logistics carrier, a carrier structure for Space Station subsystems, and an EVA tool store and work station. The Pallet can also be used in other systems using the Space Station infrastructure such as the Columbus Free Flying Laboratory, the unmanned platforms, the Industrial Space Facility, and the European Space Station. Author

N90-20113*# TRW, Inc., Huntsville, AL. System Development Div.
SPACE STATION SIMULATION COMPUTER SYSTEM (SCS) STUDY FOR NASA/MSFC. VOLUME 1: OVERVIEW AND SUMMARY Final Technical Report, Aug. 1988 - Oct. 1989
31 Oct. 1989 61 p Prepared in cooperation with Essex Corp., Huntsville, AL and Grumann Data Systems Corp., Woodbury, NY
(Contract NAS8-37745)
(NASA-CR-183840; NAS 1.26:183840; TRW-SCS-89-T7-VOL-1)
Avail: NTIS HC A04/MF A01 CSCL 22/2

NASA's Space Station Freedom Program (SSFP) planning efforts have identified a need for a payload training simulator system to serve as both a training facility and as a demonstrator to validate operational concepts. The envisioned Marshall Space Flight Center (MSFC) Payload Training Complex (PTC) required to meet this need will train the space station payload scientists, station scientists, and ground controllers to operate the wide variety of experiments that will be onboard the Space Station Freedom. The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex at MSFC. The purpose of this SCS study is to investigate issues related to the SCS, alternative requirements, simulator approaches, and state-of-the-art technologies to develop candidate concepts and designs. This study was performed August 1988 to October 1989. Thus, the results are based on the SSFP August 1989 baseline, i.e., pre-Langley configuration/budget review (C/BR) baseline. Some terms, e.g., combined trainer, are being redefined. An overview of the study activities and a summary of study results are given here. Author

N90-20114*# TRW, Inc., Huntsville, AL. System Development Div.
SPACE STATION SIMULATION COMPUTER SYSTEM (SCS) STUDY FOR NASA/MSFC. VOLUME 2: CONCEPT DOCUMENT Final Technical Report
31 Oct. 1989 151 p Prepared in cooperation with Essex Corp., Huntsville, AL and Grumann Data Systems Corp., Woodbury, NY
(Contract NAS8-37745)
(NASA-CR-183841; NAS 1.26:183841; MSFC-SPEC-1764-VOL-2)
Avail: NTIS HC A08/MF A01 CSCL 22/2

The Simulation Computer System (SCS) concept document describes and establishes requirements for the functional performance of the SCS system, including interface, logistic, and qualification requirements. The SCS is the computational

communications and display segment of the Marshall Space Flight Center (MSFC) Payload Training Complex (PTC). The PTC is the MSFC facility that will train onboard and ground operations personnel to operate the payloads and experiments on board the international Space Station Freedom. The requirements to be satisfied by the system implementation are identified here. The SCS concept document defines the requirements to be satisfied through the implementation of the system capability. The information provides the operational basis for defining the requirements to be allocated to the system components and enables the system organization to assess whether or not the completed system complies with the requirements of the system. Author

N90-20115*# TRW, Inc., Huntsville, AL. System Development Div.

SPACE STATION SIMULATION COMPUTER SYSTEM (SCS) STUDY FOR NASA/MSFC. VOLUME 3: REFINED CONCEPTUAL DESIGN REPORT Final Technical Report

31 Oct. 1989 110 p Prepared in cooperation with Essex Corp., Huntsville, AL and Grumann Data Systems Corp., Woodbury, NY (Contract NAS8-37745)

(NASA-CR-183842; NAS 1.26:183842; TRW-SCS-89-T5-VOL-3) Avail: NTIS HC A06/MF A01 CSCL 22/2

The results of the refined conceptual design phase (task 5) of the Simulation Computer System (SCS) study are reported. The SCS is the computational portion of the Payload Training Complex (PTC) providing simulation based training on payload operations of the Space Station Freedom (SSF). In task 4 of the SCS study, the range of architectures suitable for the SCS was explored. Identified system architectures, along with their relative advantages and disadvantages for SCS, were presented in the Conceptual Design Report. Six integrated designs-combining the most promising features from the architectural formulations-were additionally identified in the report. The six integrated designs were evaluated further to distinguish the more viable designs to be refined as conceptual designs. The three designs that were selected represent distinct approaches to achieving a capable and cost effective SCS configuration for the PTC. Here, the results of task 4 (input to this task) are briefly reviewed. Then, prior to describing individual conceptual designs, the PTC facility configuration and the SSF systems architecture that must be supported by the SCS are reviewed. Next, basic features of SCS implementation that have been incorporated into all selected SCS designs are considered. The details of the individual SCS designs are then presented before making a final comparison of the three designs. Author

N90-20116*# TRW, Inc., Huntsville, AL. System Development Div.

SPACE STATION SIMULATION COMPUTER SYSTEM (SCS) STUDY FOR NASA/MSFC. VOLUME 4: CONCEPTUAL DESIGN REPORT Final Technical Report

31 Oct. 1989 63 p Prepared in cooperation with Essex Corp., Huntsville, AL and Grumann Data Systems Corp., Woodbury, NY (Contract NAS8-37745)

(NASA-CR-183843; NAS 1.26:183843; TRW-SCS-89-T4-VOL-4) Avail: NTIS HC A04/MF A01 CSCL 22/2

The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex (PTC) at Marshall Space Flight Center (MSFC). The PTC will train the space station payload scientists, station scientists, and ground controllers to operate the wide variety of experiments that will be onboard the Space Station Freedom. In the first step of this task, a methodology was developed to ensure that all relevant design dimensions were addressed, and that all feasible designs could be considered. The development effort yielded the following method for generating and comparing designs in task 4: (1) Extract SCS system requirements (functions) from the system specification; (2) Develop design evaluation criteria; (3) Identify system architectural dimensions relevant to SCS system designs; (4) Develop conceptual designs based on the system requirements and architectural dimensions identified in step 1 and step 3 above; (5) Evaluate the designs with respect to the design evaluation criteria developed in step 2 above. The results of the method detailed in the above 5 steps are discussed. The results of the task 4 work provide the set of designs which two or three candidate designs are to be selected by MSFC as input to task 5-refine SCS conceptual designs. The designs selected for refinement will be developed to a lower level of detail, and further analyses will be done to begin to determine the size and speed of the components required to implement these designs. Author

N90-20117*# TRW, Inc., Huntsville, AL. System Development Div.

SPACE STATION SIMULATION COMPUTER SYSTEM (SCS) STUDY FOR NASA/MSFC. VOLUME 5: STUDY ANALYSIS REPORT Final Technical Report

31 Oct. 1989 96 p Prepared in cooperation with Essex Corp., Huntsville, AL and Grumann Data Systems Corp., Woodbury, NY (Contract NAS8-37745)

(NASA-CR-183844; NAS 1.26:183844; TRW-SCS-89-T2-VOL-5) Avail: NTIS HC A05/MF A01 CSCL 22/2

The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex (PTC) at the Marshall Space Flight Center (MSFC). The PTC will train the space station payload scientists, station scientists, and ground controllers to operate the wide variety of experiments that will be on-board the Freedom Space Station. The further analysis performed on the SCS study as part of task 2-Perform Studies and Parametric Analysis-of the SCS study contract is summarized. These analyses were performed to resolve open issues remaining after the completion of task 1, and the publishing of the SCS study issues report. The results of these studies provide inputs into SCS task 3-Develop and present SCS requirements, and SCS task 4-develop SCS conceptual designs. The purpose of these studies is to resolve the issues into usable requirements given the best available information at the time of the study. A list of all the SCS study issues is given. Author

N90-20118*# TRW, Inc., Huntsville, AL. System Development Div.

SPACE STATION SIMULATION COMPUTER SYSTEM (SCS) STUDY FOR NASA/MSFC. VOLUME 6: STUDY ISSUES REPORT Final Technical Report

31 Oct. 1989 85 p Prepared in cooperation with Essex Corp., Huntsville, AL and Grumann Data Systems Corp., Woodbury, NY (Contract NAS8-37745)

(NASA-CR-183845; NAS 1.26:183845; TRW-SCS-89-T1-VOL-6) Avail: NTIS HC A05/MF A01 CSCL 22/2

The Simulation Computer System (SCS) is the computer hardware, software, and workstations that will support the Payload Training Complex (PTC) at the Marshall Space Flight Center (MSFC). The PTC will train the space station payload specialists and mission specialists to operate the wide variety of experiments that will be on-board the Freedom Space Station. This simulation Computer System (SCS) study issues report summarizes the analysis and study done as task 1-identify and analyze the CSC study issues- of the SCS study contract.This work was performed over the first three months of the SCS study which began in August of 1988. First issues were identified from all sources. These included the NASA SOW, the TRW proposal, and working groups which focused the experience of NASA and the contractor team performing the study-TRW, Essex, and Grumman. The final list is organized into training related issues, and SCS associated development issues. To begin the analysis of the issues, a list of all the functions for which the SCS could be used was created, i.e., when the computer is turned on, what will it be doing. Analysis was continued by creating an operational functions matrix of SCS users vs. SCS functions to insure all the functions considered were valid, and to aid in identification of users as the analysis progressed. The functions will form the basis for the requirements, which are currently being developed under task 3 of the SCS study. Author

N90-22300*# General Electric Co., Moorestown, NJ. Advanced Technology Labs.
SPACE COMMUNICATIONS SCHEDULER: A RULE-BASED APPROACH TO ADAPTIVE DEADLINE SCHEDULING
NICHOLAS STRAGUZZI *In* NASA, Goddard Space Flight Center, The 1990 Goddard Conference on Space Applications of Artificial Intelligence p 75-93 May 1990
Avail: NTIS HC A15/MF A02 CSCL 09/2

Job scheduling is a deceptively complex subfield of computer science. The highly combinatorial nature of the problem, which is NP-complete in nearly all cases, requires a scheduling program to intelligently transverse an immense search tree to create the best possible schedule in a minimal amount of time. In addition, the program must continually make adjustments to the initial schedule when faced with last-minute user requests, cancellations, unexpected device failures, quests, cancellations, unexpected device failures, etc. A good scheduler must be quick, flexible, and efficient, even at the expense of generating slightly less-than-optimal schedules. The Space Communication Scheduler (SCS) is an intelligent rule-based scheduling system. SCS is an adaptive deadline scheduler which allocates modular communications resources to meet an ordered set of user-specified job requests on board the NASA Space Station. SCS uses pattern matching techniques to detect potential conflicts through algorithmic and heuristic means. As a result, the system generates and maintains high density schedules without relying heavily on backtracking or blind search techniques. SCS is suitable for many common real-world applications. Author

N90-22316*# Martin Marietta Corp., Denver, CO. Information and Communications Systems.
KNOWLEDGE STRUCTURE REPRESENTATION AND AUTOMATED UPDATES IN INTELLIGENT INFORMATION MANAGEMENT SYSTEMS
STEPHEN COREY and RICHARD S. CARNAHAN, JR. *In* NASA, Goddard Space Flight Center, The 1990 Goddard Conference on Space Applications of Artificial Intelligence p 271-285 May 1990
Avail: NTIS HC A15/MF A02 CSCL 09/2

A continuing effort to apply rapid prototyping and Artificial Intelligence techniques to problems associated with projected Space Station-era information management systems is examined. In particular, timely updating of the various databases and knowledge structures within the proposed intelligent information management system (IIMS) is critical to support decision making processes. Because of the significantly large amounts of data entering the IIMS on a daily basis, information updates will need to be automatically performed with some systems requiring that data be incorporated and made available to users within a few hours. Meeting these demands depends first, on the design and implementation of information structures that are easily modified and expanded, and second, on the incorporation of intelligent automated update techniques that will allow meaningful information relationships to be established. Potential techniques are studied for developing such an automated update capability and IIMS update requirements are examined in light of results obtained from the IIMS prototyping effort. Author

N90-22579 Rand Graduate Inst. for Policies Study, Santa Monica, CA.
US ACCESS TO SPACE: LAUNCH VEHICLE CHOICES FOR 1990 TO 2010 Ph.D. Thesis
SCOTT N. PACE 1989 406 p
Avail: Univ. Microfilms Order No. DA9005500

Combinations of U.S. launch vehicles capable of meeting a range of government space traffic needs between 1990 and 2010 are evaluated. The purpose of this evaluation is to clarify alternatives available to the United States in pursuing potential national goals and to increase understanding of the implications of those alternatives. Wartime requirements for space launches were not included. Four levels of U.S. space traffic demand for 1990 to 2010 were defined. The first level was budget constrained to limit new program starts. The second level was a continuation of current space traffic plans, including the Space Station program. The third level assumed an expansion of civil space efforts such as a return to the Moon. The fourth level assumed expanded military space efforts such as the development of strategic defenses. Differing combination of existing and proposed launch vehicles were defined to fulfill each demand level. The costs and uncertainties (e.g., payload losses) associated with each launch vehicle combination were estimated. The interrelations of payload costs, launch vehicle costs, and system reliabilities are discussed in the appendices. The space transportation planning process, current issues, and political factors affecting analysis are reviewed. Senior space transportation planners and decision-makers were interviewed on differing institutional criteria for evaluating launch vehicle mixes. Evaluation criteria were defined to assess the launch vehicle mixes for each demand level and for the case of uncertain demand. Recommendations on preferred U.S. actions in space transportation are made based both on analyses and interview results. Dissert. Abstr.

N90-23585*# Illinois Univ., Urbana. Qualitative Reasoning Group.
QUALITATIVE MODELS FOR SPACE SYSTEM ENGINEERING Final Report
KENNETH D. FORBUS Jun. 1990 75 p
(Contract NAG9-137)
(NASA-CR-180682; NAS 1.26:180682) Avail: NTIS HC A04/MF A01 CSCL 13/2

The objectives of this project were: (1) to investigate the implications of qualitative modeling techniques for problems arising in the monitoring, diagnosis, and design of Space Station subsystems and procedures; (2) to identify the issues involved in using qualitative models to enhance and automate engineering functions. These issues include representing operational criteria, fault models, alternate ontologies, and modeling continuous signals at a functional level of description; and (3) to develop a prototype collection of qualitative models for fluid and thermal systems commonly found in Space Station subsystems. Potential applications of qualitative modeling to space-systems engineering, including the notion of intelligent computer-aided engineering are summarized. Emphasis is given to determining which systems of the proposed Space Station provide the most leverage for study, given the current state of the art. Progress on using qualitative models, including development of the molecular collection ontology for reasoning about fluids, the interaction of qualitative and quantitative knowledge in analyzing thermodynamic cycles, and an experiment on building a natural language interface to qualitative reasoning is reported. Finally, some recommendations are made for future research. Author

N90-24288# Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).
DISTRIBUTED MISSION PLANNING TECHNOLOGY FOR COLUMBUS
G. OHLENDORF, A. KELLNER, and N. SCHIELOW *In* ESA, Second European In-Orbit Operations Technology Symposium p 39-44 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The implications of the distributed Columbus planning scenario and the general anticipated architecture and concrete technological requirements for the planning tool as well as the communication infrastructure are described. A brief introduction into the concepts and functions of the planning tool MARS (Mission Activities and Resource Scheduler), which was developed with particular focus on the anticipated architecture just mentioned, is given. The concept of a linkage between MARS and the Columbus mission database application is presented. ESA

N90-24294*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
HIERARCHY OF ON-ORBIT SERVICING INTERFACES
RUD V. MOE *In* ESA, Second European In-Orbit Operations

Technology Symposium p 77-81 Dec. 1989
 Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 22/1

A series of equipment interfaces is involved in on-orbit servicing operations. The end-to-end hierarchy of servicing interfaces is presented. The interface concepts presented include structure and handling, and formats for transfer of resources (power, data, fluids, etc.). Consequences on cost, performance, and service ability of the use of standard designs or unique designs with interface adapters are discussed. Implications of the interface designs compatibility with remote servicing using telerobotic servicers are discussed. ESA

N90-24306# Technische Hochschule, Darmstadt (Germany, F.R.).
EXPERIENCES WITH AND ERROR HANDLING IN A KNOWLEDGE BASE ASSISTED SYSTEM FOR PAYLOAD EXPERIMENT AUTOMATION
G. KEGEL and H. TOLLE *In* ESA, Second European In-Orbit Operations Technology Symposium p 183-189 Dec. 1989 Sponsored by BMFT
 Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The basic structure of an autonomous space experiment *manipulator system and first experiences with the handling of a* terrestrial laboratory space experiment mock-up simulating a microgravity payload are presented. The autonomy of the manipulator system is achieved by integrating multi-sensorial *information with a hierarchical control approach. The five levels of* the control system are using sensor information in a specific form of from the bottom to the top level. Every level is responsible for its own error handling mechanism reaching from direct feedback in cartesian coordinates to sequence related failure strategies. The complete implemented control scheme, and a number of sensors integrated in a multi-sensorial gripper system, thus enabling the control to perform motion-sequences planned by the knowledge based strategy level, are described. ESA

N90-25000*# Kansas Univ., Lawrence.
KEEPING THE DREAM ALIVE: MANAGING THE SPACE STATION PROGRAM, 1982 TO 1986 Final Report
THOMAS J. LEWIN and V. K. NARAYANAN (Rutgers - The State Univ., New Brunswick, NJ.) Washington NASA Jul. 1990 178 p
(Contract NASW-4248)
(NASA-CR-4272; NAS 1.26:4272) Avail: NTIS HC A09/MF A01 CSCL 05/1

The management is described and analyzed of the formative years of the NASA Space Station Program (1982 to 1986), beginning with the successful initiative for program approval by Administrator James M. Beggs through to the decision to bring program management to Reston, Virginia. Emphasis is on internal management issues related to the implementation of the various *phases of the program. Themes examined are the problem of* bringing programmatic and institutional interests together and focusing them to forward the program; centralized versus decentralized control of the program; how the history of NASA and of the individual installations affected the decisions made; and the pressure from those outside NASA. The four sections are: (1) the decision to build the space station, (2) the design of the management experiment, (3) the experiment comes to life, *and (4) the decision reversal.* *Author*

N90-25522*# Stanford Univ., CA. Knowledge Systems Lab.
AN EXPERT SYSTEM TO ADVISE ASTRONAUTS DURING EXPERIMENTS: THE PROTOCOL MANAGER MODULE
GUIDO HAYMANN-HABER, SILVANO P. COLOMBANO, NICOLAS GROLEAU, DON ROSENTHAL, PETER SZOLOVITS, and LAURENCE R. YOUNG (Massachusetts Inst. of Tech., Cambridge.) *In* NASA, Lyndon B. Johnson Space Center, Third Annaul Workshop on Space Operations Automation and Robotics (SOAR 1989) p 187-194 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 05/8

Perhaps the scarcest resource for manned flight experiments - on Spacelab or on the Space Station Freedom - will continue to be crew time. To maximize the efficiency of the crew and to make use of their abilities to work as scientist collaborators as well as equipment operators, normally requires more training in a wide variety of disciplines than is practical. The successful application of on-board expert systems, as envisioned by the Principal Investigator in a Box program, should alleviate the training bottleneck and provide the astronaut with the guidance and coaching needed to permit him or her to operate an experiment according to the desires and knowledge of the PI, despite changes in conditions. The Protocol Manager module of the system is discussed. The Protocol Manager receives experiment data that has been summarized and categorized by the other modules. The Protocol Manager acts on the data in real-time, by employing expert system techniques. Its recommendations are based on *heuristics provided by the Principal Investigator in charge of the* experiment. This prototype was developed on a Macintosh II by employing CLIPS, a forward-chaining rule-based system, and HyperCard as an object-oriented user interface builder. Author

N90-25534*# Mitre Corp., Houston, TX.
PROCESS AND INFORMATION INTEGRATION VIA HYPERMEDIA
DAVID G. HAMMEN, DANIEL L. LABASSE, *and* ROBERT M. MYERS *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 295-298 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 09/2

Success stories for advanced automation prototypes abound in the literature but the deployments of practical large systems are few in number. There are several factors that militate against the maturation of such prototypes into products. Here, the integration of advanced automation software into large systems is discussed. Advanced automation systems tend to be specific applications that need to be integrated and aggregated into larger systems. Systems integration can be achieved by providing expert user-developers with verified tools to efficiently create small systems that interface to large systems through standard interfaces. The use of hypermedia as such a tool in the context of the ground control centers that support Shuttle and space station operations is explored. Hypermedia can be an integrating platform for data, conventional software, and advanced automation software, enabling data integration through the display of diverse types of information and through the creation of associative links between chunks of information. Further, hypermedia enables process integration through graphical invoking of system functions. Through analysis and examples, researchers illustrate how diverse information and processing paradigms can be integrated into a single software platform. *Author*

N90-25562*# Ford Aerospace and Communications Corp., Sunnyvale, CA.
OMS FDIR: INITIAL PROTOTYPING
ERIC W. TAYLOR and MATTHEW A. HANSON *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 545-549 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 05/1

The Space Station Freedom Program (SSFP) Operations Management System (OMS) will automate major management *functions which coordinate the operations of onboard systems,* elements and payloads. The objectives of OMS are to improve safety, reliability and productivity while reducing maintenance and operations cost. This will be accomplished by using advanced *automation techniques* to automate much of the activity currently performed by the flight crew and ground personnel. OMS requirements have been organized into five task groups: (1) Planning, Execution and Replanning; (2) Data Gathering, Preprocessing and Storage; (3) Testing and Training; (4) Resource Management; and (5) Caution and Warning and Fault Management for onboard subsystems. The scope of this prototyping effort falls within the Fault Management requirements group. The prototyping

will be performed in two phases. Phase 1 is the development of an onboard communications network fault detection, isolation, and reconfiguration (FDIR) system. Phase 2 will incorporate global FDIR for onboard systems. Research into the applicability of expert systems, object-oriented programming, fuzzy sets, neural networks and other advanced techniques will be conducted. The goals and technical approach for this new SSFP research project are discussed here. Author

N90-26030*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NATIONAL SPACE TEST CENTERS, LEWIS RESEARCH CENTER FACILITIES
RONALD R. ROSKILLY 1990 7 p Proposed for presentation at the Space Programs and Technologies Conference, Huntsville, AL, 25-27 Sep. 1990; sponsored by AIAA
(NASA-TM-103187; E-5570; NAS 1.15:103187; AIAA-90-3593)
Avail: NTIS HC A02/MF A01 CSCL 14/2

The Lewis Research Center, NASA, presently has a number of test facilities that constitute a significant national space test resource. It is expected this capability will continue to find wide application in work involving this country's future in space. Testing from basic research to applied technology, to systems development, to ground support will be performed, supporting such activities as Space Station Freedom, the Space Exploration Initiative, Mission to Planet Earth, and many others. The major space test facilities at both Cleveland and Lewis' Plum Brook Station are described. Primary emphasis is on space propulsion facilities; other facilities of importance in space power and microgravity are also included. Author

N90-26047*# Boeing Aerospace Co., Huntsville, AL.
PLANNING FOR SPACE STATION FREEDOM LABORATORY PAYLOAD INTEGRATION
HARVEY J. WILLENBERG and LARRY P. TORRE 1989 15 p Presented in Nashville, TN, 5-10 Mar. 1989
(Contract NAS8-50000)
(NASA-CR-186751; NAS 1.26:186751) Avail: NTIS HC A03/MF A01 CSCL 22/2

Space Station Freedom is being developed to support extensive missions involving microgravity research and applications. Requirements for on-orbit payload integration and the simultaneous payload integration of multiple mission increments will provide the stimulus to develop new streamlined integration procedures in order to take advantage of the increased capabilities offered by Freedom. The United States Laboratory and its user accommodations are described. The process of integrating users' experiments and equipment into the United States Laboratory and the Pressurized Logistics Modules is described. This process includes the strategic and tactical phases of Space Station utilization planning. The support that the Work Package 01 Utilization office will provide to the users and hardware developers, in the form of Experiment Integration Engineers, early accommodation assessments, and physical integration of experiment equipment, is described. Plans for integrated payload analytical integration are also described. Author

N90-26050*# Minnesota Univ., Minneapolis. Dept. of Aerospace Engineering and Mechanics.
WINGED CARGO RETURN VEHICLE. VOLUME 1: CONCEPTUAL DESIGN NASA/USRA Advanced Design Project
2 Jun. 1990 270 p
(Contract NGT-21-002-800)
(NASA-CR-186823; NAS 1.26:186823) Avail: NTIS HC A12/MF A02 CSCL 22/2

The Advanced Design Project (ADP) allows an opportunity for students to work in conjunction with NASA and other aerospace companies on NASA Advanced Design Projects. The following volumes represent the design report: Volume 1 Conceptual Design; Volume 2 Wind Tunnel Tests; Volume 3 Structural Analysis; and Volume 4 Water Tunnel Tests. The project chosen by the University of Minnesota in conjunction with NASA Marshall Space Flight Center for this year is a Cargo Return Vehicle (CRV) to support the Space Station Freedom. The vehicle is the third generation of vehicles to be built by NASA, the first two being the Apollo program, and the Space Shuttle program. The CRV is to work in conjunction with a personnel launch system (PLS) to further subdivide and specialize the vehicles that NASA will operate in the year 2000. The cargo return vehicle will carry payload to and from the Space Station Freedom (SSF). Author

N90-26849*# Essex Corp., Huntsville, AL. Space Systems Group.
PAYLOAD TRAINING METHODOLOGY STUDY Final Report
Feb. 1990 359 p
(Contract NAS8-37737)
(NASA-CR-183907; NAS 1.26:183907) Avail: NTIS HC A16/MF A02 CSCL 14/4

The results of the Payload Training Methodology Study (PTMS) are documented. Methods and procedures are defined for the development of payload training programs to be conducted at the Marshall Space Flight Center Payload Training Complex (PCT) for the Space Station Freedom program. The study outlines the overall training program concept as well as the six methodologies associated with the program implementation. The program concept outlines the entire payload training program from initial identification of training requirements to the development of detailed design specifications for simulators and instructional material. The following six methodologies are defined: (1) The Training and Simulation Needs Assessment Methodology; (2) The Simulation Approach Methodology; (3) The Simulation Definition Analysis Methodology; (4) The Simulator Requirements Standardization Methodology; (5) The Simulator Development Verification Methodology; and (6) The Simulator Validation Methodology. Author

N90-27276*# Boeing Co., Huntsville, AL.
AGENT INDEPENDENT TASK PLANNING
WILLIAM S. DAVIS *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 1-10 May 1990
Avail: NTIS HC A25/MF A04 CSCL 05/8

Agent-Independent Planning is a technique that allows the construction of activity plans without regard to the agent that will perform them. Once generated, a plan is then validated and translated into instructions for a particular agent, whether a robot, crewmember, or software-based control system. Because Space Station Freedom (SSF) is planned for orbital operations for approximately thirty years, it will almost certainly experience numerous enhancements and upgrades, including upgrades in robotic manipulators. Agent-Independent Planning provides the capability to construct plans for SSF operations, independent of specific robotic systems, by combining techniques of object oriented modeling, nonlinear planning and temporal logic. Since a plan is validated using the physical and functional models of a particular agent, new robotic systems can be developed and integrated with existing operations in a robust manner. This technique also provides the capability to generate plans for crewmembers with varying skill levels, and later apply these same plans to more sophisticated robotic manipulators made available by evolutions in technology. Author

N90-27280*# Martin Marietta Corp., Denver, CO.
DYNAMIC TEST INPUT GENERATION FOR MULTIPLE-FAULT ISOLATION
PHIL SCHAEFER *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 33-42 May 1990
Avail: NTIS HC A25/MF A04 CSCL 09/2

Recent work is Causal Reasoning has provided practical techniques for multiple fault diagnosis. These techniques provide a hypothesis/measurement diagnosis cycle. Using probabilistic methods, they choose the best measurements to make, then update fault hypotheses in response. For many applications such as computers and spacecraft, few measurement points may be accessible, or values may change quickly as the system under

diagnosis operates. In these cases, a hypothesis/measurement cycle is insufficient. A technique is presented for a hypothesis/test-input/measurement diagnosis cycle. In contrast to generating tests a priori for determining device functionality, it dynamically generates tests in response to current knowledge about fault probabilities. It is shown how the mathematics previously used for measurement specification can be applied to the test input generation process. An example from an efficient implementation called Multi-Purpose Causal (MPC) is presented. Author

N90-27282*# Spectra Research Systems, Inc., Huntsville, AL.
THE APPLICATION OF INTELLIGENT PROCESS CONTROL TO SPACE BASED SYSTEMS
G. STEVE WAKEFIELD *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 53-58 May 1990
Avail: NTIS HC A25/MF A04 CSCL 09/2

The application of Artificial Intelligence to electronic and process control can help attain the autonomy and safety requirements of manned space systems. An overview of documented applications within various industries is presented. The development process is discussed along with associated issues for implementing an intelligence process control system. Author

N90-27286*# Boeing Computer Support Services, Inc., Huntsville, AL. Artificial Intelligence Center.
A KNOWLEDGE-BASED APPROACH TO CONFIGURATION LAYOUT, JUSTIFICATION, AND DOCUMENTATION
F. G. CRAIG, D. E. CUTTS, T. R. FENNEL, C. CASE, and J. R. PALMER (Boeing Aerospace Co., Huntsville, AL.) *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 95-101 May 1990
Avail: NTIS HC A25/MF A04 CSCL 09/2

The design, development, and implementation is described of a prototype expert system which could aid designers and system engineers in the placement of racks aboard modules on Space Station Freedom. This type of problem is relevant to any program with multiple constraints and requirements demanding solutions which minimize usage of limited resources. This process is generally performed by a single, highly experienced engineer who integrates all the diverse mission requirements and limitations, and develops an overall technical solution which meets program and system requirements with minimal cost, weight, volume, power, etc. This system architect performs an intellectual integration process in which the underlying design rationale is often not fully documented. This is a situation which lends itself to an expert system solution for enhanced consistency, thoroughness, documentation, and change assessment capabilities. Author

N90-27289*# University of Southwestern Louisiana, Lafayette. Center for Advanced Computer Studies.
AN AUTOMATED TOOL FOR THE DESIGN AND ASSESSMENT OF SPACE SYSTEMS
LOIS M. L. DALCAMBRE and STEVE P. LANDRY *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 121-127 May 1990
Avail: NTIS HC A25/MF A04 CSCL 09/2

Space systems can be characterized as both large and complex but they often rely on reusable subcomponents. One problem in the design of such systems is the representation and validation of the system, particularly at the higher levels of management. An automated tool is described for the representation, refinement, and validation of such complex systems based on a formal design theory, the Theory of Plausible Design. In particular, the steps necessary to automate the tool and make it a competent, usable assistant, are described. Author

N90-27291*# Alabama Univ., Huntsville.
ESTABLISHING A COMMUNICATIONS-INTENSIVE NETWORK TO RESOLVE ARTIFICIAL INTELLIGENCE ISSUES WITHIN NASA'S SPACE STATION FREEDOM RESEARCH CENTERS COMMUNITY
E. DAVIS HOWARD, III *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 139-145 May 1990
(Contract NAS8-36955)
Avail: NTIS HC A25/MF A04 CSCL 09/2

MITRE Corporation's, A Review of Space Station Freedom Program Capabilities for the Development and Application of Advanced Automation, cites as a critical issue the following situation, extant at the NASA facilities visited in the course of preparing the review: The major issues noted with regard to design and research facilities deal with cooperative problem solving, technology transfer, and communication between these facilities. While the authors were visiting lab and test beds to collect information, personnel at many of these facilities were interested in any information they could collect on activities at other facilities. A formal means of gathering this information could not be identified by these personnel. While communication between some facilities was taking place or was planned, for technology transfer or coordination of schedules (e.g., for SADP demonstrations), poor communication between these facilities could lead to a lack of technical standards, duplication of effort, poorly defined interfaces, scheduling problems, and increased cost. Formal mechanisms by which effective communication and cooperative problem solving can take place, and information can be disseminated, must be defined. A solution is proposed for the communications aspects of the issues addressed above; and offered at the same time a solution which can prove effective in dealing with some of the problems being encountered with expertise being lost via retirement or defection to the private sector. The proffered recommendations are recognizably cost-effective and tap the rising sector of expert knowledge being produced by the American academic community. Author

N90-27296*# National Aeronautics and Space Administration, Washington, DC.
KNOWLEDGE-BASED SYSTEMS AND NASA'S SOFTWARE SUPPORT ENVIRONMENT
TIM DUGAN, CORA CARMODY, KENT LENNINGTON (Lockheed Missiles and Space Co., Houston, TX.), and BOB NELSON *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 185-192 May 1990
Avail: NTIS HC A25/MF A04 CSCL 09/2

A proposed role for knowledge-based systems within NASA's Software Support Environment (SSE) is described. The SSE is chartered to support all software development for the Space Station Freedom Program (SSFP). This includes support for development of knowledge-based systems and the integration of these systems with conventional software systems. In addition to the support of development of knowledge-based systems, various software development functions provided by the SSE will utilize knowledge-based systems technology. Author

N90-27299*# Boeing Computer Support Services, Inc., Huntsville, AL. Artificial Intelligence Center.
GRAPHICAL EXPLANATION IN AN EXPERT SYSTEM FOR SPACE STATION FREEDOM RACK INTEGRATION
F. G. CRAIG, D. E. CUTTS, T. R. FENNEL, and B. PURVES (Boeing Aerospace Co., Huntsville, AL.) *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 211-219 May 1990
Avail: NTIS HC A25/MF A04 CSCL 22/2

The rationale and methodology used to incorporate graphics into explanations provided by an expert system for Space Station Freedom rack integration is examined. The rack integration task is typical of a class of constraint satisfaction problems for large programs where expertise from several areas is required. Graphically oriented approaches are used to explain the conclusions made by the system, the knowledge base content, and even at more abstract levels the control strategies employed by the system. The implemented architecture combines hypermedia and inference engine capabilities. The advantages of this architecture include: closer integration of user interface, explanation system, and knowledge base; the ability to embed links to deeper

knowledge underlying the compiled knowledge used in the knowledge base; and allowing for more direct control of explanation depth and duration by the user. The graphical techniques employed range from simple statis presentation of schematics to dynamic creation of a series of pictures presented motion picture style. *User models control the type, amount, and order of information* presented. Author

N90-27304*# Boeing Computer Services Co., Seattle, WA. Advanced Technology Center.
DESIGN KNOWLEDGE CAPTURE FOR A CORPORATE MEMORY FACILITY
JOHN H. BOOSE, DAVID B. SHEMA, and JEFFREY M. BRADSHAW *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 271-280 May 1990
Avail: NTIS HC A25/MF A04 CSCL 09/2

Currently, much of the information regarding decision alternatives and trade-offs made in the course of a major program development effort is not represented or retained in a way that permits computer-based reasoning over the life cycle of the program. The loss of this information results in problems in tracing design alternatives to requirements, in assessing the impact of change in requirements, and in configuration management. To address these problems, the problem was studied of building an intelligent, active corporate memory facility which would provide for the capture of the requirements and standards of a program, analyze the design alternatives and trade-offs made over the program's lifetime, and examine relationships between requirements and design trade-offs. Early phases of the work have concentrated on design knowledge capture for the Space Station Freedom. Tools are demonstrated and extended which helps automate and document engineering trade studies, and another tool is being developed to help designers interactively explore design alternatives and constraints. Author

04

SPACE ENVIRONMENTS

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

A90-31775
SPACE DEBRIS: LEGAL AND POLICY IMPLICATIONS
HOWARD A. BAKER (Centre for Research in Air and Space Law, Montreal, Canada) Dordrecht and Boston, MA, Martinus Nijhoff Publishers (Utrecht Studies in Air and Space Law, No. 6), 1989, 186 p. refs
Copyright

A comprehensive study is presented of the technical, statistical, and legal aspects of the problem posed by orbital debris encompassing inactive payloads (20 percent), operational debris (26 percent), fragmentation debris (49 percent), and microparticulate matter (unacertainable, due to the current impossibility of its detection and tracking). If the orbital period of a given object is less than 95 min, natural orbit-decay mechanisms will cause the fragments to decay in a comparatively short time. With longer periods, space debris can constitute an essentially permanent threat to space navigation. Attention is given to jurisdiction and regulatory control over space refuse, as well as to estimates of collision probabilities in LEO, GEO, and geosynchronous transfer orbit. O.C.

A90-32030#
ORBITAL DEBRIS DETECTION - TECHNIQUES AND ISSUES
NICHOLAS L. JOHNSON and DAVID J. NAUER (Teledyne Brown Engineering, Colorado Springs, CO) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 9 p.
(AIAA PAPER 90-1330) Copyright

The primary data sources for analyses of the measured earth satellite population are the U.S. Space Command's Satellite File and Satellite Catalog. *The accuracies, limitations, and utility of* these data are not well understood by most users. The actual cataloged satellite population is found to be less than 6500 with more than 200 objects currently lost. To date published population distribution and spatial density calculations do not adequately account for database deficiencies. Another U.S. Space Command data source is the Radar Cross-Section (RCS) Catalog. Radar cross-sectional data are subject to many influences which may result in size estimate errors of an order of magnitude or more. The orbital lifetime of LEO satellite debris has often been over-estimated as a result of ballistic coefficient assumptions and failure to model atmospheric variations with sufficient detail. Individual sensors of the U.S. Space Surveillance Network can provide substantially more information on satellite numbers and characteristics than the network as a whole. Author

A90-32035*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ADVANCED METEOROID AND DEBRIS SHIELDING CONCEPTS
ERIC L. CHRISTIANSEN (NASA, Johnson Space Center, Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 15 p. refs
(AIAA PAPER 90-1336) Copyright

The results of the shielding screening and optimization work conducted at the NASA Johnson Space Center Hypervelocity Impact Research Laboratory (HIRL) are described. The impact tests to investigate and optimize certain aspects of the aluminum mesh double-bumper concept, which was considered the best performer in the screening test, are analyzed. Preliminary results indicate that the aluminum mesh double-bumper concept shows a 30 to 40 percent weight reduction compared to an aluminum Whipple shield in the velocity range study, besides such advantages as an increased resistance to penetration and the fact that the aluminum mesh does not produce damaging secondary ejecta particles. It is suggested that the ballistic protection can be improved even more if an intermediate layer of a high-strength cloth is attached near the rear wall. N.B.

A90-32036*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
COLLISION WARNING AND AVOIDANCE CONSIDERATIONS FOR THE SPACE SHUTTLE AND SPACE STATION FREEDOM
FAITH VILAS, MICHAEL F. COLLINS, PAUL C. KRAMER, G. DICKEY ARNDT, and JERRY H. SUDDATH (NASA, Johnson Space Center, Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 10 p.
(AIAA PAPER 90-1337) Copyright

The increasing hazard of manmade debris in low earth orbit (LEO) has focused attention on the requirement for collision detection, warning and avoidance systems to be developed in order to protect manned (and unmanned) spacecraft. With the number of debris objects expected to be increasing with time, the *impact hazard will also be increasing. The safety of the Space* Shuttle and the Space Station Freedom from destructive or catastrophic collision resulting from the hypervelocity impact of a LEO object is of increasing concern to NASA. A number of approaches to this problem are in effect or under development. The collision avoidance procedures now in effect for the Shuttle are described, and detection and avoidance procedures presently being developed at the Johnson Space Center for the Space Station Freedom are discussed. Author

A90-32037#
COLLISION AVOIDANCE ANALYSIS
J. BENDISCH and D. REX (Braunschweig, Technische Universitaet,

Brunswick, Federal Republic of Germany) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 8 p. Research supported by BMFT.
(AIAA PAPER 90-1338) Copyright

The feasibility and efficiency of orbiting manned platform collision-avoidance maneuvers are discussed; such collision-avoidance capabilities are rendered necessary by the insufficiency of shielding as the sole means of protecting a space structure from impact. Such avoidance maneuvers as tangential thrust, or the raising the orbital altitude, can be performed with less than 1 m/s velocity increment. These maneuvers do not require additional fuel since they are a part of the scheduled altitude stationkeeping strategy. The onboard tracking of objects that cannot be cataloged by ground-based sensors appears an attractive procedure for incorporation by collision-avoidance systems. O.C.

A90-32039*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
OPTICAL OBSERVATIONS OF SPACE DEBRIS
KARL G. HENIZE and JOHN F. STANLEY (NASA, Johnson Space Center, Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 5 p.
(AIAA PAPER 90-1340) Copyright

The Johnson Space Center is processing optical data on orbital debris from five sources. The greatest amount of data so far obtianed is from the GEODSS system for which an analysis is presented of 80.9 hours of zenith observations. A total of 622 satellites were found of which 255 have been identified with objects in the USAF Space Command catalog (SCC). When objects in the SCC but which are not seen by GEODSS are accounted for, an SCC completeness factor of 0.46 over all diameters in the 500 to 1100 km height range is found. For objects with diameters between 8 and 30 cm this factor is 0.26. Comparison of GEODSS-derived diameters with RCS-derived diameters yields a revised mean albedo of approximately 0.08. Author

A90-32040#
DETECTING SPACE DEBRIS ABOVE 900 KM USING IRAS
A. R. W. DE JONGE and P. R. WESSELIUS (SRON, Laboratorium voor Ruimteonderzoek, Groningen, Netherlands) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 4 p. Research supported by ESA.
(AIAA PAPER 90-1341) Copyright

The Infrared Astronomical Satellite IRAS was launched in 1983 to perform a sky survey at wavelengths of 10 to 100 microns. Even though the design of both telescope and data processing tried to filter out responses due to transient events, orbital debris has been detected, and identified because of its movement with respect to the celestial background. The full unprocessed IRAS data is proposed to be reanalyzed in order to characterize the infrared emission of orbital debris objects, and to extract a comprehensive set of debris sightings. Author

A90-32041#
MU RADAR MEASUREMENTS OF ORBITAL DEBRIS
TORU SATO, HIDETOSHI KAYAMA, AKIRA FURUSAWA, and IWANE KIMURA (Kyoto University, Japan) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 10 p. refs
(AIAA PAPER 90-1343) Copyright

Distributions of orbital debris versus height and scattering cross section are determined from a series of observations made with a high-power VHF Doppler radar (MU radar) of Japan. An automated data processing algorithm has been developed to discriminate echoes of orbiting objects from those of undesired signals such as meteor trail echoes or lightning atmospherics. Although the results are preliminary, they showed good agreement with those from NORAD tracking radar observations using a much higher frequency. It is found that the collision frequency of a Space Station of 1 km x 1 km size at an altitude of 500 km with orbiting debris is expected to be as high as once per two years. Author

A90-32042#
RADAR MEASUREMENTS OF DEBRIS SIZE
D. MEHRHOLZ (Forschungsgesellschaft fuer angewandte Naturwissenschaften, Wachtberg-Werthhoven, Federal Republic of Germany) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 9 p.
(AIAA PAPER 90-1344) Copyright

Explosions and collisions in space are the major source of man-made orbital debris. They pose a hazard to large spacecraft planned to operate for long periods of time. For risk assessment and dimensioning of a shielding the size, shape, and mass of impacting space debris objects must be known. The paper discusses features of spaceborne objects which can be assessed by radar, describes analysis methods used to derive physical characteristics of space debris, and shows some preliminary results. The discussion is restricted to objects with dimensions larger than 2 meters. Author

A90-32043#
NASA DEBRIS ENVIRONMENT CHARACTERIZATION WITH THE HAYSTACK RADAR
J. U. BEUSCH and I. KUPIEC (MIT, Lexington, MA) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 7 p.
(Contract F19628-90-C-002)
(AIAA PAPER 90-1346) Copyright

This paper describes the potential use of the Haystack Long Range Imaging Radar and its Auxiliary Ku-band System to help characterize the space debris environment. The fundamental radar sensitivity issues for small object detection are reviewed, and the unique Haystack suitability for this radar application is explained. Initial test results in preparation for future measurements are briefly described. A low elevation geometry for space debris detection, which can provide NASA with timely data, is introduced. The planned processing, real time and post nmission, for this geometry is delineated. The Ku-band auxiliary, a Near Earth Assessment Radar (NEAR), is also introduced and the way its measurements will contribute to the space debris characterization effort is discussed. Author

A90-32044*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
RELATIONSHIP OF RADAR CROSS SECTION TO THE GEOMETRIC SIZE OF ORBITAL DEBRIS
GAUTAM D. BADHWAR (NASA, Johnson Space Center, Houston, TX) and PHILLIP D. ANZ-MEADOR (Lockheed Engineering and Sciences Co., Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 4 p.
(AIAA PAPER 90-1347) Copyright

An accurate determination of the sizes of orbiting debris objects is essential to predicting collision rates, atmospheric decay rates, and fragmentation laws for orbiting objects. The radar cross section (RCS) is the most common means of estimating the size of orbiting objects. However, the RCS is prone to error due to Mie scattering, compositional effects, geometrical effects, tumbling, and other dependencies. Optical measurement methods are theoretically much more accurate, but necessitate estimates of the object's albedo. This paper examines the relationship of RCS and optical cross section to physical size and albedo, and presents rules useful for quantizing the physical size of space objects. Author

A90-32045#
ORBITAL ELEMENTS DETERMINATION FOR BREAKUP AND DEBRIS
STEPHEN H. KNOWLES (U.S. Navy, Naval Space Surveillance Center, Dahlgren, VA) AIAA, NASA, and DOD, Orbital Debris

Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 7 p. refs
(AIAA PAPER 90-1348)

This contribution describes the general procedures and resources required for a specific determination of orbits of space debris resulting from satellite breakups and other causes. Examples of events processed by the Naval Space Surveillance Center are included. Author

A90-32046*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
RESULTS FROM RETURNED SPACECRAFT SURFACES
HERBERT A. ZOOK, DAVID S. MCKAY (NASA, Johnson Space Center, Houston, TX), and RONALD P. BERNHARD (Lockheed Engineering and Sciences Co., Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 7 p. refs
(AIAA PAPER 90-1349) Copyright

Meteoroid and space debris impact data obtained from space exposed spacecraft parts or meteoroid experiments is analyzed. The returned space exposed surfaces considered include spacecraft windows, meteoroid experiments exposed on space flights, and samples of opportunity such as foil wrapped around a cosmic ray package. The debris flux is found to exceed the meteoroid flux in creating impact craters smaller than 20 microns in diameter, and may again exceed it for impact structures larger than a few mm in diameter. For impact structures between 100 microns and 1 mm in diameter, the debris flux is found to be several times less than the meteoroid flux. Determining more accurately the meteoroid or orbital debris mass that makes a given crater or hole size remains is considered to be the main remaining problem. V.T.

A90-32048*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ORBITAL DEBRIS ENVIRONMENT FOR SPACECRAFT IN LOW EARTH ORBIT
DONALD J. KESSLER (NASA, Johnson Space Center, Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 8 p. refs
(AIAA PAPER 90-1353) Copyright

Modeling and measurement results used in formulating an environment model that can be used for the engineering design of spacecraft are reviewed. Earth-based and space-based sensors are analyzed and it is noted that the effects of satellite breakups can be modeled to predict a uncatalogued population, if the nature of the breakup is understood. It is observed that the telescopic data indicate that the current model is too low for sizes slightly larger than 10 cm, and may be too low for sizes between 2 cm and 10 cm, while there is an uncertainty in the current development, especially for sizes smaller than 10 cm, and at altitudes different from 500 km. Projections for the catastrophic collision rate for different growth conditions are made, emphasizing that the rate of growth of fragments will be twice the rate of intact objects. V.T.

A90-32049#
A REVIEW OF ORBITAL DEBRIS MODELING IN EUROPE
D. REX, J. ZHANG, and P. EICHLER (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 9 p. Research supported by BMFT. refs
(AIAA PAPER 90-1354) Copyright

The importance of mathematical debris models is pointed out. The past debris model of particles larger than 1 cm is briefly reviewed. The objects in this model are composed from two classes: the cataloged objects larger than 10 cm, and the objects between 1 cm and 10 cm, obtained from the simulation of explosions in space. Subsequently the problem of modeling the flux of small particles in the size range between 0.1 mm and 10 mm is discussed. It is supposed that those particles are mainly generated by collisions between a small particle and a satellite. Using the collision mechanisms for such events as developed in the literature, the orbital dynamics of small particle debris is analyzed. The influence of this collision-generated small-particle debris on the altitude range 450 to 500 km (Space Station altitude) is shown to be extremely dependent on the altitude and eccentricity of the orbit in which the collision occurred. Author

A90-32050*# System Planning Corp., Houston, TX.
A REVIEW OF ORBITAL DEBRIS ENVIRONMENT MODELING AT NASA/JSC
ROBERT C. REYNOLDS (System Planning Corp., Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 22 p. Research supported by NASA.
(AIAA PAPER 90-1355) Copyright

Orbital debris modeling in three areas is presented in this paper. These are: (1) debris environment evolution, as characterized by a numerical processor using detailed mission model projections, (2) debris cloud evolution for the time immediately after breakup, and (3) two-dimensional flux density modeling to characterize both flux levels and directionality for a debris environment. Author

A90-32051#
A REVIEW OF ORBITAL DEBRIS MODELING AT THE AEROSPACE CORPORATION
V. A. CHOBOTOV and D. B. SPENCER (Aerospace Corp., El Segundo, CA) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 6 p. refs
(AIAA PAPER 90-1356) Copyright

This paper is an overview of the space-debris modeling techniques and tools used at the Aerospace Corporation in support of USAF space-debris efforts. A discussion of the software tools IMPACT, which does the breakup analysis, and DEBRIS, which does collision hazard assessment, is presented. Additionally, the analysis done to improve the operational characteristics of these programs is shown. Author

A90-32052#
BREAKUPS AND THEIR EFFECTS ON THE CATALOG POPULATION
D. S. MCKNIGHT (U.S. Air Force Academy, Colorado Springs, CO) and N. L. JOHNSON (Teledyne Brown Engineering, Colorado Springs, CO) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 14 p. refs
(AIAA PAPER 90-1358)

The effects of satellite breakups on on-orbit population growth are assessed with the total population divided into lower low earth orbit (LEO1), upper LEO (LEO2), high earth orbit (HEO), and geosynchronous orbit (GEO) regimes. Most of these subsets of the total population exhibit linear growth rates combining to result in a catalog population increase of 240 per year. It is especially important in LEO where solar activity acts to cleanse much of it from orbit. The LEO population contains 75 percent of all cataloged objects in similar proportions to the total catalog, with HEO and GEO regions showing a larger percentage of payloads and rocket bodies and a smaller amount of fragmentation debris. It is shown that changes in breakup characteristics significantly alter the debris environment of the LEO2 region, while objects in geosynchronous transfer orbits pose a negligible hazard to both LEO and GEO due to their small number and orbital geometries. V.T.

A90-32053*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ON-ORBIT BREAKUP CHARACTERISTICS
GAUTAM D. BADHWAR (NASA, Johnson Space Center, Houston, TX) and PHILLIP D. ANZ-MEADOR (Lockheed Engineering and Sciences Co., Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 11 p. refs
(AIAA PAPER 90-1359) Copyright

Techniques allowing the user to categorize the cause of an on-orbit fragmentation and to describe the properties of debris fragments in the breakup of a satellite are discussed. These techniques rely upon the examination of radar cross section (RCS) and plane change angle to ascertain the cause of breakup. Additionally, the mass distribution of orbital debris is examined and this technique is applied to a set of 'calibration' satellites of known physical dimensions and mass and to the orbital debris population. The results indicate that for debris size greater than 15 cm the velocity distribution can be fitted to a beta function and shows a much larger range of velocities than used earlier. This function is also dependent on the nature of breakup and, although there is insufficient data to prove it, it is also depends on size. As expected, the results show a general decrease of velocity with debris mass. V.T.

A90-32054#
FUTURE PLANNED SPACE TRAFFIC - 1990-2010 AND BEYOND
PHILLIP D. ANZ-MEADOR (Lockheed Engineering and Sciences Co., Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 9 p. refs
(AIAA PAPER 90-1360) Copyright

Traffic models project the launch rate of spacecraft (and hence rocket bodies and operational debris) into orbit. Since these activities add numbers of objects and collisional area into the environment, the traffic models can drastically effect the growth of orbital debris. Current traffic models are examined for (1) numerical growth rate, (2) dry mass growth rate, and (3) areal growth rate. These rates are compared with historical data. Trends in the historical growth, the projected growth, and post-2010 traffic growth are examined to characterize each of the three above interpretations of on-orbit growth. Author

A90-32057*# Lockheed Engineering and Sciences Co., Houston, TX.
ANALYTICAL MODEL FOR ORBITAL DEBRIS ENVIRONMENTAL MANAGEMENT
DAVID L. TALENT (Lockheed Engineering and Sciences Co., Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 11 p. refs
(Contract NAS9-17900)
(AIAA PAPER 90-1363)

A differential equation, also referred to as the PIB (particle-in-a-box) model, expressing the time rate of change of the number of objects in orbit, is developed, and its applicability is illustrated. The model can be used as a tool for the assessment of LEO environment stability, and as a starting point for the development of numerical evolutionary models. Within the context of the model, evolutionary scenarios are examined, and found to be sensitive to the growth rate. It is determined that the present environment is slightly unstable to catastrophic growth, and that the number of particles on orbit will continue to increase until approximately 2250-2350 AD, with a maximum of 2,000,000. The model is expandable to the more realistic (complex) case of multiple species in a multiple-tier system. N.B.

A90-32058*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
TECHNIQUES FOR DEBRIS CONTROL
ANDREW J. PETRO (NASA, Johnson Space Center, Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 8 p. refs
(AIAA PAPER 90-1364) Copyright

This paper will summarize a range of techniques which have been proposed for controlling the growth of man-made debris in earth orbit. Several techniques developed in studies at the Johnson Space Center will be described in detail. These techniques include the retrieval of inoperative satellites with an orbital maneuvering vehicle and self-disposal devices for satellites and upper stages. Self-disposal devices include propulsive deorbit motors and passive drag-augmentation devices. Concepts for sweeping small debris from the orbital environment will also be described. An evaluation of the technical feasibility and economic practicality of the various control methods will be summarized. In general, methods which prevent the accumulation of large debris objects were found to provide greater promise for control of the debris problem than methods of removing small debris particles. Author

A90-32059#
DEBRIS CHAIN REACTIONS
P. EICHLER and D. REX (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 10 p. Research supported by BMFT. refs
(AIAA PAPER 90-1365) Copyright

The collision risk posed by the increasing amount of orbital debris is analyzed. The results of the analysis of the current population and its possible evolution show that the population of larger space objects is of decisive importance for the fragment generation by collisions. The critical population for the setting-in of a chain reaction is only about 2 to 3 times the current population, and could be reached within 20 to 50 years, unless the population of larger objects, especially in the critical higher altitudes, is reduced by active removal. Therefore, the number of larger space objects must be limited in the next few decades by actively controlled reentry maneuvers after the end of their missions. N.B.

A90-32060#
REMOVAL OF DEBRIS FROM ORBIT
P. EICHLER and A. BADE (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 9 p. Research supported by BMFT. refs
(AIAA PAPER 90-1366) Copyright

A new strategy for economical debris removal, using only techniques expected to be available in the near future, is examined. The strategy is developed as a cycle of energy transfer and conversion with the help of a conductive space tether, aimed at drastically reducing the propellant consumption for the necessary rendezvous and deorbit maneuvers. It is concluded that the orbital energy, instead of being consumed in the process of forcing debris to reenter, can be transferred to a remover and converted into electrical energy, utilizing the electrodynamic effect of a conductive tether which moves within the earth's magnetic field. The energy is stored and can be used for the next rendezvous maneuver. N.B.

A90-32062#
TECHNOLOGY REQUIREMENTS FOR THE DISPOSAL OF SPACE NUCLEAR POWER SOURCES AND IMPLICATIONS FOR SPACE DEBRIS MANAGEMENT STRATEGIES
JAMES LEE (Sandia National Laboratories, Albuquerque, NM), DAVE BUDEN (Idaho National Engineering Laboratory, Idaho Falls), THOMAS ALBERT, W. MARGOPOLOUS (Science Applications International Corp., San Diego, CA), JOE ANGELO (EG&G, Inc., Wellesley, MA) et al. AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 15 p. refs
(AIAA PAPER 90-1368)

This paper reports the significant findings of a concept study on the rescue of a space nuclear reactor to prevent its reentry into the biosphere. Required system functions are described as well as needed technologies. The needed technologies are related to the existing ground-based and space-based infrastructures. The challenge of reactor rescue is related to the broader problem of space debris and its effect on satellite and space station survivability. The effects of active orbited debris removal are presented. Significant study findings are discussed. Author

A90-32063*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ENVIRONET - A SPACE ENVIRONMENT DATA RESOURCE
MICHAEL LAURIENTE and WALTER HOEGY (NASA, Goddard Space Flight Center, Greenbelt, MD) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 10 p. Research supported by USAF. refs
(AIAA PAPER 90-1370) Copyright

This paper reviews the features of EnviroNET that make it a valuable space data resource. This computerized data base provides rapid access to the latest information on space debris and other space environments and spacecraft interactions of importance to the space community. Although originally conceived as an information resource for Space Shuttle users, EnviroNET has expanded into other areas including space debris and the near-earth environments of potential interest to the conference attendees. Author

A90-32064#
USE OF GBR-X FOR ORBITAL DEBRIS RADAR
J. KRASNAKEVICH, D. M. GREELEY, and P. M. CUNNINGHAM (Raytheon Co., Equipment Div., Wayland, MA) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 13 p. Research sponsored by the U.S. Army and SDIO.
(AIAA PAPER 90-1352)

The paper discusses the application of the GBR-X radar, scheduled for operation in March of 1993 for the measurement of orbital debris. A brief overview of the radar is initially presented to acquaint the reader with its capabilities. A detailed discussion of its operational configuration to meet the ODR mission requirements follows. Author

A90-33153
THE DYNAMICS OF ORBITING DEBRIS AND THE IMPACT ON EXPANDED OPERATIONS IN SPACE
V. A. CHOBOTOV and M. G. WOLFE (Aerospace Corp., Los Angeles, CA) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 38, Jan.-Mar. 1990, p. 29-39. refs
Copyright

This paper analyzes the dynamics of a cloud of particles resulting from a breakup of an orbiting object. Linearized equations of motion are used to obtain the shape and volume of the cloud as a function of time and the initial debris particle spread velocities. Spatial density is calculated for representative breakup models, and the probability of collision with a spacecraft in orbit is examined. The results show that the greatest hazard occurs at or shortly after the breakup event when the cloud volume is small and the density large. The collision hazard is found to decrease rapidly with time. Author

A90-34753
SIGNATURES OF THE HIGH-ALTITUDE POLAR CUSP AND DAYSIDE AURORAL REGIONS AS SEEN BY THE VIKING ELECTRIC FIELD EXPERIMENT
G. T. MARKLUND, L. G. BLOMBERG, C.-C. FALTHAMMAR (Kungliga Tekniska Hogskolan, Stockholm, Sweden), R. E. ERLANDSON, and T. A. POTEMRA (Johns Hopkins University, Laurel, MD) Journal of Geophysical Research (ISSN 0148-0227), vol. 95, May 1, 1990, p. 5767-5780. Research supported by the Swedish Board for Space Activities. refs
Copyright

Electric-field and satellite-potential (which is a rough measure of plasma density) observations along 42 Viking orbits in the high-altitude (2 earth radii) polar cusp and dayside auroral region have been examined. A useful straightforward way to identify the polar cusp from the satellite potential is demonstrated, the results being in excellent agreement with those based on particle data. Within the cusp the plasma density usually reaches a maximum, and it is typically very homogeneous, in contrast to the irregular and lower density in the cleft and dayside auroral regions. The maxima in the plasma density are sometimes anticorrelated with the magnetic field strength, indicating a diamagnetic effect. The entire cusp and dayside auroral regions are characterized by irregular and burstlike electric fields, comprising field reversals on various scales (up to 3 min or 500 km), the larger scales, however, being rare in the cusp. Author

A90-34761
A STATISTICAL STUDY OF HIGH-ALTITUDE ELECTRIC FIELDS MEASURED ON THE VIKING SATELLITE
P.-A. LINDQVIST and G. T. MARKLUND (Kungliga Tekniska Hogskolan, Stockholm, Sweden) Journal of Geophysical Research (ISSN 0148-0227), vol. 95, May 1, 1990, p. 5867-5876. Research supported by the Swedish Board for Space Activities. refs
Copyright

Characteristics of high-altitude data from the Viking electric field instrument are presented in a statistically study based on 109 Viking orbits. The study is focused in particular on the signatures of and relationships between various parameters measured by the electric field instrument, such as the parallel and transverse (to B) components of the electric field, the satellite potential, and the electric field variability. A major goal of the Viking mission was to investigate the occurrence and properties of parallel electric fields and their role in the auroral acceleration process. The results in this paper on the altitude distribution of the electric field variability confirm earlier findings on the distribution of small-scale electric fields and indicate the presence of parallel fields up to about 11,000 km altitude. The directly measured parallel electric field is also investigated in some detail. It is in general directed upward with an average value of 1 mV/m, but depends on, for example, altitude and plasma density. Possible sources of error in the measurement of the parallel field are also considered and accounted for. Author

A90-34782* Colorado Univ., Boulder.
ELECTRON BEAM INJECTION DURING ACTIVE EXPERIMENTS. II - COLLISIONAL EFFECTS
R. M. WINGLEE (Colorado, University, Boulder) Journal of Geophysical Research (ISSN 0148-0227), vol. 95, May 1, 1990, p. 6191-6207. refs
(Contract NAGW-1587; NAGW-91; NSG-7287; NSF ATM-87-19371)
Copyright

During active beam experiments, the presence of high neutral densities at low altitudes and/or during thruster firings has been observed to modify the spacecraft charging and the properties of the beam. Two-dimensional (three-velocity) electromagnetic particle simulations with ionizing collisions incorporated are used to investigate the modification of the beam-plasma interaction as the neutral density is increased. It is shown that when the spacecraft is uniformly immersed in a neutral cloud, most of the ionization is produced by direct ionization by the beam and its secondaries, rather than via vehicle-induced or wave-induced ionization for the neutral densities considered. Author

A90-36191*# Massachusetts Inst. of Tech., Cambridge.
ION DRAG FOR A NEGATIVELY BIASED SOLAR ARRAY IN LOW EARTH ORBIT
DANIEL E. HASTINGS and MENGU CHO (MIT, Cambridge, MA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, May-June 1990, p. 279-284. refs
(Contract AF-AFOSR-87-0340; NAG3-695)
Copyright

Highly biased solar arrays in the space environment are found to have a number of significant interactions with the space environment. The enhanced drag suffered by highly biased solar arrays is studied with the particle-in-cell code. The results are compared to recent numerical work. The drag calculations contain the effect of having the conductor surrounded by dielectrics as well as the charging of the dielectric by electrons. The results are used to calculate the attitude change expected on the high-voltage solar array of the Japanese Space Flyer Unit. Author

A90-37101
RAREFIED GAS DYNAMICS: SPACE-RELATED STUDIES; INTERNATIONAL SYMPOSIUM, 16TH, PASADENA, CA, JULY 10-16, 1988, TECHNICAL PAPERS
E. P. MUNTZ, ED. (Southern California, University, Los Angeles, CA), D. P. WEAVER, ED., and DAVID H. CAMPBELL, ED. (USAF, Astronautics Laboratory, Edwards AFB, CA) Symposium sponsored by Los Alamos National Laboratory, SDIO, U.S. Army, et al. Washington, DC, American Institute of Aeronautics and Astronautics, Inc. (Progress in Astronautics and Aeronautics. Volume 116), 1989, 590 p. For individual items see A90-37102 to A90-37138.

Various papers on space-related applications of rarefied gas dynamics are presented. Individual topics addressed include: semiclassical approach to atomic and molecular interactions, options for generating greater than 5 eV atmospheric species, backscatter contamination analysis, rarefied gas flow through rectangular tubes and tubes of various surface properties, translational nonequilibrium effects in expansion flows of argon, three-dimensional freejet flow from a finite length slit, simulation of multicomponent nozzle flows into a vacuum, radially directed underexpanded jet from a ring-shaped nozzle, three-dimensional structures of interaction freejets, particle surface interaction in the orbital context, determination of momentum accommodation from satellite objects, nonreciprocity in noble gas metal-surface scattering, thermal accommodation and conduction in the transition regime, models for temperature jumps in vibrationally relaxing gases. C.D.

A90-37109*# Physical Sciences, Inc., Andover, MA.
LABORATORY SIMULATIONS OF ENERGETIC ATOM INTERACTIONS OCCURRING IN LOW EARTH ORBIT
G. E. CALEDONIA (Physical Sciences, Inc., Andover, MA) IN: Rarefied gas dynamics: Space-related studies; International Symposium, 16th, Pasadena, CA, July 10-16, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 129-142. Research supported by Physical Sciences, Inc. refs
(Contract NAS7-963)

The Space Shuttle flights provided the first significant data base on the environment experienced by a large space structure operating in LEO. A number of interesting and unanticipated effects were observed, including material erosion induced by ambient oxygen atoms, the visible Shuttle glow occurring above surfaces exposed to the ram flow, and large near-field perturbations and variability in the gaseous neutral and plasma environment about the Shuttle. This paper provides a brief overview of these observations and their phenomenological interpretation, and then discusses laboratory approaches to their investigation. The emphasis is on the state of the art in the development of energetic oxygen atoms sources and the variety of experiments presently being performed with such devices. Author

A90-37114#
BACKSCATTER CONTAMINATION ANALYSIS
B. C. MOORE, T. S. MOGSTAD, S. L. HUSTON, and J. L. NARDACCI, JR. (McDonnell Douglas Space Systems Co., Huntington Beach, CA) IN: Rarefied gas dynamics: Space-related studies; International Symposium, 16th, Pasadena, CA, July 10-16, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 216-225. Research supported by McDonnell Douglas Space Systems Co. refs

A numerical procedure has been developed to compute the return flux due to backscattering of ambient molecules off of molecules emitted from a spacecraft. This analysis procedure computes the contamination of a particular surface from a selected point in space, given the local densities and velocity distributions of the two groups of molecules. This procedure has been used to determine the conditions behind an orbiting molecular wake shield. The effects of different emitted gas species, ambient and emitted gas temperatures, distance from emission source, and shield size are considered. The calculations show that N2 emissions are more important than H2O emissions for scattering ambient molecules. Author

A90-37129#
PARTICLE SURFACE INTERACTION IN THE ORBITAL CONTEXT - A SURVEY
F. C. HURLBUT (California, University, Berkeley) IN: Rarefied gas dynamics: Space-related studies; International Symposium, 16th, Pasadena, CA, July 10-16, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 419-450. refs

Present data on the interaction between gas molecules and solid surfaces under conditions of extremely high relative velocities are summarized, and the relevant literature is reviewed. Particular attention is given to the aspects of the gas/wall interaction that directly influence the dynamical behavior of flight vehicles and bear on the aerothermodynamic effects, and accordingly, to the distributions of translational velocities of molecules scattered from surfaces and in their rotational and vibrational states. The majority of studies discussed are ground-based, using ion or neutralized beam methods and yield scattered flux distributions or, in a few cases, both flux and energy distributions. Several examples are included of close correspondence between experimental mappings and trajectory simulation. It is concluded that earth based experimentation by beam methods is practicable for the relevant energy range and is able to provide a valuable complement to flight experiments. N.B.

A90-38090
THE EFFECT OF SPACECRAFT CHARGING TRANSIENT IN GEO SATELLITES
J. M. BODEAU, W. R. ELKMAN, J. F. DIAZ, D. P. HANSEN, C. KIRSTEN (TRW Space and Technology Group, Redondo Beach, CA) et al. IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 375-383. refs

Satellites in geosynchronous orbit have been experiencing electronic switching anomalies and component failures since the early seventies. These upsets are believed to be due to encounters with geomagnetic substorm environments. This concept is examined. Background data are used to establish the frequency and intensity of encounters. Analytical models of generic three-axis-stabilized spacecraft are used to predict the charging and demonstrate the mechanism of coupling to the spacecraft electrical system. It is found that environmentally induced discharges can couple into these systems and cause anomalies. I.E.

A90-38273
BREAKDOWN EXPERIMENTS IN GAS CONTAMINATED VACUUM REGIONS
L. B. GORDON, J. C. LITTLE, and S. A. MERRYMAN (Auburn University, AL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2657-2662. Research supported by SDIO.
(Contract DNA001-85-C-0183)

The possibility of using the space vacuum for electrical insulation is under investigation. To predict the gas flow and pressure throughout a given geometry of interconnected regions (i.e., a spacecraft payload), a computer model which includes source terms such as outgassing, leaks, and effluents was developed. For vacuum regions dominated by outgassing the electrical breakdown process is most likely to be low-pressure gas breakdown governed by Paschen's law. Thus the gas distribution model is coupled to a

gas breakdown model to predict potential breakdown locations. Preliminary experimental results are presented. Two applications to actual space experiments are described. I.E.

A90-38411*# TRW Space Technology Labs., Redondo Beach, CA.
PLUME IMPINGEMENT STUDY FOR REACTION CONTROL SYSTEM OF THE ORBITAL MANEUVERING VEHICLE
R. D. MCGREGOR, P. D. LOHN, and D. E. HAFLINGER (TRW Space and Technology Group, Redondo Beach, CA) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 14 p. refs
(Contract NAS8-36800)
(AIAA PAPER 90-1708) Copyright

A study has been performed to assess plume impingement effects from the reaction control system of NASA's OMV. A key aspect of this modeling effort has been the use of the direct Monte Carlo method as an integral part of the nozzle/plume flowfield modeling and to compute the impingement effects for configurations in which vehicle structure or multiple plumes resulted in highly three-dimensional rarefied plume flowfields. The calculation of the flowfield for a pair of interacting thruster plumes has shown that backflow in the region between the thrusters is greatly enhanced by the interaction of the two plumes. Although the present analyses have focussed on impingement force and heating effects, this methodology would also be valuable for contamination assessments since it properly accounts for the species separation effects that are inherent in the nonequilibrium nature of rarefied gas flows. R.E.P.

A90-38460#
NON-STANDARD METHOD FOR MATERIAL OUTGASSING RATE MEASUREMENT
A. T. CHEN, M. M. THORNTON, S. J. LEET, C. G. SHAW, D. R. BOWMAN (Boeing Aerospace and Electronics, Seattle, WA) et al. AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 7 p. Research supported by USAF.
(AIAA PAPER 90-1768) Copyright

Consideration is given to a laboratory study to perform nonstandard outgassing measurements for a set of materials as functions of time, source temperature, and receiver temperature. This paper reports the measurement procedure including the calibration technique and discusses the data interpolation schemes. The outgassing rates of each material are presented as functions of outgassing source and receiver temperature. The results show the material outgassing characteristics are strong functions of the material source temperature, receiver temperature, and outgassing time. Author

A90-38697*# Systems Science and Software, La Jolla, CA.
PLASMA SOURCES FOR SPACECRAFT NEUTRALIZATION
V. A. DAVIS, I. KATZ, and M. J. MANDELL (Systems Science and Software, La Jolla, CA) AIAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, 21st, Seattle, WA, June 18-20, 1990. 12 p. refs
(Contract NAS3-23881)
(AIAA PAPER 90-1556) Copyright

The principles of the operation of plasma sources for the neutralization of the surface of a spacecraft traveling in the presence of hot plasma are discussed with special attention given to the hollow-cathode-based plasma contactors. Techiques are developed that allow the calculation of the potentials and particle densities in the near environment of a hollow cathode plasma contactor in both the test tank and the LEO environment. The techniques and codes were validated by comparison of calculated and measured results. I.S.

A90-38701#
PROPERTIES OF AN ENERGETIC O ATOM STREAM FROM A GAS DISCHARGE SOURCE
GERALD PHAM-VAN-DIEP, DAVID WEAVER, DAVID DE WITT (Southern California, University, Los Angeles, CA; USAF, Astronautics Laboratory, Edwards AFB, CA), JAVIER TRELLES, TOM RANDOLPH et al. AIAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, 21st, Seattle, WA, June 18-20, 1990. 33 p. Research supported by USAF and U.S. Navy. refs
(AIAA PAPER 90-1560) Copyright

Due to the rapidly increasing activity in near-earth space, a program has been initiated to develop a university scale source for atmospheric species that provides energies between 5 eV and about 40 eV in laboratory coordinates. Modern surface diagnostics and laser gas phase spectroscopic techniques present the ability to obtain detailed surface state characteristics and gas phase energy state populations. Since the latest spectroscopic techniques permit detailed specifications of the state of the gases that are used to simulate LEO conditions, it appears attractive to look at sources that may have been rejected in the past due to their potential for the production of unknown energy level populations in the test gas. In summary, an oxygen ion source has been designed and operated at levels consistent with producing substantial fluxes of fast O atoms to simulate conditions in LEO. The source operates reliably and for extended (tens of hours) periods. R.E.P.

A90-39999#
VEHICLE CHARGING AND ASSOCIATED HF WAVE PHENOMENA DURING ELECTRON BEAM EMISSIONS
J. ERNSTMEYER and D. E. DONATELLI (USAF, Electromagnetics Directorate, Hanscom AFB, MA) Radio Science (ISSN 0048-6604), vol. 25, May-June 1990, p. 263-275. refs

A series of preflight tests was conducted in Chamber A at the NASA-Johnson facility, using the instruments on the Beam-Emitting Rocket Test. The change in beam morphology, which results in abrupt changes in the DC electric fields and wave intensity below the electron cyclotron frequency measured at the nose cone 'ERNIE', is analyzed, together with the direction of these abrupt changes. A one-dimensional analytical model of the reflection process is used to explain the threshold current and its variation with epsilon exp 3/2 for an unneutralized beam. It is concluded that the appearance of HF waves is associated with virtual cathode formation rather than beam plasma discharge. A suggestion is made that properties of the beam reflection observed in the experiment should cause concern for payload safety. N.B.

A90-40545*# Cincinnati Univ., OH.
SPACE VEHICLE PROPULSION SYSTEMS - ENVIRONMENTAL SPACE HAZARDS
G. K. BAHR and P. J. DISIMILE (Cincinnati, University, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs
(Contract NAG3-948)
(AIAA PAPER 90-1881) Copyright

An evaluation of hazards which exist in geo-lunar space and have the potential to negatively affect a long-term mission-oriented spacecraft systems is presented based on published data. The hazards are categorized as pervasive (radiation), incident specific (meteoroids and thermal shock), and chemically corrosive (monatomic oxygen). It appears that the number one priority should be the development of new materials; and the secondary concern should be the development of fabrication techniques for the exterior hull, so that incident specific hazards can be minimized in an active fashion. The pervasive hazard can be dealt with by exploring on-board circuit technology with ancillary monitoring systems. Effects of thermal shock on the exterior nozzle, directional gimbals, and internal combustion chamber geometry seem to need more investigation. N.B.

A90-44527* Stanford Univ., CA.
THE INTERACTION OF AN ARTIFICIAL ELECTRON BEAM WITH THE EARTH'S UPPER ATMOSPHERE - EFFECTS ON SPACECRAFT CHARGING AND THE NEAR-PLASMA EVIRONMENT
T. NEUBERT, P. M. BANKS, B. E. GILCHRIST, A. C. FRASER-SMITH, P. R. WILLIAMSON (Stanford University, CA) et al. Journal of Geophysical Research (ISSN 0148-0227), vol. 95,

Aug. 1, 1990, p. 12209-12217. refs
(Contract NAGW-1566; NAG5-607; NAS8-35350; F19628-89-K-0040)
Copyright

The ionization created in the earth's upper atmosphere by an electron beam emitted from a low altitude spacecraft is described by two coupled nonlinear differential electron transport equations for the up-going and down-going differential energy flux. The equations are solved numerically, yielding estimates of the differential electron energy flux density at the spacecraft location. At altitudes below 200-250 km and for beam energies around 1 keV, it is shown that secondary electrons supply a significant contribution to the return current to the spacecraft and thereby reduce the spacecraft potential. The numerical results are in good agreement with observations from the Charge 2 sounding rocket experiment. Author

A90-44558#
METHODS OF CONTROLLING SPACECRAFT MAGNETIC PROPERTIES
YOUGAO SONG (Beijing Institute of Environmental Test Engineering, People's Republic of China) Chinese Space Science and Technology (ISSN 1000-758X), vol. 9, Feb. 1989, p. 53-58. In Chinese, with abstract in English. refs

Spacecraft magnetic properties may disturb the attitude of a spacecraft and may affect the performance of sensitive instruments, and thus must be controlled in the process of spacecraft design and development. In this paper, space magnetic fields and the sources of spacecraft magnetic properties are briefly presented. Design criteria and test methods are emphatically clarified for controlling spacecraft properties. Author

A90-44574#
THIN CONDUCTIVE FILMS FOR CHARGING STATE PASSIVE CONTROL ON SPACECRAFT SURFACE
YUSUN LU, HUA LI, and XIAOWEN HAN (Lanzhou Institute of Physics, People's Republic of China) Chinese Space Science and Technology (ISSN 1000-758X), vol. 9, Aug. 1989, p. 20-27. In Chinese, with abstract in English.

The concept and advantages of charging state passive control on the spacecraft surface have been represented in this article. The indium oxide/tin oxide film, indium oxide film and tin oxide film for the charging state passive control has been prepared by reacted magnetron sputtering. The transparence, radiant emittance and surface resistivity of the films has been given. The charging characteristic of the films in the simulated space environment, which contains vacuum, solar irradiation and substorm, was also evaluated. The results of experiments and measurements prove that the performances of the films agree with the NASA specifications about the prevention of charging on spacecraft surface. Author

A90-46777
ESTIMATING AND MODELING THE BACKGROUND ORBITAL DEBRIS POPULATION
ROBERT D. CULP (Colorado, University, Boulder), TIMOTHY D. MACLAY, and RON MADLER IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 1. San Diego, CA, Univelt, Inc., 1990, p. 365-376. refs
(AAS PAPER 89-376) Copyright

Two methods of constructing a spatial density matrix describing the untrackable 1-mm to 10-cm background space debris population are offered. One method is based on the present trackable population, and the other simulates the 97 known satellite breakups by generating the resulting debris fragments and establishes a spatial density matrix of debris. Focus is placed on object classification, weighting factors, and spatial density in the first method, and on debris generation, distribution range, and atmospheric decay in the second approach. It is demonstrated that the results from both methods are sensitive to various model parameters, and it is shown that the methods produce similar spatial density averaged over latitude with a wide peak between 800 km and 1000 km and a narrow one at approximately 1500 km. V.T.

A90-46778
A NONLINEAR DYNAMICAL MODEL OF RELATIVE MOTION FOR THE ORBITING DEBRIS PROBLEM
RICHARD S. HUJSAK (Applied Technology Associates, Inc., Lionville, PA) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 1. San Diego, CA, Univelt, Inc., 1990, p. 393-409. refs
(Contract F04690-86-C-0006)
(AAS PAPER 89-397) Copyright

A nonlinear dynamical model of relative motion is presented for the orbital breakup problem. The model is applied to the analysis of debris density, starting at the time of breakup and proceeding until the cloud rings the earth. A linear relative motion model generalizing the Clohessy and Wiltshire equations to all eccentricity and secular J(2) is produced, and selected higher-order terms are added. It is shown that an improvement over linear relative motion methods is achieved for the expanding debris cloud. The inverse of the relative motion transformation enables an analysis of debris differentially at a location in space as a function of initial breakup-spread velocity statistics. The structure of a debris cloud is considered, and it is concluded that debris density increases by four orders of magnitude around the well-known pinched features of the cloud and at locations internal to the cloud. V.T.

A90-46779
STUDY OF POSSIBLE COLLISION-INDUCED BREAKUPS
DARREN S. MCKNIGHT (U.S. Air Force Academy, Colorado Springs, CO) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 1. San Diego, CA, Univelt, Inc., 1990, p. 411-416. refs
(AAS PAPER 89-398) Copyright

A group of tests (Satellite Fragmentation Event - SAFE - Test III) used to define characteristics of a breakup event is reported. First, the prebreakup parameters including mission duration, collision hazzard, fragment lethality, and past history are outlined; then postbreakup debris analysis is performed. Emphasis is placed on the velocity and mass distributions of the resulting debris and on hypervelocity impact data. Preliminary results of 14 satellite breakups are presented, and it is suggested that a number of unknown breakup events has characteristics of a hypothetical collision-induced fragmentation. V.T.

A90-46780
AVOIDING COLLISIONS WITH RESIDENT SPACE OBJECTS
RALPH G. SCHINNERER (Ford Aerospace Corp., Colorado Springs, CO) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 1. San Diego, CA, Univelt, Inc., 1990, p. 417-424. refs
(Contract F19628-83-C-0019)
(AAS PAPER 89-399) Copyright

The minimum velocity impulse maneuver that can be employed by a satellite at a specific time to allow 'safe' passage with all other known satellites for a specific time in the future is determined. A technique employed for defining the maneuver is based on the linearization of the problem about the nominal 'nonmaneuvered' orbit; it uses partial derivatives relating position and velocity at the locations of the closest approach to the proposed maneuver-velocity impulse. It is shown that this approach is efficient in terms of computer resources since it employs a linearized representation and recursive formulas to reduce the computation time required at each point investigated in the 'velocity' space. The Program Design Language representation of a simple scheme for examining the 'velocity' space is presented, and a test case is discussed. V.T.

A90-47025
THE RISK OF COLLISION BETWEEN MANNED SPACE VEHICLES AND ORBITAL DEBRIS - ANALYSIS AND BASIC CONCLUSIONS

P. EICHLER and D. REX (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 14, no. 3, 1990, p. 145-154. Research supported by BMFT. refs
Copyright

The risk of collision of man-made objects with space vehicles is studied. The number and sources of these man-made objects in space are discussed. A deterministic calculation procedure is utilized to examine the orbital mechanics of every object in earth orbit. The structure and attitude orientation of larger structures, and the angle, velocity, and mass distribution of the object flux are investigated. Various structures and flight attitudes for cylinders corresponding to the Space Station, Columbus, and MTFF are considered. It is noted that the collision risk can be reduced by more than half by rotating the attitude in flight by 90 deg. I.F.

A90-47529
ORBITAL SPRAWL, SPACE DEBRIS AND THE GEOSTATIONARY RING
PATRICIA M. STERNS and LESLIE I. TENNEN Space Policy (ISSN 0265-9646), vol. 6, Aug. 1990, p. 221-229. refs
Copyright

Potential opportunities for the law of outer space to provide an effective framework for responding to the growing and changing character of space activities are explored. It is noted that contamination of outer space by debris and nonfunctional objects presents a significant challange to scientists, mission planners, and jurists, and that a continuation of present activities will result in a condition of orbital sprawl whereby certain orbits, notably the geostationary ring, will become saturated with objects, forcing the location of spacecraft at a distance from the optimal slot and posing a growing risk of collision. L.K.S.

A90-48320
ANTIPROTONS IN THE VICINITY OF THE EARTH [ANTIPROTONY V OKRESTNOSTI ZEMLI]
S. A. VORONOV, A. M. GAL'PER, S. V. KOLDASHOV, L. V. MASLENNIKOV, V. V. MIKHAILOV et al. Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, July-Aug. 1990, p. 632-635. In Russian. refs
Copyright

An attempt was made to use the Mariia-2 spectrometer onboard the Mir orbital station to detect antiproton fluxes at the spurs of the earth's radiation belt in the region of the Brazilian geomagnetic anomaly. Analysis results indicate that a finite antiproton flux was not detected in the radiation belt. It can thus be concluded that the upper limit to the antiproton/proton ratio in the energy range of several dozen MeV does not exceed 0.01, which evidently excludes the possibility of the generation and accumulation of antiprotons in the radiation belt on account of some unknown processes. B.J.

A90-48541* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MASS ESTIMATION IN THE BREAKUPS OF SOVIET SATELLITES
GAUTAM D. BADHWAR (NASA, Johnson Space Center, Houston, TX) and PHILLIP D. ANZ-MEADOR (Lockheed Engineering and Sciences Co., Houston, TX) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Sept. 1990, p. 403-410. refs
Copyright

An attempt is made to estimate the mass of the parent satellite from the mass of the debris remaining from its breakup using a technique based on the decay rate and radar cross-section time history. The decay of perigee and apogee with time of an object in orbit provides the area-to-mass ratio and the radar cross-section provides a measure of the effective area of the object, while combining the two gives the mass of the object. The technique has been successfully applied to 12 U.S. breakups and one Arianespace breakup. Calculations exhibiting good agreement with reference mass are also discussed for Soviet intact C-class boosters, intact ASAT target satellites, and intact navigational satellites. It is found that the calculated mass of the ASAT interceptor spacecraft is about one-half of the expected mass, but it is pointed out that this may be due to fuel carried on board. For ASAT target breakups the calculated mass is 20-30 times too low; no clear explanation can yet be found for this phenomenon. L.K.S.

A90-49419
AN EXPERT SYSTEM FOR ATOMIC OXYGEN EFFECT ANALYSIS
ALECK L. LEE (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 7 p. refs
(SAE PAPER 901410) Copyright

An atomic-oxygen (AO) fluence expert system (AOxpert) designed as a user-friendly software package emulating the way the problem is approached by human experts is presented. In a problem-formulation phase, it is shown that the human expert draws his expertise from an available database compiled from previous flight experiences and test results and makes appropriate decisions. The AOxpert system consists of knowledge bases and inference algorithm, while the analytical power of the system comes from an orbit model and a neutral atmospheric model. The output provides a report of the total AO fluence and the predicted mass loss; a pass or fail flag is available if a threshold value is specified. Fluence calculations performed for the Space Station Freedom and Long Duration Exposure Facility are presented. V.T.

A90-49422
GLOW MODELING USING THE INTEGRATED SPACECRAFT ENVIRONMENT MODEL
T. D. GORDON SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 8 p.
(SAE PAPER 901413) Copyright

The Integrated Spacecraft Environment Model (ISEM) was developed to model the neutral molecular environment in the immediate vicinity of a spacecraft. The modeling methodology used in ISEM computes species specific parameters for collisional interactions induced by the spacecraft. The model provides a good starting point from which to model other induced phenomena such as spacecraft glow. As such, ISEM has been used to model several of the proposed ultraviolet glow mechanisms, and thereby provide a modeling test bed to help with glow studies and eventually make glow predictions for Space Station and other orbiting spacecraft. Author

A90-50358
PROPERTIES OF LASER-INDUCED STIMULATED EMISSION FOR DIAGNOSTIC PURPOSES
U. WESTBLOM, S. AGRUP, M. ALDEN, H. M. HERTZ (Lund Institute of Technology, Sweden), and J. E. M. GOLDSMITH (Sandia National Laboratories, Livermore, CA) Applied Physics B - Photophysics and Laser Chemistry (ISSN 0721-7269), vol. B 50, June 1990, p. 487-497. Research supported by the Styrelsen for Teknisk Utveckling, Swedish Energy Administration, and DOE. refs
Copyright

An experimental and semi-quantitative theoretical investigation of the characteristics of two-photon-induced stimulated emission related to diagnostic applications is described. The laser power dependence, pressure dependence, and the spectral shape of the stimulated emission signal in CO are discussed and compared with those for laser-induced fluorescence. The discussion also covers decreases in the laser-induced fluorescence signal caused by the stimulated emission process, and a method is proposed for providing increased spatial resolution in measurements made using stimulated emission detection. Author

A90-50437* Iowa Univ., Iowa City.
TRANSITION FROM RING TO BEAM ARC DISTRIBUTIONS OF WATER IONS NEAR THE SPACE SHUTTLE ORBITER
IVER H. CAIRNS (Iowa, University, Iowa City) Journal of Geophysical Research (ISSN 0148-0227), vol. 95, Sept. 1, 1990,

p. 15167-15173. refs
(Contract NAGW-1488)
Copyright

The distribution function of water ions produced near the Space Shuttle by charge exchange between ionospheric oxygen ions and outgassed water molecules is studied. The transition from a ring to a beam arc distribution function is described. The number density of water ions is found to increase monotonically with decreasing distance from the Shuttle. K.K.

A90-51057* Lockheed Engineering and Sciences Co., Houston, TX.
DESIGN OF AN ORBITAL DEBRIS RADAR GROUND DEMONSTRATION
I. PAZ, J. R. CARL, R. W. SHAW, J. K. KOVITZ (Lockheed Engineering and Sciences Co., Houston, TX), and G. D. ARNDT (NASA, Johnson Space Center, Houston, TX) IN: 1989 IEEE Aerospace Applications Conference, Breckenridge, CO, Feb. 12-17, 1989, Conference Digest. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, 15 p. refs
Copyright

A breadboard radar system is being designed and tested at NASA Johnson for dealing with the space debris problem that could present a growing threat to Space Station Freedom. The *major design problems are due to the small radar cross section* of such debris (below -30 dBm2), the high closing velocities of the particles with respect to the Space Station (10 km/sec and higher), and the stringent weight, power-consumption, maintenance, and reliability constraints on spaceborne systems. Consideration is given to the preliminary implementation of a ground demonstration radar for testing concepts, technologies, and performance envelopes for application to the space-borne debris *detection and tracking radar. Simulation results and techniques* developed for predicting system performance and for evaluating antenna parameters are given. The design process of the electronically steered phased array antenna is briefly described, and block diagrams for the implementation of the radar system are given. I.E.

A90-52567*# Colorado State Univ., Fort Collins.
ION OPTICS SYSTEM INCORPORATING RADIO FREQUENCY MASS SEPARATION
JOHN R. ANDERSON (Colorado State University, Fort Collins) and M. R. CARRUTH, JR. (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 21st, Orlando, FL, July 18-20, 1990. 11 p. refs
(Contract NGT-50370)
(AIAA PAPER 90-2567) Copyright

Results of an experimental study are presented. They show that an RF mass discriminator, based on a Bennett mass spectrometer concept, can be used to discriminate between two species of ions with about a 2-to-1 charge-to-mass ratio. Such a *device would be useful for separating monatomic and diatomic* oxygen ions in a system designed to simulate the environment that spacecraft encounter in low earth orbit. The influence of changing mass discriminator parameters - such as the spacing of its grids, the amplitude and frequency of RF voltage signals applied to it and the current density of ions incident upon it - on its species discrimination capabilities is discussed. Experimental results are also compared to the results of a simple theoretical *model to gain insight into the processes occurring in the* discriminator. These results are shown to be in good agreement. Author

A90-53045*# Colorado Univ., Boulder.
VOLUMETRIC IMAGING OF SPACE DEBRIS USING SUN MICROSYSTEM'S TAAC-1 APPLICATION ACCELERATOR BOARD
KELLY G. LUETKEMEYER, ROBERT D. CULP (Colorado, University, Boulder), TIMOTHY D. MACLAY, and RONALD A. MADLER IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 847-855. Research supported by the Martin Marietta Corp.
(Contract F08635-89-K-0227; NAG9-407)
(AIAA PAPER 90-2977) Copyright

Analysis of space debris requires the researcher to have a three-dimensional spatial framework and understanding. By using computers to image and display the space debris volumes, the researcher is provided with an added visual analysis tool. This paper describes volumetric visualization of space debris. Two imaging approaches are used. The first method visualizes the cube faces of the volumetric image. The second method uses a *ray-tracing technique to display surfaces within the volume. Three* examples of space debris volumes are described. Author

A90-53046#
THE COLLISION HAZARD POSED BY THE COMBINED RELEASE AND RADIATION EFFECTS SATELLITE SPACECRAFT'S CANISTERS
M. E. SORGE and D. B. SPENCER (Aerospace Corp., El Segundo, CA) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 856-861.
(AIAA PAPER 90-2979)

This paper examines the collision hazard posed by the ejection of the chemical canisters from the Combined Release and Radiation Effects Satellite (CRRES) on the CRRES spacecraft and the resident satellite population. Using a probabilistic approach, the trajectories of the canisters, following release and ignition, can be determined and the interaction with the immediate volume surrounding the CRRES vehicle can be suited. Additionally, the effects of releasing canisters into the space environment is *examined, with the goal being assessment of any additional risk* to the resident space population. Author

A90-53047#
THE EVOLUTION OF AN ORBITING DEBRIS CLOUD IN HIGHLY ECCENTRIC ORBITS
K. ZARE (Applied Technology Associates, Mountain View, CA) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 862-865. refs
(AIAA PAPER 90-2980) Copyright

An analytical model is developed for the debris cloud dynamics following a breakup or a collision with a space object in an elliptic *orbit. The shape and volume of the debris cloud are determined* for a spherically symmetric distribution of the initial spread velocities. Author

N90-20101# Utah State Univ., Logan. Center for Atmospheric and Space Sciences.
USU CENTER OF EXCELLENCE IN THEORY AND ANALYSIS OF THE GEO-PLASMA ENVIRONMENT Final Technical Report
ROBERT W. SCHUNK 30 Nov. 1989 49 p
(Contract F49620-86-C-0109)
(AD-A217736; AFOSR-90-0106TR) Avail: NTIS HC A03/MF A01 CSCL 20/14

A team of eleven Ph.D. scientists and several graduate students was assembled at USU to work in close collaboration with scientists at the Air Force Geophysics Lab on a number of problems that are relevant to Air Force systems, including OTH radars, *communications, and orbiting space structures. The overall goal* of the research was to obtain a better understanding of the basic chemical and physical processes operating in the geoplasma environment, including the ionosphere, thermosphere, and magnetosphere. Some of the specific tasks included the following: (1) Studies of ionospheric structure and irregularities; (2) Study the feasibility of developing better operational ionospheric models for the Air Force; (3) Conduct model/data comparisons in order to validate the ionospheric models; (4) Study plasma convection characteristics in the high latitude ionosphere; (5) Study magnetosphere-ionosphere coupling problems; (6) Construct a thermospheric general circulation model; (7) Develop a 3D, time

dependent model of the outer plasmasphere; (8) Develop a 3D, time dependent MHD model of the earth's magnetosphere; (9) Conduct satellite drag studies; and (10) Study certain spacecraft-environment interaction problems, including those related to high voltage power sources, spacecraft outgassing, and spacecraft charging at LEO altitudes. GRA

N90-21108*# Texas A&M Univ., College Station. Dept. of Nuclear Engineering.
A RADIOLOGICAL ASSESSMENT OF NUCLEAR POWER AND PROPULSION OPERATIONS NEAR SPACE STATION FREEDOM Contract Report, Jan. 1988 - Jan. 1990
WESLEY E. BOLCH, J. KELLY THOMAS, K. LEE PEDDICORD, PAUL NELSON, DAVID T. MARSHALL, and DONNA M. BUSCHE Mar. 1990 115 p
(Contract NAG3-944)
(NASA-CR-185185; NAS 1.26:185185) Avail: NTIS HC A06/MF A01 CSCL 10/2

Scenarios were identified which involve the use of nuclear power systems in the vicinity of Space Station Freedom (SSF) and their radiological impact on the SSF crew was quantified. Several of the developed scenarios relate to the use of SSF as an evolutionary transportation node for lunar and Mars missions. In particular, radiation doses delivered to SSF crew were calculated for both the launch and subsequent return of a Nuclear Electric Propulsion (NEP) cargo vehicle and a Nuclear Thermal Rocket (NTR) personnel vehicle to low earth orbit. The use of nuclear power on co-orbiting platforms and the storage and handling issues associated with radioisotope power systems were also explored as they relate to SSF. A central philosophy in these analyses was the utilization of a radiation dose budget, defined as the difference between recommended dose limits from all radiation sources and estimated doses received by crew members from natural space radiations. Consequently, for each scenario examined, the dose budget concept was used to identify and quantify constraints on operational parameters such as launch separation distances, returned vehicle parking distances, and reactor shutdown times prior to vehicle approach. The results indicate that realistic scenarios do not exist which would preclude the use of nuclear power sources in the vicinity of SSF. The radiation dose to the SSF crew can be maintained at safe levels solely by implementing proper and reasonable operating procedures. Author

N90-21792*# Southwest Research Inst., San Antonio, TX. Dept. of Space Sciences.
PIC CODE MODELING OF SPACECRAFT CHARGING POTENTIAL DURING ELECTRON BEAM INJECTION INTO A BACKGROUND OF NEUTRAL GAS AND PLASMA, PART 1
J. K. KOGA, C. S. LIN, and R. M. WINGLEE (Colorado Univ., Boulder.) 1989 48 p
(Contract NAGW-1231)
(NASA-CR-186602; NAS 1.26:186602) Avail: NTIS HC A03/MF A01 CSCL 22/2

Injections of nonrelativistic electron beams from an isolated equipotential conductor into a uniform background of plasma and neutral gas were simulated using a 2-D electrostatic particle code. The ionization effects on spacecraft charging are examined by including interactions of electrons with neutral gas. The simulations show that the conductor charging potential decreases with increasing neutral background density due to the production of secondary electrons near the conductor surface. In the spacecraft wake, the background electrons accelerated towards the charged spacecraft produce an enhancement of secondary electrons and ions. Simulations run for longer times indicate that the spacecraft potential is further reduced and short wavelength beam-plasma oscillations appear. The results are applied to explain the spacecraft charging potential measured during the SEPAC experiments from Spacelab 1. Author

N90-24341# Oak Ridge National Lab., TN. Dept. of Engineering Physics and Mathematics.
EFFECTS OF X RADIATION ON THE LAMPSHADE ORBITAL DEBRIS SATELLITE SHIELD, 2
M. S. SMITH and R. T. SANTORO Apr. 1990 9 p
(Contract DE-AC05-84OR-21400)
(DE90-008214; ORNL/TM-11514) Avail: NTIS HC A02/MF A01

One-dimensional thermo-hydrodynamic calculations have been performed to estimate the response of the lead (Pb) bumper plate and aluminum (Al) foam liquidator screen of the LAMPSHADE orbital debris satellite shield. Mass fractions in the solid, liquid, and vapor phases as a function of time after irradiation for two incident x ray spectra, were calculated using the PUFF-TFT code. Materials losses due to phase changes did not exceed 3 percent, but fracture and spallation may seriously reduce the performance of the lead component against incident debris. DOE

N90-24342# Hughes Research Labs., Malibu, CA.
FLIGHT MODEL DISCHARGE SYSTEM Final Report, Sep. 1983 - May 1989
R. R. ROBSON and W. S. WILLIAMSON Sep. 1989 267 p
(Contract F19628-83-C-0143; AF PROJ. 2823)
(AD-A220261; HAC-REF-F4890; GL-TR-89-0270) Avail: NTIS HC A12/MF A02 CSCL 22/2

The Flight Model Discharge System (FMDS) Program is an autonomous system that detects both absolute and differential charging of high-altitude satellites and actively discharges the associated potentials before hazardous arcing levels are reached by emitting a low-energy inert-gas plasma. FMDS operating principles are based on empirical results from the Air Force 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 space-charge-neutral plasma - effectively grounding the spacecraft frame and dielectric surfaces to the potential of the ambient space plasma. FMDS uses a xenon plasma source capable of igniting within one second and of emitting a flow of space-charge-neutral plasma containing more than 1 mA of Xe(+) ions. The spacecraft charging level is detected by sensors similar to those that operated aboard SCATHA (i.e., ion and electron electrostatic energy analyzers and surface-potential monitors). This report describes the development details for the breadboard and flight models of the FMDS instrument. Operational characteristics of the electrostatic analyzers, surface-potential monitors, transient-pulse monitor, plasma source, microprocessor-based controller, and software architecture are described. Results of vacuum-chamber testing under simulated geosynchronous environmental conditions are also presented. GRA

N90-25169*# Alabama Univ., Huntsville. Center for Space Plasma and Aeronomic Research.
SPACE STATION CONTAMINATION STUDY: ASSESSMENT OF CONTAMINANT SPECTRAL BRIGHTNESS
D. G. TORR 1990 17 p
(Contract NAS8-37106; NAS9-17133; NAGW-922)
(NASA-CR-186173; NAS 1.26:186173) Avail: NTIS HC A03/MF A01 CSCL 22/2

The results presented show that spectral emissions which arise as a result of vehicle-ambient atmospheric interactions are significant and can become competitive with the natural zodiacal background up to altitudes as high as 400 km for the Vacuun Ultraviolet (VUV) and Visible Infrared Spectra (VIS) for the worst case conditions used. The empirical database on the induced environment of space vehicles is very sparse, and these results are based on a number of assumptions and cannot be regarded as definitive at the present time. Since the technique for doing calculations of this kind was developed in its preliminary form for the purpose of this study, a list of greatly improved estimates are provided of the contamination irradiances. Tasks which are considered most important in order to achieve a higher confidence level for the preliminary conclusions drawn are provided. Author

N90-25519*# Photometrics, Inc., Woburn, MA.
GASEOUS OPTICAL CONTAMINATION OF THE SPACECRAFT ENVIRONMENT: A REVIEW
N. H. TRAN, M. A. MARIS, I. L. KOFSKY, and E. MURAD (Air Force Geophysics Lab., Hanscom AFB, MA.) *In* NASA, Lyndon

B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 159-166 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 20/6

Interactions between the ambient atmosphere and orbiting spacecraft, sounding rockets, and suborbital vehicles, and with their effluents, give rise to optical (extreme UV to LWIR) foreground radiation which constitutes noise that raises the detection threshold for terrestrial and celestial radiations, as well as military targets. Researchers review the current information on the on-orbit optical contamination. Its source species are created in interaction processes that can be grouped into three categories: (1) Reactions in the gas phase between the ambient atmosphere and desorbates and exhaust; (2) Reactions catalyzed by exposed ram surfaces, which occur spontaneously even in the absence of active material releases from the vehicles; and (3) Erosive excitative reactions with exposed bulk (organic) materials, which have recently been identified in the laboratory though not as yet observed on spacecraft. Researchers also assess the effect of optical pumping by earthshine and sunlight of both reaction products and effluents. Author

N90-25520*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACECRAFT EXTERNAL MOLECULAR CONTAMINATION ANALYSIS
H. K. F. EHLERS *In its* Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 171-178 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 22/2

Control of contamination on and around spacecraft is required to avoid adverse effects on the performance of instruments and spacecraft systems. Recent work in this area is reviewed and discussed. Specific issues and limitations to be considered as part of the effort to predict contamination effects using modeling techniques are addressed. Significant results of Space Shuttle missions in the field of molecule/surface interactions as well as their implications for space station design and operation are reviewed. Author

N90-25529*# Calspan Field Services, Inc., Arnold AFS, TN. AEDC Operations.
SATELLITE MATERIAL CONTAMINANT OPTICAL PROPERTIES
B. E. WOOD, W. T. BERTRAND, B. L. SEIBER, E. L. KIECH, P. M. FALCO, and J. D. HOLT (Arnold Engineering Development Center, Arnold Air Force Station, TN.) *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 257-262 Mar. 1990 Sponsored in part by AF
Avail: NTIS HC A99/MF A04 CSCL 20/6

The Air Force Wright Research and Development Center and the Arnold Engineering Development Center are continuing a program for measuring optical effects of satellite material outgassing products on cryo-optic surfaces. Presented here are infrared (4000 to 700 cm(-1)) transmittance data for contaminant films condensed on a 77 K geranium window. From the transmittance data, the contaminant film refractive and absorptive indices (n, k) were derived using an analytical thin-film interference model with a nonlinear least-squares algorithm. To date 19 materials have been studied with the optical contents determined for 13 of those. The materials include adhesives, paints, composites, films, and lubricants. This program is continuing and properties for other materials will be available in the future. Author

N90-25543*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE ENVIRONMENTS AND THEIR EFFECTS ON SPACE AUTOMATION AND ROBOTICS
HENRY B. GARRETT *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 361-380 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 22/2

Automated and robotic systems will be exposed to a variety of environmental anomalies as a result of adverse interactions with the space environment. As an example, the coupling of electrical transients into control systems, due to EMI from plasma interactions and solar array arcing, may cause spurious commands that could be difficult to detect and correct in time to prevent damage during critical operations. Spacecraft glow and space debris could introduce false imaging information into optical sensor systems. The presentation provides a brief overview of the primary environments (plasma, neutral atmosphere, magnetic and electric fields, and solid particulates) that cause such adverse interactions. The descriptions, while brief, are intended to provide a basis for the other papers presented at this conference which detail the key interactions with automated and robotic systems. Given the growing complexity and sensitivity of automated and robotic space systems, an understanding of adverse space environments will be crucial to mitigating their effects. Author

N90-25545*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PLASMA INTERACTIONS AND EFFECTS FOR LARGE SYSTEMS
DAVID B. SNYDER *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 393-404 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 20/9

Information on plasma-spacecraft interactions and the effects on spacecraft systems and materials is given in viewgraph form. Information is given on plasma characteristics, ionospheric charge density; spacecraft floating potential, floating potentials of self-biased solar arrays, and geosynchronous earth orbit issues. Author

N90-25557*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
INTERACTIONS BETWEEN THE SPACE STATION AND THE ENVIRONMENT: A PRELIMINARY ASSESSMENT OF EMI
G. B. MURPHY and HENRY B. GARRETT *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 493-507 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 22/2

A review of the interactions between proposed Space Station systems/payloads and the environment that contribute to electromagnetic interference was performed. Seven prime sources of interference have been identified. These are: The Space Station power system; active experiments such as beam injection; ASTROMAG; ram and wake density gradients; pick up ions produced by vented or offgassed clouds; waves produced by current loops that include the plasma and structure; arcing from high voltage solar arrays (or possible ESD in polar orbit). This review indicates that: minimizing leakage current from the 20 kHz power system to the structure; keeping the surfaces of the Space Station structure, arrays, and radiators nonconducting; minimizing venting of payloads or systems to non-operational periods; careful placement of payloads sensitive to magnetic field perturbations or wake noise; and designing an operational timeline compatible with experiment requirement are the most effective means of minimizing the effects of this interference. High degrees of uncertainty exist in the estimates of magnitudes of gas emission induced EMI, radiation of 20 kHz and harmonics, ASTROMAG induced interference, and arc threshold/frequency of the solar array. These processes demand further attention so that mitigation efforts are properly calibrated. Author

N90-26024# General Accounting Office, Washington, DC. Information Management and Technology Div.
SPACE PROGRAM: SPACE DEBRIS A POTENTIAL THREAT TO SPACE STATION AND SHUTTLE
STEPHEN A. SCHWARTZ, RONALD W. BEERS, COLLEEN M. PHILLIPS, and YVETTE RAMOS Apr. 1990 38 p

(GAO/IMTEC-90-18; B-237832) Avail: NTIS HC A03/MF A01; also available from GAO, Gaithersburg, MD HC first five copies free; additional copies $2.00

Experts estimate that more than 3.5 million man-made objects are orbiting the earth. These objects - space debris - include whole and fragmentary parts of rocket bodies and other discarded equipment from space missions. About 24,500 of these objects are 1 centimeter across or larger. A 1-centimeter man-made object travels in orbit at roughly 22,000 miles per hour. If it hit a spacecraft, it would do about the same damage as would a 400-pound safe traveling at 60 miles per hour. The Government Accounting Office (GAO) reviews NASA's plans for protecting the space station from debris, the extent and precision of current NASA and Defense Department (DOD) debris-tracking capabilities, and the extent to which debris has already affected shuttle operations. GAO recommends that the space debris model be updated, and that the findings be incorporated into the plans for protecting the space station from such debris. GAO further recommends that the increased risk from debris to the space shuttle operations be analyzed. J.P.S.

N90-26044*# Arizona Univ., Tucson.
AUTONOMOUS SPACE PROCESSOR FOR ORBITAL DEBRIS Final Report, 1989 - 1990
KUMAR RAMOHALLI, DAVID CAMPBELL, MICKY MARINE, MOHAMAD SAAD, DANIEL BERTLES, and DAVE NICHOLS 1990 101 p Presented at the Universities Space Research Association Summer Conference, Cleveland, OH, 12-15 Jun. 1990 (Contract NASW-4435)
(NASA-CR-186691; NAS 1.26:186691) Avail: NTIS HC A06/MF A01 CSCL 22/2

Advanced designs are being continued to develop the ultimate goal of a GETAWAY special to demonstrate economical removal of orbital debris utilizing local resources in orbit. The fundamental technical feasibility was demonstrated in 1988 through theoretical calculations, quantitative computer animation, a solar focal point cutter, a robotic arm design and a subcase model. Last year improvements were made to the solar cutter and the robotic arm. Also performed last year was a mission analysis which showed the feasibility of retrieve at least four large (greater than 1500 kg) pieces of debris. Advances made during this reporting period are the incorporation of digital control with the existing placement arm, the development of a new robotic manipulator arm, and the study of debris spin attenuation. These advances are discussed. Author

N90-26232*# Jet Propulsion Lab., California Inst. of Tech., Pasadena. Telecommunications Science and Engineering Div.
RINGS OF EARTH DETECTED BY ORBITAL DEBRIS RADAR
R. GOLDSTEIN and L. RANDOLPH *In its* The Telecommunications and Data Acquisition Report p 191-195 15 May 1990
Avail: NTIS HC A10/MF A02 CSCL 03/2

Small particles moving at an orbital velocity of 7.6 kilometers per second can present a considerable hazard to human activity in space. For astronauts outside of the protective shielding of their space vehicles, such particles can be lethal. The powerful radar at NASA's Goldstone Deep Communications Complex was used to monitor such orbital debris. This radar can detect metallic objects as small as 1.8 mm in diameter at 600 km altitude. The results of the preliminary survey show a flux (at 600 km altitude) of 6.4 objects per square kilometer per day of equivalent size of 1.8 mm or larger. Forty percent of the observed particles appear to be concentrated into two orbits. An orbital ring with the same inclination as the radar (35.1 degrees) is suggested. However, an orbital band with a much higher inclination (66 degrees) is also a possibility. Author

N90-26477*# San Francisco Univ., CA. Physics Research Lab.
EXPERIMENT K-6-24, K-6-25, K-6-26: RADIATION DOSIMETRY AND SPECTROMETRY
E. V. BENTON, A. FRANK, E. R. BENTON, V. DUDKIN, and A. MARENNYI (Institute of Biomedical Problems, Moscow, USSR) *In* NASA, Ames Research Center, The US Experiments Flown on the Soviet Biosatellite Cosmos 1887 p 483-511 Feb. 1990
(Contract NCC2-521; NAG9-235)
Avail: NTIS HC A22/MF A03 CSCL 06/3

Radiation experiments flown by the University of San Francisco on the Cosmos 1887 spacecraft were designed to measure the depth dependence of both total dose and heavy particle flux, dose and dose equivalent, down to very thin shielding. Three experiments were flown and were located both inside and outside the Cosmos 1887 spacecraft. Tissue absorbed dose rates of 264 to 0.028 rad d(-1) under shielding of 0.013 to 3.4 g/sq cm of (7)LiF were found outside the spacecraft and 0.025 rad d(-1) inside. Heavy particle fluxes of 3.43 to 1.03 x 10 to the minus 3rd power cm -2 sub s -1 sub sr -1 under shielding of 0.195 to 1.33 g/sq cm plastic were found outside the spacecraft and 4.25 times 10 to the minus 4th power cm -2 sub s -1 sub sr -1 inside (LET infinity H2O greater than or equal to 4 keV/micron m). The corresponding heavy particle dose equivalent rates outside the spacecraft were 30.8 to 19.8 mrem d(-1) and 11.4 mrem d(-1) inside. The large dose and particle fluxes found at small shielding thicknesses emphasize the importance of these and future measurements at low shielding, for predicting radiation effects on space materials and experiments where shielding is minimal and on astronauts during EVA. The Cosmos 1887 mission contained a variety of international radiobiological investigations to which the measurements apply. The high inclination orbit (62 degrees) of this mission provided a radiation environment which is seldom available to U.S. investigators. The radiation measurements will be compared with those of other research groups and also with those performed on the Shuttle, and will be used to refine computer models employed to calculate radiation exposures on other spacecraft, including the Space Station. Author

N90-26860*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SEMI-ACTIVE ORBITAL DEBRIS SWEEPER Patent Application
ANDREW J. PETRO, inventor (to NASA) 16 Feb. 1990 16 p
(NASA-CASE-MSC-21534-1; NAS 1.71:MSC-21534-1; US-PATENT-APPL-SN-480985) Avail: NTIS HC A03/MF A01 CSCL 22/2

An orbital debris sweeper is provided for removing particles from orbit which otherwise may impact and damage an orbiting spacecraft. The debris sweeper includes a central sweeper core which carries a debris monitoring unit, and a plurality of large area impact panels rotatable about a central sweeper rotational axis. In response to information from the debris monitoring unit, a computer determines whether individual monitored particles preferably impact one of the rotating panels or pass between the rotating panels. A control unit extends or retracts one or more booms which interconnect the sweeper core and the panels to change the moment of inertia of the sweeper and thereby the rotational velocity of the rotating panels. According to the method of the present invention, the change in panel rotational velocity increases the frequency of particles which desirably impact one of the panels and are thereby removed from orbit, while large particles which may damage the impact panels pass between the trailing edge of one panel and the leading edge of the rotationally succeeding panel. NASA

N90-27174# Spectral Sciences, Inc., Burlington, MA.
ATMOSPHERICALLY INDUCED OPTICAL CONTAMINATION FROM ORBITING THRUSTERS Scientific Report No. 1, 9 May 1988 -31 Aug. 1989
J. B. ELGIN (RADEX, Inc., Bedford, MA.) and M. TAUTZ 19 Sep. 1989 66 p
(Contract F19628-88-C-0074; AF PROJ. 7601)
(AD-A223112; SSI-TR-160; GL-TR-89-0263) Avail: NTIS HC A04/MF A01 CSCL 03/2

This paper presents the result of the SOCRATES (Shuttle Orbiter Contamination Representation Accounting for Transiently Emitted Species) code which has been developed to assess the effects of contamination of measurements aboard spacecraft in low earth orbit. SOCRATES is a Monte Carlo code which includes in its present version scattering, collisions leading to

kinetic-to-vibrational energy transfer, and reactive collisions. The application of this code to actual measurements aboard spacecraft in low earth orbit makes it possible to evaluate data obtained on these platforms with a view towards extracting the data of interest from contaminated signals. GRA

N90-27206# McDonnell-Douglas Space Systems Co., Huntington Beach, CA. Design and Technology Center.
THE NEAR-EARTH ORBITAL ENVIRONMENT COUPLING TO ITS ENERGY SOURCES Final Report, 1 Mar. 1987 - 28 Feb. 1990
WILLIAM P. OLSEN, S. L. HUSTON, K. A. PFITZER, and T. S. MOGSTAD 21 May 1990 79 p
(Contract F49620-87-C-0039)
(AD-A222435; AFOSR-90-0658TR) Avail: NTIS HC A05/MF A01 CSCL 20/9

Under the present study the qualitative work performed earlier has been extended to perform quantitative calculations of the entry of plasma into the magnetosphere. These calculations include the structure of the low-latitude boundary layer and the energy spectrum of the particles within the plasma sheet. These calculations were performed using actual satellite data and virtually no assumed parameters. The success of these calculations provides impressive evidence for the validity of the Gradient Drift Entry theory. It also proves that the widely held notion that the magnetosheath cannot be the source of plasma sheet particles is in error. The success of this study permits the development of quantitative models of the magnetosphere required for the prediction of magnetospheric and upper atmospheric and ionospheric effects on those hardware systems which must operate in Earth orbital space. GRA

N90-27475# Air Force Geophysics Lab., Hanscom AFB, MA. Space Physics Div.
LABORATORY STUDY OF ION-NEUTRAL COLLISIONS AT SUPRATHERMAL ENERGIES Interim Report, Jan. 1988 - Dec. 1989
JAMES A. GARDNER, RAINER A. DRESSLER, RICHARD H. SALTER, and EDMOND MURAD 28 Dec. 1989 49 p Sponsored by AFOSR, Bolling AFB, Washington, DC
(Contract AF PROJ. 2303)
(AD-A222117; GL-TR-89-0345) Avail: NTIS HC A03/MF A01 CSCL 20/5

A double mass-spectrometer system for the study of the dynamics of ion-neutral collisions at suprathermal energies is described in detail. The system consists of a Wien Filter, which acts as a source of mass-selected and velocity analyzed ions, coupled to a static-pressure collision chamber followed by a quadrupole mass filter, which acts as a mass analyzer for the products and the projectile ions. This apparatus has been used to measure ion-neutral collision cross sections and ion product times-of-flight. The methods utilized in the processing of raw experimental data are also described. The raw cross section data is corrected with respect to the collection efficiency, yielding integral cross sections which can be used in codes designed to predict the environment of spacecraft in low earth orbit. The performance of the experiment is demonstrated by measuring the known ion-neutral collision systems: N2(+) + Ar, N2(+) + D2, and O(+) + H2O. GRA

N90-27739*# Texas Univ., Austin.
FINAL DESIGN FOR A COMPREHENSIVE ORBITAL DEBRIS MANAGEMENT PROGRAM
4 May 1990 113 p Prepared in cooperation with Space Trash Removal and Elimination Systems, Inc., TX
(Contract NASW-4435)
(NASA-CR-186674; NAS 1.26:186674) Avail: NTIS HC A06/MF A01 CSCL 22/2

The rationale and specifics for the design of a comprehensive program for the control of orbital debris, as well as details of the various components of the overall plan, are described. The problem of orbital debris has been steadily worsening since the first successful launch in 1957. The hazards posed by orbital debris suggest the need for a progressive plan for the prevention of future debris, as well as the reduction of the current debris level. The proposed debris management plan includes debris removal systems and preventative techniques and policies. The debris removal is directed at improving the current debris environment. Because of the variance in sizes of debris, a single system cannot reasonably remove all kinds of debris. An active removal system, which deliberately retrieves targeted debris from known orbits, was determined to be effective in the disposal of debris tracked directly from earth. However, no effective system is currently available to remove the untrackable debris. The debris program is intended to protect the orbital environment from future abuses. This portion of the plan involves various environment from future abuses. This portion of the plan involves various methods and rules for future prevention of debris. The preventative techniques are protective methods that can be used in future design of payloads. The prevention policies are rules which should be employed to force the prevention of orbital debris. Author

N90-28590*# Science and Engineering Associates, Inc., Englewood, CO.
SPACE STATION CONTAMINATION MODELING Final Report
T. D. GORDON 15 Dec. 1989 17 p
(Contract NASA ORDER H-80598-B)
(NASA-CR-183871; NAS 1.26:183871; SEA-D470-2) Avail: NTIS HC A03/MF A01 CSCL 22/2

Current plans for the operation of Space Station Freedom allow the orbit to decay to approximately an altitude of 200 km before reboosting to approximately 450 km. The Space Station will encounter dramatically increasing ambient and induced environmental effects as the orbit decays. Unfortunately, Shuttle docking, which has been of concern as a high contamination period, will likely occur during the time when the station is in the lowest orbit. The combination of ambient and induced environments along with the presence of the docked Shuttle could cause very severe contamination conditions at the lower orbital altitudes prior to Space Station reboost. The purpose here is to determine the effects on the induced external environment of Space Station Freedom with regard to the proposed changes in altitude. The change in the induced environment will be manifest in several parameters. The ambient density buildup in front of ram facing surfaces will change. The source of such contaminants can be outgassing/offgassing surfaces, leakage from the pressurized modules or experiments, purposeful venting, and thruster firings. The third induced environment parameter with altitude dependence is the glow. In order to determine the altitude dependence of the induced environment parameters, researchers used the integrated Spacecraft Environment Model (ISEM) which was developed for Marshall Space Flight Center. The analysis required numerous ISEM runs. The assumptions and limitations for the ISEM runs are described. Author

N90-28594# Royal Aerospace Establishment, Farnborough (England).
SPACECRAFT CHARGING EFFECTS
G. L. WRENN 6 Mar. 1990 15 p Presented at Solar Terrestrial Predictions Workshop, Sydney, Australia, 16-20 Oct. 1989
(RAE-TM-SPACE-375; BR113453; ETN-90-97529; AD-A221461)
Copyright Avail: NTIS HC A03/MF A01

The way in which spacecraft surfaces become electrostatically charged in their interactions with incident space radiations is described and consequential effects which can have dramatic impact on operations are discussed. An extensive chronicle of in-orbit anomalies gathered for geosynchronous satellites makes it possible to search for links between the timing and freqeuncy of these events, flux measurements of charging particles, and solar terrestrial sources. This is a difficult exercise, due to the scarcity of suitable data, but results from the ESA METEOSAT and MARECS satellites are presented to define the boundary conditions of the problem. Special consideration of differential charging and deep dielectric charging, with likely modes of breakdown, highlights the roles of energetic electrons, cold plasma concentration and secondary emission yields is given and

recommended prevention techniques are outlined to stress the merit of improved solar-geomagnetic predictions. ESA

N90-29726# Regis Coll., Weston, MA.
EFFECTS OF ENERGY, MOMENTUM AND PARTICLE TRANSPORT IN THE NEAR-EARTH SOLAR TERRESTRIAL SYSTEM Final Report, 2 Dec. 1986 - 1 May 1990
P. B. ANDERSON, E. M. BASINSKA-LEWIN, M. E. GREENSPAN, J. H. JAMES, and D. R. WEIMER 1 Jun. 1990 83 p
(Contract F19628-86-K-0045)
(AD-A224393; GL-TR-90-0084) Avail: NTIS HC A05/MF A01
CSCL 04/1

This work has included the scientific studies of high-latitude plasma irregularities and the physics of the aurora, engineering of space environmental sensors, and data processing services. Scientific studies were conducted in the areas of energy dissipation, magnetosphere-ionosphere interactions and ionospheric plasma. Design work has been done on a series of plasma instruments for the Defense Meteorological Satellite Program (DMSP), the Combined Release and Radiation Effects Studies (CRRES), the Photovoltaic Array Space Power (PASP), the Interactions Measurements Payload for Shuttle (IMPS) and the NASA POLAR satellite program. Computer programs have been written to process RPA and Drift Meter data from the F8 and F9 DMSP satellites. GRA

05

MATERIALS

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

A90-31501
INTERNATIONAL SAMPE SYMPOSIUM AND EXHIBITION, 34TH, RENO, NV, MAY 8-11, 1989, PROCEEDINGS. BOOKS 1 & 2
G. A. ZAKRZEWSKI, ED. (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA), STANLEY T. PETERS, ED. (Westinghouse Electric Corp., Sunnyvale, CA), CHARLES D. DEAN, ED. (Amoco Performance Products, Inc., Ridgefield, CT), and DON MAZENKO, ED. Covina, CA, Society for the Advancement of Material and Process Engineering (Science of Advanced Materials and Process Engineering Series. Volume 34), 1989, p. Book 1, 1351 p.; book 2, 1330 p. For individual items see A90-31502 to A90-31585, A90-31587 to A90-31634, A90-31636 to A90-31658.
Copyright

The present conference on advanced materials discusses the curing of thick laminates with internal heat sources, the use of wide-angle X-ray scattering to determine solvent-induced polymer matrix crystallization, long-term degradation of fibrous silica composites, cyanate ester matrix resins, the 977 family of toughened epoxies, an all-thermoplastic matrix composite fighter forward fuselage, a high-temperature BMI matrix system for composite structures, and the design and analysis of elevated-temperature aerospace structures. Also discussed are on-orbit fabrication of Space Station structures, a novel infiltration process for metal-matrix composites, Boeing 360 helicopter honeycomb sandwich primary structures, recent advancements in honeycomb structures, thermoplastic-toughened epoxy resins, the LARC-CPI semicrystalline polyimide, torsion in filament-wound tubes, monolithic graphite tooling, stitching for laminate damage-tolerance improvement, and advanced composite structures for cryogenic applications. O.C.

A90-31546* National Aeronautics and Space Administration, Washington, DC.
DESIGN AND ANALYSIS OF AEROSPACE STRUCTURES AT ELEVATED TEMPERATURES
C. I. CHANG (NASA, System Assessment Div., Washington, DC) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 656-666. refs
Copyright

An account is given of approaches that have emerged as useful in the incorporation of thermal loading considerations into advanced composite materials-based aerospace structural design practices. Sources of structural heating encompass not only propulsion system heat and aerodynamic surface heating at supersonic speeds, but the growing possibility of intense thermal fluxes from directed-energy weapons. The composite materials in question range from intrinsically nonheat-resistant polymer matrix systems to metal-matrix composites, and increasingly to such ceramic-matrix composites as carbon/carbon, which are explicitly intended for elevated temperature operation. O.C.

A90-31554
GRAPHITE AND KEVLAR THERMOPLASTIC COMPOSITES FOR SPACECRAFT APPLICATIONS
EDWARD M. SILVERMAN, RICHARD A. GRIESE, and WARD F. WRIGHT (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 770-779. refs
Copyright

The experimental present study indicates that several thermoplastic polymers offer superior performance in spacecraft structure composite-matrix applications over epoxy resins. AS-4 fiber-reinforced PEEK composites exhibited lower moisture uptake, reduced outgassing in vacuum conditions, and mechanical properties fully equivalent to those of a T-300 fiber-reinforced 934 epoxy material. A combination of kevlar 49 fibers with the thermoplastic resins PEI, PPS, and PES, yielded composites with lower moisture absorption and hygroscopic strain than kevlar 49-reinforced epoxy. An additional advantage of the thermoplastic matrix resins is the ability to use heat to weld structural components in space environments. O.C.

A90-31555* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MEASUREMENTS OF PRINT-THROUGH IN GRAPHITE FIBER EPOXY COMPOSITES
DONALD A. JAWORSKE (NASA, Lewis Research Center, Cleveland, OH), TIMOTHY T. JEUNNETTE, and JUDITH M. ANZIC (Cleveland State University, OH) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 780-789.
Copyright

High-reflectance accurate-contour mirrors are needed for solar dynamic space power systems. Graphite fiber epoxy composites are attractive candidates for such applications owing to their high modulus, near-zero coefficient of thermal expansion, and low mass. However, mirrors prepared from graphite fiber epoxy composite substrates often exhibit print-through, a distortion of the surface, which causes a loss in solar specular reflectance. Efforts to develop mirror substrates without print-through distortion require a means of quantifying print-through. Methods have been developed to quantify the degree of print-through in graphite fiber epoxy composite specimens using surface profilometry. Author

A90-31579* Boeing Aerospace Co., Seattle, WA.
MATERIALS RESISTANCE TO LOW EARTH ORBIT ENVIRONMENTAL EFFECTS
H. G. PIPPIN, L. P. TORRE (Boeing Aerospace, Seattle, WA), R. G. LINTON, and A. F. WHITAKER (NASA, Marshall Space Flight

Center, Huntsville, AL) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1143-1151.
(Contract NAS8-36586)
Copyright

A number of flexible polymeric materials have been considered as condidates for protective coatings on Kapton film. These coatings have been tested under a variety of environments, each of which simulates one or more aspects of the low earth orbit space environment. Mass loss rates vs fluence and temperatue, optical properties, and surface characteristics under exposure to the various environments will be presented. Kinetics data on Kapton and other materials is interpreted in terms of bond strengths and relative thermodynamic stabilities of potential products. Activation energy for degradation of Kapton by oxygen atoms was determined to be 30 + or - 5 kJ/mol. Materials tested include silicones, fluorosilicones, fluorophosphazenes, fluorocarbons, and hydrocarbons. Author

A90-31580
APPLICATION AND PERFORMANCE OF SILICON-BASED ATOMIC OXYGEN PROTECTIVE COATINGS
JEFFREY H. SANDERS, PETER B. LLOYD, and BRUCE J. TATARCHUK (Auburn University, AL) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1152-1162. refs
Copyright

Silicon-based coatings, applied in the form of sputtered silica overlayers or in the form of 'paint-on' silicone fluids, provide resistance to the corrosive effects of atomic oxygen encountered in LEO. In this study, conversion electron Mossbauer spectroscopy (CEMS) has been used as a diagnostic technique to evaluate overall coating effectiveness by measuring substrate oxidation below coatings to better than monolayer sensitivity. Iron/silver layered specimens were used as substrates and 30 nm silica coatings were found to significantly decrease substrate oxidation. Preferential separation of silver from coated and uncoated specimens was noted. Silicone fluids were also found to provide good protection of silver foils. Author

A90-31581* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EVALUATION OF ATOMIC OXYGEN RESISTANT PROTECTIVE COATINGS FOR FIBERGLASS-EPOXY COMPOSITES IN LEO
SHARON K. RUTLEDGE (NASA, Lewis Research Center, Cleveland, OH), PHILLIP E. PAULSEN (Cleveland State University, OH), and JOYCE A. BRADY (Sverdrup Technology, Inc., Middleburg Heights, OH) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1163-1174. Previously announced in STAR as N89-21100. refs
Copyright

Fiberglass-epoxy composite masts are the prime structural members for the Space Station Freedom solar array. At the altitude where Space Station Freedom will operate, atomic oxygen atoms are the most predominant species. Atomic oxygen is highly reactive and has been shown to oxidize organic and some metallic materials. Tests with random and directed atomic oxygen exposure have shown that the epoxy is removed from the composite exposing brittle glass fibers which could be easily removed from the surface where they could contaminate space Station Freedom Systems. Protection or fiber containment systems, inorganic based paints, aluminum braid, and a metal coatinsg, were evaluated for resistance to atomic oxygen, vacuum ultraviolet radiation, thermal cycling, and mechanical flexing. All appeared to protect well against atomic oxygen and provide fiber containment except for the single aluminum braid covering. UV radiation resistance was acceptable and in general, thermal cycling and flexure had little to no effect on the mass loss rate for most coatings. Author

A90-31582* Advanced Research and Applications Corp., Sunnyvale, CA.
RADIATION AND THERMAL EFFECTS ON THE TIME-DEPENDENT RESPONSE OF T300/934 GRAPHITE/EPOXY
ROBERT N. YANCEY (Advanced Research and Applications Corp., Sunnyvale, CA), MAREK-JERZY PINDERA (Virginia, University, Charlottesville), WAYNE SLEMP, and JOAN G. FUNK (NASA, Langley Research Center, Hampton, VA) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1175-1189. refs
(Contract NAG1-343)
Copyright

Experimental studies have suggested that, radiation, in conjunction with elevated temperatures, may lead to an exacerbation of the time-dependent response of such materials as T300/934 graphite/epoxy. Attention is given to the results of an investigation into such radiation/temperature effects with this composite system; creep tests were conducted on specimens of both irradiated and nonirradiated T300/934 composite and neat 934 resin specimens, at room temperature and 121 C. The radiation was of 1 MeV electrons, for a total dose of 10,000 Mrads; this simulates a 30-year exposure to radiation in geosynchronous orbit. Irradiation at elevated temperature led to a significant creep-response increase in the initial stages of loading. O.C.

A90-31583* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
RESULTS OF PROTECTIVE COATING STUDIES FOR THE HUBBLE SPACE TELESCOPE SOLAR ARRAY
ROGER C. LINTON, RAYMOND L. GAUSE, ROGER J. HARWELL, ROBERT F. DEHAYE, HOWARD DEWITT BURNS, JR., J. M. REYNOLDS (NASA, Marshall Space Flight Center, Huntsville, AL) et al. IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1190-1200. refs
Copyright

An account is given of the methods, results, and interpretive conclusions obtained by a series of comprehensive performance verification/qualification tests conducted on candidate coatings for the Hubble Space Telescope's (HST) solar array. These coatings are intended to minimize the effects of orbital atomic oxygen impingement on exposed materials. Attention was given to atomic oxygen exposure, UV exposure, thermal cycling, and electron and proton exposure. The V-10 and CVI-1140-1 candidate coatings were demonstrated to be adequately resistant to a five-year HST mission's environmental exposure. O.C.

A90-31584* Boeing Aerospace Co., Seattle, WA.
MATERIALS SCREENING CHAMBER FOR TESTING MATERIALS RESISTANCE TO ATOMIC OXYGEN
H. G. PIPPIN (Boeing Aerospace, Seattle, WA) and RALPH CARRUTH (NASA, Marshall Space Flight Center, Huntsville, AL) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1201-1206. refs
Copyright

A unique test chamber for exposing material to a known flux of oxygen atoms is described. The capabilities and operating parameters of the apparatus include production of an oxygen atom flux in excess of 5 x 10 to the 16th atoms/sq cm-sec, controlled heating of the sample specimen, RF circuitry to contain the plasma within a small volume, and long exposure times. Flux measurement capabilities include a calorimetric probe and a light titration system. Accuracy and limitations of these techniques are discussed. An extension to the main chamber to allow simultaneous ultraviolet and atomic oxygen exposure is discussed. The oxygen atoms produced are at thermal energies. Sample specimens are maintained at any selected temperature between ambient and 200

C, to within + or - 2 C. A representative example of measurements made using the chamber is presented. Author

A90-31585
EXTENDED THERMAL CYCLE TESTING OF GRAPHITE/EPOXY COMPOSITE STRUTS FOR SPACE STATION APPLICATIONS
RANDY JONES, RUDY LUKEZ (Morton Thiokol, Inc., Aerospace Group, Brigham City, UT), BRYAN PETERSON, J. CLAIR BATTY, and FRANK J. REDD (Utah State University, Logan) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1207-1213. refs
Copyright

Graphite composite struts designed for the planned NASA Space Station have successfully undergone extended thermal cycle testing. These tests were conducted as part of a continuing effort to verify that composites will survive the LEO environment. Using equipment designed specifically for the test program, two different strut designs were subjected to 10,000 thermal cycles between + 93 C and - 101 C. Periodic inspections identified no microcracking damage. Coefficient of thermal expansion and axial modulus tests showed that the struts were not significantly affected by the extensive temperature cycling. Test objectives, equipment, schedule, and results are discussed. Author

A90-31611
THERMAL STABILITY CONSIDERATIONS FOR SPACE FLIGHT OPTICAL BENCHES
KELLY J. DODSON and JOHN E. RULE (Composite Optics, Inc., San Diego, CA) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 2. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1578-1589.
Copyright

This paper presents Composite Optics Incorporated's experience in design, analysis, and fabrication of thermally stable optical benches utilizing high-modulus or ultra-high modulus (UHM) graphite/epoxy. The performance of critical instruments such as telescopes, interferometric optics, and fold mirrors is dependent upon moisture and temperature (hygrothermal) stability of their optical bench substrates. Design approaches and problem solutions from several space flight optical bench programs at Composite Optics, Incorporated (COI), will be discussed. Each program features unique requirements and although designs may appear to be similar, they may feature different design drivers (i.e., thermal stability, moisture stability, stress, stiffness, or weight). Based on the criticality of the specific design driver(s), the material system selection is made and the final design is formulated. Author

A90-31622
AIR FORCE ASTRONAUTICS COMPOSITE LABORATORY OVERVIEW
JAMES L. KOURY (USAF, Astronautics Laboratory, Edwards AFB, CA) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 2. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 1814-1821.
Copyright

A brief overveiw of the AFAL Composite Structure Facility's capabilities is presented, and a synopsis of its R&D efforts is given. The laboratory objectives are described, and two areas of research, carbon-carbon and filament-wound composite structures, are reviewed. The filament winding process for high-temperature thermosetting resins, and fabrication and testing of carbon-carbon cones, cylinders, and space structures are demonstrated as a result of joint efforts with industry. Research efforts such as the current work in smart structures and the imbedding of sensors inside the composite structure to monitor the structure state of health are presented. N.B.

A90-31658* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
QUALIFICATION OF ROOM-TEMPERATURE-CURING STRUCTURAL ADHESIVES FOR USE ON JPL SPACECRAFT
ALAIN CARPENTER and TIM O'DONNELL (JPL, Pasadena, CA) IN: International SAMPE Symposium and Exhibition, 34th, Reno, NV, May 8-11, 1989, Proceedings. Book 2. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 2530-2543. refs
(Contract NAS7-918)
Copyright

An evaluation is made of the comparative advantages of numerous room temperature-cure structural primers and adhesives applicable to spacecraft structures. The EA 9394 adhesive and BR 127 primer were chosen for use in all primary structure bonding on the Galileo spacecraft, in virtue of adequate room-temperature lap shear and peel strengths and superior mechanical properties above 200 F. EA 9394 also offers superior work life, shelf-life, and storage properties, by comparison with the EA 934 alternative. O.C.

A90-31985
EFFECTS OF SIMULATED SPACE ENVIRONMENTS ON DICHROMATED GELATIN HOLOGRAMS
ANDREW MCKAY and JOHN WHITE (National Technical Systems, Inc., Los Angeles, CA) IN: Optomechanical design of laser transmitters and receivers; Proceedings of the Meeting, Los Angeles, CA, Jan. 16, 17, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 269-275. Research supported by DNA. refs
Copyright

Recent investigations have demonstrated the applicability of dichromated gelatin holograms to a number of optical communication, sensor and solar energy applications. This has prompted interest in using these elements in space based optical systems. In order to establish the suitability of using DCG holograms in space based optical systems an investigation was undertaken to determine the effects of simulated space environments on the performance of these elements. Testing was conducted to determine the effects of UV radiation, charged particle radiation and vacuum effects. Further testing established methods of protecting DCG holograms from humidity prior to launch. Author

A90-32857* McDonnell-Douglas Corp., Huntington Beach, CA.
FIBER OPTIC SMART STRUCTURES AND SKINS II; PROCEEDINGS OF THE MEETING, BOSTON, MA, SEPT. 5-8, 1989
ERIC UDD, ED. (McDonnell Douglas Electronic Systems Co., Huntington Beach, CA) Meeting sponsored by SPIE, New Mexico State University, JPL, et al. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 1170), 1990, 584 p. For individual items see A90-32858 to A90-32908.
(SPIE-1170) Copyright

The present conference on embedded fiber-optics incorporating 'smart' structural systems and structural surfaces discusses topics in the nature and current status of university- and government-sponsored smart-structure development programs; manufacturing and cure-monitoring for composite smart structures, smart-structure damage assessment, smart-structure actuators, and smart-structure sensors and components. Attention is given to fiber-optic sensor selection, the optical properties of curing epoxies, the automated production of smart structures, damage-detection in composites with embedded fiber-optic interferometers, fiber-optic strain and impact sensors, dynamically-tunable smart composites, smart structures incorporating artificial neural networks, active structural acoustic control with smart structures, and fiber-optic shape sensing for flexible structures. O.C.

A90-32894* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THERMAL EFFECTS ON FIBER OPTIC STRAIN SENSORS EMBEDDED IN GRAPHITE-EPOXY COMPOSITES

R. S. ROGOWSKI, M. S. HOLBEN, JR., J. S. HEYMAN (NASA, Langley Research Center, Hampton, VA), D. W. DEHART (USAF, Astronautics Laboratory, Edwards AFB, CA), and SUSAN MARGULIES (AS&M, Inc., Hampton, VA) IN: Fiber optic smart structures and skins II; Proceedings of the Meeting, Boston, MA, Sept. 5-8, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 435-439.
Copyright

Smart structures deployed in low earth orbit will be exposed to a hostile environment which will include temperature extremes during each orbit as the platform moves from the day to the night side. The stresses due to thermal cycling may compromise the performance of embedded fiber optic strain sensors because of differential thermal expansion of the fiber and the composite material. The effects of elevated temperature and thermal cycling on the performance of a fiber optic strain sensor embedded in a graphite-epoxy tube have been investigated for temperatures from 65 to 220 F. The results indicate that the fiber optic strain sensor measurements correlate well with conventional resistance strain gages attached to the tube. Author

A90-32943#
CFRP - A MATERIAL FOR SPACE VEHICLES
GUENTER HELWIG and BERND ABT *Dornier Post* (ISSN 0012-5563), no. 4, 1989-no. 1, 1990, p. 14-16.
Copyright

The use of CFRP in space structures is discussed. The characteristics of CFRP, such as low specific weight, high stiffness, high strength, small thermal expansion, and good thermal conductivity, correlate well with space structure requirements. Consideration is given to the use of CRFP in the Rosat X-ray satellite, the X-ray Multi-Mirror, satellite communications antennas, a multibeam deployable antenna, and the payload carrier assembly of the Titan launcher. I.F.

A90-33101
ADVANCED COMPOSITES FOR A DIMENSIONALLY STABLE SPACE STRUCTURE
L. RUBIN, D. J. CHANG, E. Y. ROBINSON, and C. TSENG (Aerospace Corp., El Segundo, CA) IN: International SAMPE Technical Conference, 21st, Atlantic City, NJ, Sept. 25-28, 1989, Proceedings. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 345-358. refs
Copyright

A study was conducted to compare the relative utility of several advanced composite structural materials as candidates for a space boom having stringent requirements of dimensional stability. The selected baseline structure was a thin-beam element of rectangular cross section. The criteria for assessing dimensional stability were thermomechanical response to the natural temperature extremes of the space environment, specific stiffness, and a natural vibrational frequency greater than 1 Hz. Materials considered were graphite fabric reinforced epoxy (Gr/Ep) as a baseline composite, graphite fabric reinforced carbon-carbon (C-C), unidirectional graphite-magnesium (Gr/Mg), and unidirectional graphite-aluminum (Gr/Al). The major attributes sought were high through-thickness thermal conductivity, near-zero thermal expansion, and high specific modulus. The Gr/Mg and Gr/Al offered the best design options because they could be used as unidirectionally oriented composites, which allowed maximum effectiveness of the reinforcement fibers, and because of their high through-thickness thermal conductivities. Author

A90-33119
DEVELOPMENT OF COMPOSITE MIRROR WITH GR/EP BODY AND RESIN SUBSTRATE
HIDEO MORITA, MASAHITO OGUMA, and MISAO KONDOH (Ishikawajima-Harima Heavy Industries Co., Ltd., Yokohama, Japan) IN: International SAMPE Technical Conference, 21st, Atlantic City, NJ, Sept. 25-28, 1989, Proceedings. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 626-637. refs
Copyright

An account is given of the fabrication method and performance for graphite-epoxy composite mirrors that are to be assembled into segmented solar collectors for spacecraft deployment. The mirrors require lightweight, high specular reflectance and surface accuracy, and durability in space environments. Safety requirements also entail that the mirror surfacing material be shatterproof. The graphite/epoxy structure is of honeycomb sandwich type. A mean specular reflectance of 0.87 has been achieved in the 0.2-2.0 microns range; the angle-of-reflection error is less than 0.001 radian. O.C.

A90-33120
HIGH STRENGTH HIGH MODULUS CARBON EPOXY COMPOSITES
G. A. JENSEN, D. M. MAZENKO, and T. P. STANKUNAS (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: International SAMPE Technical Conference, 21st, Atlantic City, NJ, Sept. 25-28, 1989, Proceedings. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 638-646.
Copyright

The M40J fiber and F584 epoxy resin system presently evaluated are judged to constitute a superior basis for carbon fiber-reinforced epoxy spacecraft structures; these structures will henceforth be capable of achieving the requisite tensile strength without compromising stiffness. Laminates were found to possess 371,000 psi tensile strength, 34.2 million psi modulus, and about 1 percent ultimate elongation. Excellent results were also obtained for compression, transverse strength, and moduli in plane and short beam shear, as well as in microcrack resistance. Open-hole compression results were comparable with those of composites developed earlier for these purposes. O.C.

A90-33133
HIGH TEMPERATURE ORGANIC AND CERAMIC HYBRID COMPOSITE
S. E. HSU, J. C. CHEN, J. F. CHANG, B. J. WENG, D. G. HWANG (Chung Shan Institute of Science and Technology, Lungtan, Republic of China) et al. IN: International SAMPE Technical Conference, 21st, Atlantic City, NJ, Sept. 25-28, 1989, Proceedings. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 803-811. refs
Copyright

This paper introduces the properties of hybrid composites made from a self-made high-temperature heat-resistant polyimide, called CSPI with a reinforcement of carbon fiber. Two types of hybrid composites have been developed. One is an intraply hybrid carbon-matrix composite (CMC) with CSPI-treated carbon fiber, and the other is an interply hybrid composite with carbon/CSPI and carbon/CMC plies. Both hybrid composites were cocured by laying-up the specific prepregs, respectively. This process, which can be cured at low temperature and applied at high temperature, is a unique and cost-effective method for practical application in space industries. Author

A90-33144
ATOMIC OXYGEN RESISTANT, THERMALLY STABLE EPOXIES
S. L. OLDHAM (Hughes Aircraft Co., El Segundo, CA) IN: International SAMPE Technical Conference, 21st, Atlantic City, NJ, Sept. 25-28, 1989, Proceedings. Covina, CA, Society for the Advancement of Material and Process Engineering, 1989, p. 984-993. refs
Copyright

A family of compliant, modified epoxies was synthesized for use as coatings, adhesives and encapsulants. They combine low viscosities, glass transition temperatures, and outgassing characteristics with high peel strengths and decomposition temperatures. Based on the excellent mechanical erosion resistance of one of these unoptimized systems, HRG-3/T, investigations into its potential suitability as a LEO protective coating were performed. When HRG-3/T was exposed to a mixed oxygen plasma environment, its erosion rate was less than half of

VM-1, the currently used LEO protective coating for the KU-band antenna reflector. Additional HRG-3 formulations were then subjected to combined UV radiation and air plasma exposure in a plasma asher. While all of these specimens exhibited low erosion rates, HRG-3/Al and HRG-3/A2 also showed minimal changes in thermooptical properties. Optimization of HRG-3 is expected to result in a superior coating that will increase the lifetimes of hardware subjected to the LEO environment. Author

A90-34372
FRACTURE-RESISTANT ULTRALLOYS FOR SPACE-POWER APPLICATIONS - NORMAL-SPECTRAL-EMISSIVITY AND ELECTRON-EMISSION STUDIES OF TUNGSTEN, RHENIUM HAFNIUM-CARBIDE ALLOYS AT ELEVATED TEMPERATURES
B. H. TSAO, D. TANG, D. L. JACOBSON, and J. F. MORRIS (Arizona State University, Tempe) Engineering Fracture Mechanics (ISSN 0013-7944), vol. 35, no. 6, 1990, p. 1049-1055, 1057-1059. Research supported by SDIO and DOE. refs
Copyright

This paper reports radiative and thermionic effects of hafnium carbide (HfC) and Re variation in W alloys. The spectral emissivity and effective work function trends of W, Re, 0.35HfC with 5-20 pct Re were measured in the range of 1700-2500 K. The results indicate that spectral emissivity decreases with increasing temperatures and Re contents. The presence of HfC produced higher spectral emissivity values than those of sintered materials with comparable W, Re alloy contents. The results also indicate that the effective work function increases with rhenium contents. This can be explained as growth of the potential barrier at the metal, vacuum boundary associated with a volume effect - the decrease in the lattice constant of W. Author

A90-34924* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MATERIALS SELECTION FOR LONG LIFE IN LOW EARTH ORBIT - A CRITICAL EVALUATION OF ATOMIC OXYGEN TESTING WITH THERMAL ATOM SYSTEMS
S. L. KOONTZ, K. ALBYN, and L. LEGER (NASA, Johnson Space Center, Houston, TX) (Space Simulation Conference, 15th, Williamsburg, VA, Oct. 1988) IES, Journal (ISSN 0022-0906), vol. 33, Mar.-Apr. 1990, p. 50-59. refs
Copyright

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 in thermal atom environments are compared with those observed in LEO and in high-quality LEO simulations. Reaction efficiencies (cu cm/atom) measured in a new type of thermal atom apparatus are one-thousandth to one ten-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 eight 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 speciic thermal atom test environments can be used as reliable materials screening tools. Author

A90-36188*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EFFECT OF ELEVEN YEARS IN EARTH ORBIT ON A MIRROR SURFACE
MICHAEL J. MIRTICH (NASA, Lewis Research Center, Cleveland, OH), HERMAN MARK, and WILLIAM R. KERSLAKE Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, May-June 1990, p. 258-266. Previously cited in issue 05, p. 639, Accession no. A89-17939. refs
Copyright

A90-36200*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
VACUUM ULTRAVIOLET RADIATION/ATOMIC OXYGEN SYNERGISM IN MATERIALS REACTIVITY
STEVEN KOONTZ, LUBERT LEGER, KEITH ALBYN (NASA, Johnson Space Center, Houston, TX), and JON CROSS (Los Alamos National Laboratory, NM) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, May-June 1990, p. 346-348. refs
Copyright

Experimental results are presented which indicate that low fluxes of vacuum UV (VUV) radiation exert a pronounced influence on the atomic oxygen reactivity of such fluorocarbon and fluorocarbon spacecraft materials as the FEP Teflon and PCTFE that are under consideration for the Space Station Freedom. With simultaneous exposure to VUV fluxes comparable to those experienced in LEO, the reactivity of these materials becomes comparable to that of Kapton; VUV radiation has also been shown to increase the reactivity of Kapton with thermal-energy oxygen atoms. O.C.

A90-36327
DESIGN, ANALYSIS AND TESTING OF GRAPHITE EPOXY (GR/EP) SPACECRAFT EQUIPMENT
J. HAMILTON and R. CHAN (Lockheed Missiles and Space Co., Inc., Space Systems Div., Sunnyvale, CA) SAMPE Journal (ISSN 0091-1062), vol. 26, May-June 1990, p. 61-66. refs
Copyright

This presentation briefly describes the methods used to produce a lightweight, cost effective, and 'minimum part count' Gr/Ep spacecraft with concurrent engineering, using computer integrated engineering, and manufacturing technologies (CIEM). An estimated weight savings of 20 percent compared to aluminum was achieved while demonstrating improved stiffness, dimensional stability and lower cost. The structure was configured to satisfy mission requirements and coordinated system integration. A 3-D CADAM wireframe design definition assured geometric integrity and provided a common engineering database for analysis, manufacturing, and test. Finite element models and closed form methods were used to define laminate specifications for optimal strength/stiffness and to minimize the structural risk of the evolving geometry. 'Full up' structure tests of stiffness, strength, dynamics and pyro-shock, verified satisfaction of design criteria. Author

A90-36691* DSET Labs., Inc., Phoenix, AZ.
EVALUATION OF METALLIZED PAINT COATINGS FOR COMPOSITE SPACECRAFT STRUCTURES
JOHN E. BRZUSKIEWICZ (DSET Laboratories, Inc., Phoenix, AZ) SAMPE Quarterly (ISSN 0036-0821), vol. 21, April 1990, p. 9-17. refs
(Contract NAS1-18825)
Copyright

The extreme temperature excursions of composite spacecraft structures in LEO must be minimized through the use of thermal-control coatings. Attention is presently given to tests of silicone resin coatings which were pigmented with either leafing aluminum or combinations of leafing aluminum with silicate-treated zinc oxide pigment. Atomic oxygen, UV/vacuum, and outgassing screening tests were conducted on several such coating formulations in order to characterize the performance characteristics of this coating concept. Performance was found to depend on pigment volume concentration. O.C.

A90-36699#
RISK ASSESSMENT OF ATOMIC-OXYGEN-EFFECTED SURFACE EROSION AND INDUCED OUTGASSING OF POLYMERIC MATERIALS IN LEO SPACE SYSTEMS
Y. HARUVY (Israel Atomic Energy Commission, Soreq Nuclear Research Centre, Yavne) ESA Journal (ISSN 0379-2285), vol. 14, no. 1, 1990, p. 109-119. refs
Copyright

The atomic oxygen present in low earth orbit can severely erode the external layers of polymeric materials. Degradation is manifested by changes in thermo-optical properties and by the

production of scissioned polymeric chains, which add to the inventory of outgassed materials, and volatile condensed mass (VCM) in particular. The relationship between in-flight erosion data for polymers and their chemical nature, the calibration of simulation experiments with space-flight results, and the analysis of various damage scenarios are discussed. The risk-assessment conclusion derived is that nonexternal materials exposed to only traces of atomic oxygen may involve the highest risk of VCM outgassing, and hence spacecraft contamination. R.E.P.

A90-37112#
LABORATORY RESULTS FOR 5-EV OXYGEN ATOMS ON SELECTED SPACECRAFT MATERIALS
GARY W. SJOLANDER and JOSEPH F. FROECHTENIGT (Martin Marietta Corp., Denver, CO) IN: Rarefied gas dynamics: Space-related studies; International Symposium, 16th, Pasadena, CA, July 10-16, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1989, p. 180-186. refs
Copyright

A laboratory facility called Oxydation/Materials Erosion and Glow Analysis has been developed to test spacecraft materials to characterize mass loss rates and corresponding degradation effects and to study the mechanism and influencing parameters for both oxidation and glow. Initial laboratory tests with atomic oxygen shows close agreements with atomic oxygen materials testing in space. Initial qualitative results are presented on silver, Kapton, and quantitative ion chemistry reaction rates on copper and various carbon samples. The carbon results are compared with neutral oxygen reaction rates derived from Space Shuttle flight experiments. Author

A90-38272
ATOMIC-OXYGEN-RESISTENT POLYMER FOR USE IN THE LOW EARTH ORBIT
D. A. VANCE, M. MCCARGO, R. HASTERT (Lockheed Missiles and Space Co., Inc., Palo Alto, CA), M. KATZ, and J. P. OCHSNER (Du Pont de Nemours and Co., Circleville, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2651-2655. Research supported by the Lockheed Missiles and Space Co., Inc.
Copyright

An oxygen plasma reactor operating at low pressure (3 x 10-2 torr) was used to reproduce within laboratory samples of an experimental atomic-oxygen-resistant polymide coating a degradation morphology and material mass loss similar to that obtained in low earth orbit. The coating, Kapton AOR92-1, was developed to be used as a flexible Kapton solar array blanket. Material erosion rates were measured as a function of flux and fluence and preliminary mechanical property data were obtained. The results indicate the material's suitability for the intended application. It demonstrated an erosion rate two orders of magnitude better than Kapton and is amenable to large-scale production. I.E.

A90-38293
ENVIRONMENTAL EFFECTS ON GALLIUM ARSENIDE SOLAR CELLS - A LIPS-III EXPERIMENT
KENNETH A. FREEMAN (Martin Marietta Corp., Astronautics Group, Denver, CO) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2841-2845. Research supported by Martin Marietta Corp. refs
Copyright

Two gallium arsenide (GaAs) solar cell coupons interconnected by welding were flown on the LPS-III satellite to study integrated flight environmental effects. One coupon contained cells fabricated by metalorganic chemical vapor deposition, and the other contained cells produced by liquid phase epitaxy. The coupons have been on orbit for about 1.5 yr. Performance data are presented together with a preliminary analysis and comparison to preflight performance. The current condition of the experimental package is described. I.E.

A90-40624#
MATERIALS AND DESIGN SELECTION FOR MINIMUM WEIGHT PRESSURE VESSELS
B. D. VICKERS, H. W. BABEL, and H. S. PARECHANIAN (McDonnell Douglas Space Systems Co., Huntington Beach, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs
(AIAA PAPER 90-2349) Copyright

The design criteria used in the evaluation of minimum weight pressure vessels, made of graphite/epoxy composite that is overwrapped on a thin metal linear, are discussed. These designs were for a hydrogen/oxygen propulsion system which was once baselined for Space Station Freedom. The use of high-strength, 40 Msi modulus graphite fibers for the composite overwrap material is assessed. Design requirements and fabrication considerations of metal liners are summarized. Material compatibility with hydrogen and high pressure oxygen gas, and long life issues associated with service in a low earth orbit environment are also addressed. The results of the study showed that composite designs were well-suited for extended space missions. Author

A90-41100
HYPERVELOCITY IMPACT PENETRATION PHENOMENA IN ALUMINUM SPACE STRUCTURES
WILLIAM P. SCHONBERG (Alabama, University, Huntsville) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 3, July 1990, p. 173-185. refs
Copyright

In order to develop adequate protection against micrometeorite or orbiting debris penetration of crew compartments and other critical spacecraft systems, a clear view of the penetration mechanics of hypervelocity impact loadings must be obtained for a variety of structural components. Attention is presently given to the results of an experimental investigation of penetration phenomena associated with oblique hypervelocity impacts on aluminum dual-wall structures, as well as to equations that arrive at quantitative characterizations of these phenomena as functions of the geometric and material properties of the impacted structure and the diameter, obliquity, and velocity of the projectile. Penetration is noted to be highly dependent on impact obliquity. O.C.

A90-42258#
ON-ORBIT ANNEALING OF SATELLITE SOLAR PANELS
SHERIF MICHAEL and R. S. SOMMERS (U.S. Naval Postgraduate School, Monterey, CA) IN: Annual AIAA/Utah State University Conference on Small Satellites, 2nd, Logan, UT, Sept. 18-21, 1988, Proceedings. Logan, UT, Utah State University, 1988, 14 p.

Because solar panel output plays a fundamental role in satellite service life definition, the effective recovery of progressively lost generation capacity becomes very attractive. An investigation has accordingly been conducted of the possibility of annealing radiation-damaged solar panels, under conditions feasibly employed aboard orbiting spacecraft. An evaluation is made of preliminary data on moderate-temperature forward-biased current annealing of GaAs solar cells. An autonomous microprocessor-controlled experiment has been defined which can conduct these annealing process tasks while monitoring and recording solar cell performance parameters. O.C.

A90-43119* State Univ. of New York, Buffalo.
A BRIEF SURVEY OF RADIATION EFFECTS ON POLYMER DIELECTRICS
JAVAID R. LAGHARI (New York, State University, Buffalo) and AHMAD N. HAMMOUD (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 37, pt. 2, April 1990, p. 1076-1083. refs
Copyright

Future space power needs are extrapolated to be at least three to four orders of magnitude more than is currently available. This long-term reliable power will be required on missions such as the Space Station, Pathfinder, Space Plane, and high-powered satellites, and for defense. Electrical insulation and dielectrics are the key electrical materials needed to support these power systems, where a single-point system failure could prove catastrophic or even fatal for the whole mission. Therefore, the impact of radiation, an environmental stress, on the properties and performance of insulation and dielectrics must be understood. The influence of radiation on polymer dielectrics, the insulating materials most commonly used for power transmission and storage, is reviewed. The effects of the type of radiation, dose, rate, and total exposure on the key electrical, mechanical, and physical properties of polymer dielectrics are described and explained. I.E.

A90-43808
DEVELOPMENT OF AN EVALUATION METHOD OF FUNCTIONALLY GRADIENT MATERIALS
HIDEAKI TAKAHASHI and TOSHIYUKI HASHIDA (Tohoku University, Sendai, Japan) JSME International Journal, Series I (ISSN 0914-8809), vol. 33, July 1990, p. 281-287. refs
Copyright

The current status of the functionally gradient material (FGM) project is examined. Particular attention is given to the material evaluation methods. The development and procedures of the small punch test, laser heating thermal shock test, and thermal shielding performance test, which are designed to evaluate the mechanical and thermal barrier functions of FGMs, are described. The importance of standard testing procedures and the development of a material property data base are discussed. Diagrams of the testing apparatus are presented. I.F.

A90-44569#
EVALUATION OF CONDUCTIVITY OF TWO SURFACE PAINTS FOR SPACECRAFT
YUSUN LU, HUA LI, XIAOWEN HAN (Lanzhou Institute of Physics, People's Republic of China), and WENYING CHEN (Beijing Orient Scientific Instrument Factory, People's Republic of China) Chinese Space Science and Technology (ISSN 1000-758X), vol. 9, June 1989, p. 41-46. In Chinese, with abstract in English.

The preparation process of two paints, 956 grey paint and 956 green paint is briefly discussed in this article. Conduction characteristics of both paints and their irregularities in a simulated space vacuum, electron irradiation and solar irradiation have been studied. Therefore, the charging states of these paint surfaces in orbit can be predicted by the experimental results. In addition, the possibility of using these paints in high orbit can be expected. Author

A90-45186
EFFECT OF A SIMULATED SPACE ENVIRONMENT ON SULFURIC ACID ANODIZED ALUMINUM FOR SPACECRAFT THERMAL CONTROL
HUONG G. LE, CHARLES A. SMITH, and DUDLEY L. O'BRIEN (McDonnell Douglas Space Systems Co., Huntington Beach, CA) IN: Space optical materials and space qualification of optics; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 59-72. Research supported by McDonnell Douglas Space Systems Co. refs
Copyright

The severe environmental conditions in LEO have a detrimental effect on the performance and longevity of some thermal control coatings. Sulfuric acid anodized aluminum has been evaluated as a thermal control coating for the radiators of the Space Station Freedom. The evaluation included: study of processing parameters necessary to achieve suitable solar absorptance and thermal emittance properties; study of temperature effects on the stability of the aluminum oxide produced by sulfuric acid anodizing; ultraviolet radiation, and electron radiation testing of sulfuric acid anodized aluminum; and characterization of surface chemistry and morphology before and after environmental testing to determine the cause of degradation. Results show that sulfuric acid anodized aluminum may be a satisfactory thermal control coating for the radiators of the Space Station Freedom. Author

A90-45610
METALLURGICAL ASSESSMENT OF SPACECRAFT PARTS AND MATERIALS
BARRIE D. DUNN (ESTEC, Noordwijk, Netherlands) Chichester, England/Englewood Cliffs, NJ, Ellis Horwood, Ltd./Prentice Hall, 1989, 367 p. refs
Copyright

The application of metallographic methods in the fabrication and evaluation of spacecraft structural and electronic components is discussed, with an emphasis on recent European experience. Chapters are devoted to the requirements for spacecraft materials, the integration of metallurgy into product-assurance schemes, metallography applied to spacecraft production, metallography applied to spacecraft test failures, failure analysis of electrical interconnections, and the problem of whisker growth. Extensive diagrams, drawings, photographs, and micrographs are provided. T.K.

A90-47106#
THERMAL DISTORTION BEHAVIOR OF GRAPHITE REINFORCED ALUMINUM SPACE STRUCTURES
D. G. ZIMCIK (Canadian Space Agency, Ottawa, Canada) and B. M. KOIKE (Composite Tecnologia, Sao Paulo, Brazil) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, July-Aug. 1990, p. 380-385. Previously cited in issue 12, p. 1852, Accession no. A89-30715. refs
Copyright

A90-48819* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCED REFRACTORY METALS AND COMPOSITES FOR EXTRATERRESTRIAL POWER SYSTEMS
R. H. TITRAN and TONI L. GROBSTEIN (NASA, Lewis Research Center, Cleveland, OH) JOM (ISSN 1047-4838), vol. 42, Aug. 1990, p. 8-10. refs
Copyright

Concepts for future space power systems include nuclear and focused solar heat sources coupled to static and dynamic power-conversion devices; such systems must be designed for service lives as long as 30 years, despite service temperatures of the order of 1600 K. Materials are a critical technology-development factor in such aspects of these systems as reactor fuel containment, environmental protection, power management, and thermal management. Attention is given to the prospective performance of such refractory metals as Nb, W, and Mo alloys, W fiber-reinforced Nb-matrix composites, and HfC precipitate-strengthened W-Re alloys. O.C.

A90-49420
STUDIES OF THE INTERACTION OF 8 KM/S OXYGEN ATOMS WITH SELECTED MATERIALS
GEORGE E. CALEDONIA and ROBERT H. KRECH (Physical Sciences, Inc., Andover, MA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 8 p. refs
(SAE PAPER 901411) Copyright

The technique of laser-induced gas breakdown is used to generate a high flux pulsed beam of 8 km/s oxygen atoms. The beam contains approximately 10 to the 18th oxygen atoms per pulse, can be operated at a frequency as high as 10 Hz and be expanded to encompass an area greater than 1000 sq cm. The beam is used to simulate the interactions between the ambient atmosphere and spacecraft materials to be encountered in low earth orbit applications. The device and its operating characteristics are described and an example results on material erosion, surface modification, and surface glow is presented. Author

A90-50135
NEW CYANATE ESTER RESIN WITH LOW TEMPERATURE (125-200 C) CURE CAPABILITY
D. A. SHIMP and S. J. ISING (Hi-Tek Polymers, Inc., Louisville, KY) IN: International SAMPE Symposium and Exhibition, 35th, Anaheim, CA, Apr. 2-5, 1990, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1990, p. 1045-1056. refs
Copyright

The development of a liquid cyanate ester resin molecularly designed to process/cure like conventional epoxy resins and improve on three featured properties of polycyanurates (low moisture absorption, low dielectric loss, and dimensional stability) is described. Comparisons with commercial cyanate esters and other high-temperature thermosetting resins demonstrate new capabilities with respect to achieving practical conversions at 121-204 C curing temperatures. Typical RTX-366 homopolymer properties are a dielectric constant of 2.6-2.8, a dissipation factor of 0.0004-0.0008, 0.7 percent water absorption at 100 C saturation, no stress-inducing shrinkage during polymerization, and Tg range of 125-190 C. The asymmetrically linked, three-benzene-ring bisphenol derivative, RTX-366 dicyanate monomer, is shown to develop matrix performance properties associated with advancements in composites for radomes, microwave antennas, space structures, aircraft with low radar signatures, and high speed/high density electronic circuitry. Author

A90-50607*# Globesat, Inc., Logan, UT.
MEASUREMENT OF SURFACE REACTIONS IN THE SPACE ENVIRONMENT
WEDAD A. ABDOU, LAWRENCE R. MEGILL (Globesat, Inc., Logan, UT), DAVID A. BRINZA (JPL, Pasadena, CA), ROGER C. HART, R. GILBERT MOORE (Utah State University, Logan) et al. IN: Annual AIAA/Utah State University Conference on Small Satellites, 3rd, Logan, UT, Sept. 26-28, 1989, Proceedings. Logan, UT, Utah State University, 1989, 20 p. refs

The Atomic Oxygen Measurement Spacecraft, ATOMS, and a suite of associated instruments, designed to measure the performance of improved atomic-oxygen-resistant materials and coatings in orbit and to telemeter the resulting data and video images to earth at intervals during a one-year mission, have been described in a definition study sponsored by the Langley Research Center under NASA's In-Space Technology Experiments Program. The objective of the program is to work toward an improvement of base materials and surface coatings which will resist the serious degradation experienced by the external surfaces of LEO spacecraft as a result of the ablative effects of atmospheric oxygen, possibly catalyzed by solar UV radiation. This miniature orbiting laboratory includes a radio-frequency mass spectrometer, a set of osmium actinometers, and a scanning optical microscope. The design of these instruments and their use in the overall experiment are discussed. L.K.S.

N90-20645*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT AND APPLICATION OF NONFLAMMABLE, HIGH-TEMPERATURE BETA FIBERS
FREDERIC S. DAWN Dec. 1989 40 p
(NASA-TM-102158; NAS 1.15:102158) Avail: NTIS HC A03/MF A01 CSCL 06/11

Recent advances in fiber technology have contributed to the success of the U.S. space program. The inorganic fiber Beta, developed as a result of efforts begun in the early 1960's and heightened following the January 27, 1967 Apollo fire is unique among inorganic and organic fibers. It has been developed into woven, nonwoven, knitted, braided, coated and printed structures. All of these were used extensively for the Apollo, Skylab, Apollo-Soyuz test project, space shuttle, Spacelab, and satellite programs. In addition to being used successfully in the space program, Beta fibers are being used commercially as firesafe fabrics in homes, hospitals, institutions, public buildings, aircraft, and public transportation, wherever total nonflammability is required. One of the most unique applications of the Beta composite structure is the roofing material for the 80,000-seat Detroit Lion's Silverdome and 5 square miles of the Jeddah International Airport in Saudi Arabia. This fiber has been successfully incorporated into 165 major public construction projects around the globe. The United States alone has used more than 12 million square yards of the material. Beta fiber has been used successfully to date and has a promising future with unlimited potential for both space and commercial application. Efforts are currently underway to improve Beta fiber to meet the requirements of extended service life for the Space Station Freedom, lunar outpost, and Mars exploration missions. Author

N90-21110*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE EFFECT OF LEVELING COATINGS ON THE ATOMIC OXYGEN DURABILITY OF SOLAR CONCENTRATOR SURFACES
KIM K. DEGROH, THERESE M. DEVER, and WILLIAM F. QUINN (Cleveland State Univ., OH.) Apr. 1990 18 p Presented at the 8th International Conference on Thin Films, and the 17th International Conference on Metallurgical Coatings, San Diego, CA, 2-6 Apr. 1990; spons. in part by Intern. Union for Vacuum Sci., Tech., and Appl. and the Amer. Vacuum Society
(NASA-TM-102557; E-5375; NAS 1.15:102557) Avail: NTIS HC A03/MF A01 CSCL 10/1

Space power systems for Space Station Freedom will be exposed to the harsh environment of low earth orbit (LEO). Neutral atomic oxygen is the major constituent in LEO and has the potential of severely reducing the efficiency of solar dynamic power systems through degradation of the concentrator surfaces. Several transparent dielectric thin films have been found to provide atomic oxygen protection, but atomic oxygen undercutting at inherent defect sites is still a threat to solar dynamic power system survivability. Leveling coatings smooth microscopically rough surfaces, thus eliminating potential defect sites prone to oxidation attack on concentrator surfaces. The ability of leveling coatings to improve the atomic oxygen durability of concentrator surfaces was investigated. The application of a EPO-TEK 377 epoxy leveling coating on a graphite epoxy substrate resulted in an increase in solar specular reflectance, a decrease in the atomic oxygen defect density by an order of magnitude and a corresponding order of magnitude decrease in the percent loss of specular reflectance during atomic oxygen plasma ashing. Author

N90-22628*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PULTRUSION PROCESS DEVELOPMENT FOR LONG SPACE BOOM MODEL
MAYWOOD L. WILSON and ROBERT MISERENTINO Jan. 1988 21 p Presented at the 41st Annual Conference of the Society of the Plastics Industry Reinforced Plastics/Composites Inst., Atlanta, GA, 27-31 Jan. 1986 Previously announced in IAA as A87-20083
(NASA-TM-4017; L-16365; NAS 1.15:4017) Avail: NTIS HC A03/MF A01 CSCL 11/4

Long flexible-boom models were required to develop ground-vibration test methods for very-low-frequency space structures with applications to the proposed Space Station. Pultruded quasi-isotropic composite beams were selected as an option over extruded aluminum alloy structures because of the lower cost potential, the higher specific strength, the flexural properties, and the dynamic similarity considerations. The reinforcement material that was used was biaxial (0 deg/90 deg) fiberglass roving held in place with knitted polyester yarn such that equal fiber volume in 0 deg and 90 deg orientations provided nearly equal strength in both longitudinal and transverse directions. An isophthalic polyester resin system was used as the matrix. Continuous lengths up to 270 ft were easily pultruded with biaxial fabric. Tracking problems were encountered with similar unidirectional fabrics. Analyses of processing problems were conducted to determine causes for delamination, scaling, and sloughing. Ultrasonic C-scanning and scanning electron microscope

examinations were conducted as well as mechanical testing to failure. Test results indicate that pultrusion processes can be used to produce quasi-isotropic composite structures. Author

N90-23664*# Johns Hopkins Univ., Baltimore, MD. Center for Nondestructive Evaluation.
ACOUSTO-ULTRASONIC NONDESTRUCTIVE EVALUATION OF MATERIALS USING LASER BEAM GENERATION AND DETECTION M.S. Thesis
ROBERT D. HUBER and ROBERT E. GREEN, JR. 1990 97 p (Contract NAG3-728)
(NASA-CR-186694; NAS 1.26:186694) Avail: NTIS HC A05/MF A01 CSCL 09/3

The acousto-ultrasonic method has proven to be a most interesting technique for nondestructive evaluation of the mechanical properties of a variety of materials. Use of the technique or a modification thereof, has led to correlation of the associated stress wave factor with mechanical properties of both metals and composite materials. The method is applied to the nondestructive evaluation of selected fiber reinforced structural composites. For the first time, conventional piezoelectric transducers were replaced with laser beam ultrasonic generators and detectors. This modification permitted true non-contact acousto-ultrasonic measurements to be made, which yielded new information about the basic mechanisms involved as well as proved the feasibility of making such non-contact measurements on terrestrial and space structures and heat engine components. A state-of-the-art laser based acousto-ultrasonic system, incorporating a compact pulsed laser and a fiber-optic heterodyne interferometer, was delivered to the NASA Lewis Research Center. Author

N90-25170*# Cockerham (John M.) and Associates, Inc., Huntsville, AL.
OPTICAL PROPERTIES MONITOR: EXPERIMENT DEFINITION PHASE Final Report, 16 Sep. 1988 - 29 Sep. 1989
DONALD R. WILKES, JEAN M. BENNETT, LEIGH L. HUMMER, RUSSELL A. CHIPMAN, JAMES B. HADAWAY, and LARRY PEZZANITI Washington NASA May 1990 147 p (Contract NAS8-37755)
(NASA-CR-4293; NAS 1.26:4293) Avail: NTIS HC A07/MF A01 CSCL 22/2

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

N90-25176# European Space Agency, Paris (France).
MATERIALS AND PROCESSES FOR SPACECRAFT: THE ESTEC APPROACH
J. DAUPHIN (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) Feb. 1990 16 p Revised
(ESA-STM-244; ESA-STM-237; ISSN-0379-4075; ETN-90-96983) Copyright Avail: NTIS HC A03/MF A01; EPD, ESTEC, Noordwijk, Netherlands, HC 20 Dutch guilders

The approach to materials and processes problems used by ESTEC is described. The approach combines pragmatism with standardization. The need to further formalize the work of the division in tackling larger and more complex future projects is discussed. The need to maintain flexibility and the ability to make ad hoc interventions is stressed. The training of new staff, engineers and technicians in the specialized domain of space materials and processes is identified as the biggest challenge facing ESTEC in preparing itself to meet future challenges. ESA

N90-25507*# Air Force Systems Command, Hanscom AFB, MA.
SPACECRAFT CONTAMINATION PROGRAMS WITHIN THE AIR FORCE SYSTEMS COMMAND LABORATORIES
EDMOND MURAD *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 97-98 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 22/2

Spacecraft contamination programs exist in five independent AFSC organizations: Geophysics Laboratory (GL), Arnold Engineering and Development Center (AEDC), Rome Air Development Center (RADC/OSCE), Wright Research and Development Center (MLBT), Armament Laboratory (ATL/SAI), and Space Systems Division (SSD/OL-AW). In addition, a sizable program exists at Aerospace Corp. These programs are complementary, each effort addressing a specific area of expertise: GL's effort is aimed at addressing the effects of on-orbit contamination; AEDC's effort is aimed at ground simulation and measurement of optical contamination; RADC's effort addresses the accumulation, measurement, and removal of contamination on large optics; MLBT's effort is aimed at understanding the effect of contamination on materials; ATL's effort is aimed at understanding the effect of plume contamination on systems; SSD's effort is confined to the integration of some contamination experiments sponsored by SSD/CLT; and Aerospace Corp.'s effort is aimed at supporting the needs of the using System Program Offices (SPO) in specific areas, such as contamination during ground handling, ascent phase, laboratory measurements aimed at understanding on-orbit contamination, and mass loss and mass gain in on-orbit operations. These programs are described in some detail, with emphasis on GL's program. Author

N90-25531*# Los Alamos National Lab., NM. Chemical and Laser Sciences Div.
LABORATORY INVESTIGATIONS: LOW EARTH ORBIT ENVIRONMENT CHEMISTRY WITH SPACECRAFT SURFACES
JON B. CROSS *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 269-275 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 20/8

Long-term space operations that require exposure of material to the low earth orbit (LEO) environment must take into account the effects of this highly oxidative atmosphere on material properties and the possible contamination of the spacecraft surroundings. Ground-based laboratory experiments at Los Alamos using a newly developed hyperthermal atomic oxygen (AO) source have shown that not only are hydrocarbon based materials effected but that inorganic materials such as MoS2 are also oxidized and that thin protective coatings such as Al2O3 can be breached, producing oxidation of the underlying substrate material. Gas-phase reaction products, such as SO2 from oxidation of MoS2 and CO and CO2 from hydrocarbon materials, have been detected and have consequences in terms of spacecraft contamination. Energy loss through gas-surface collisions causing spacecraft drag has been measured for a few select surfaces and has been found to be highly dependent on the surface reactivity. Author

N90-26075*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PROCEEDINGS OF THE LDEF MATERIALS DATA ANALYSIS WORKSHOP
BLAND A. STEIN, comp. and PHILIP R. YOUNG, comp. Jul. 1990 289 p Workshop held at Cocoa Beach, FL, 13-14 Feb. 1990
(NASA-CP-10046; NAS 1.55:10046) Avail: NTIS HC A13/MF A02 CSCL 07/1

The 5-year, 10-month flight of the Long Duration Exposure Facility (LDEF) greatly enhanced the potential value of most LDEF materials, compared to the original 1-year flight plan. NASA recognized this potential by forming the LDEF Space Environmental Effects on Materials Special Investigation Group in early 1989 to address the expanded opportunities available in the LDEF structure and on experimental trays, so that the value of all LDEF materials to current and future space missions would be assessed and documented. The LDEF Materials Data Analysis Workshop served as one step toward the realization of that responsibility and ran concurrently with activities surrounding the successful return of the spacecraft to the NASA Kennedy Space Center. A compilation of visual aids utilized by speakers at the workshop is presented. Session 1 summarized current information on analysis responsibilities and plans and was aimed at updating the workshop attendees: the LDEF Advisory Committee, Principle Investigators, Special Investigation Group Members, and others involved in LDEF analyses or management. Sessions 2 and 3 addressed materials data analysis methodology, specimen preparation, shipment and archival, and initial plans for the LDEF Materials Data Base. A complementary objective of the workshop was to stimulate interest and awareness of opportunities to vastly expand the overall data base by considering the entire spacecraft as a materials experiment. Author

N90-26932# Vanderbilt Univ., Nashville, TN. Dept. of Physics and Astronomy.
SURFACE REACTIONS IN THE SPACE ENVIRONMENT Final Report, 1 Oct. 1986 - 30 Sep. 1989
NORMAN H. TOLK and RICHARD F. HAGLUND 3 May 1990 26 p
(Contract F49620-86-C-0125; AF PROJ. 3484)
(AD-A221767; AFOSR-90-0623TR) Avail: NTIS HC A03/MF A01 CSCL 07/4

A central goal has been to establish a multidisciplinary Center of Excellence concentrating on the atomic-scale dynamics of surface reactions in the space environment. The major research focus has been the investigation of the ways in which energy deposited by incident atoms, ions, electrons and short wavelength photons is absorbed and localized to produce bond-making and bond-breaking on surfaces and in the near-surface bulk. Knowledge of these microscopic mechanisms provides detailed clues which lead to an understanding of the macroscopic processes which manifest themselves as surface erosion, modification and damage. This research program bears directly on a broad spectrum of questions germane to the long-term operation of platforms in space, including long-term structural, optical and electronic degradation of materials in the ambient near-earth environment, survivability under and hardening against irradiation from directed-energy weapons, vulnerability in disturbed nuclear atmospheres, and discrimination and sensing techniques based on characteristic radiation (glow) signatures. Significant, and in some cases, startling progress has been made in carrying out the research goals of this effort. GRA

06

STRUCTURAL MEMBERS & MECHANISMS

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

A90-31891
DEVELOPMENT OF A LARGE DEPLOYABLE CARBON FIBER COMPOSITE ANTENNA STRUCTURE FOR FUTURE ADVANCED COMMUNICATIONS SATELLITES
F. GRIMALDI and G. TEMPESTA (Selenia Spazio S.p.A., L'Aquila, Italy) IN: Materials and processing - Move into the 90's; Proceedings of the Tenth International European Chapter Conference of SAMPE, Birmingham, England, July 11-13, 1989. Amsterdam, Elsevier Science Publishers, 1989, p. 197-210.
Copyright

A very advanced antenna subsystem has been developed for future communications satellite missions. The antenna consists of a multiple beam high frequency Ka-band (20/30 GHz) feed array with a 4-m diameter carbon fiber composite reflector structure. The engineering effort involved in the materials, processes and manufacturing technology for this advanced composite structure are described in this paper. Author

A90-32031*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
IMPLICATION OF ORBITAL DEBRIS FOR SPACE STATION DESIGN
RAYMOND L. NIEDER (NASA, Johnson Space Center, Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 7 p.
(AIAA PAPER 90-1331) Copyright

A large increase in the debris environment combined with the existing space station program requirements results in larger design debris particle sizes being used for designing the Space Station meteoroid and debris protection system. Equipment affecting survivability of the Space Station and its crew is identified and the amount of protection needed is assessed. A combination of passive shielding and active techniques is considered along with the requirements for developing easily augmentable shielding and the use of new shielding materials to reduce launch weight and volume. In addition to passive protection development, collision avoidance procedures moving the station out of the path of very large debris particles must be developed. Innovative solutions, including on-orbit debris detection and tracking devices, active debris interceptors, and 'storm cellars' are addressed. V.T.

A90-32032*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SHIELDING REQUIREMENTS FOR THE SPACE STATION HABITABILITY MODULES
SHERMAN L. AVANS, JENNIFER R. HORN, and JOEL E. WILLIAMSEN (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 9 p. refs
(AIAA PAPER 90-1333) Copyright

The design, analysis, development, and tests of the total meteoroid/debris protection system for the Space Station Freedom habitability modules, such as the habitation module, the laboratory module, and the node structures, are described. Design requirements are discussed along with development efforts, including a combination of hypervelocity testing and analyses. Computer hydrocode analysis of hypervelocity impact phenomena associated with Space Station habitability structures is covered and the use of optimization techniques, engineering models, and parametric analyses is assessed. Explosive rail gun development efforts and protective capability and damage tolerance of multilayer insulation due to meteoroid/debris impact are considered. It is concluded that anticipated changes in the debris environment definition and requirements will require rescoping the tests and analysis required to develop a protection system. V.T.

A90-32033#
SHIELDING FOR COLUMBUS
H. K. LO (ESTEC, Noordwijk, Netherlands) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 8 p. refs
(AIAA PAPER 90-1334) Copyright

Design considerations for the Columbus shielding concept are discussed, taking into account the larger size of the vehicle elements and the longer operational lifetimes which make several failure modes possible, so that inspection, repair, and replaceable procedures are required. The subsystem requirements, in-orbit

maintenance problems, and risk assessment are analyzed. The results of the analysis show (1) that empirical equations for the analysis of a shield against particle impact are inaccurate for large particles; (2) that numerical simulation for analysis of impacts of particles at velocities above 10 km/s has to be further improved, taking into consideration its dependence on characterization of the debris cloud, fragmentation, and material modeling; and (3) that the risk assessment should be performed especially for meteoroid and debris impact to determine the residual risk inherent in the selected design. N.B.

A90-32034#
SHIELDING CONSIDERATIONS FOR THE JAPANESE EXPERIMENT MODULE
K. SHIRAKI, E. HASHIMOTO, and K. TASAKI (NASDA, Tokyo, Japan) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 7 p. refs
(AIAA PAPER 90-1335)

The general concept of a bumper design approach employed to protect the Japanese Experiment Module against relatively small debris (less than 1 cm in diameter) is explained. A two-stage helium light gas gun is utilized for hypervelocity impact tests in which velocity is varied from 3 km/s to 4 km/s. The test results are analyzed and correlated to computational simulated results. It is shown that a fracture mode is closely related to the tensile strength and thickness of the front bumper and that there is an optimum front plate thickness which causes the front plate and projectile to melt and minimize rear plate damage. In future experiments an artificial pressure wall will be placed behind a double-bumper structure, and the effect on the pressure module will be observed for verification. V.T.

A90-32339
COMPUTATIONAL EXPERIMENTS; PROCEEDINGS OF THE ASME/JSME PRESSURE VESSELS AND PIPING CONFERENCE, HONOLULU, HI, JULY 23-27, 1989
W. K. LIU, ED. (Northwestern University, Evanston, IL), P. SMOLINSKI, ED. (Pittsburgh, University, PA), R. OHAYON, ED. (ONERA, Chatillon-sous-Bagneux, France), J. NAVICKAS, ED. (McDonnell Douglas Astronautics Co., Huntington Beach, CA), and J. GVILDYS, ED. (Argonne National Laboratory, IL) Conference sponsored by ASME and JSME. New York, American Society of Mechanical Engineers, 1989, 142 p. For individual items see A90-32340 to A90-32349.
Copyright

Papers applying FEM to engineering problems are presented, covering topics such as a numerical approach to software development for thermoforming simulations, flow three-dimensional analysis of pressure responses in an enclosed launching system, comparing flow three-dimensional calculations with very large amplitude slosh data, and the computational analysis of stress concentrations in pressure vessel cascades. Other topics include FEM studies of flow past an array of plates, stochastic finite elements for automotive impact, numerical simulation in the deployment of space structures, axial buckling of a thin cylindrical shell, applying FEM to the prediction of vibrations of liquid propelled launch vehicles, analysis of a large bore piping system supported with viscodampers, stochastic simulation of lubricant depletion on a magnetic storage disk, and two-dimensional crak inclusion interaction effects. Additional topics include analyzing damage mechanisms using the energy release rate, the suspension of solid particles in an aerospace plane's slush hydrogen tanks, modal methods for the analysis of vibrations of structures coupled with fluids, the elastic-plastic behavior of fibrous metal matrix composites, and stochastic finite element analysis of nonlinear media. R.B.

A90-33378#
AN OVERVIEW OF MATHEMATICAL MODEL UPDATING AND VERIFICATION METHODS FOR SPACECRAFT APPLICATIONS
E. FISSETTE and C. STAVRINIDIS (ESTEC, Noordwijk, Netherlands) IN: European Forum on Aeroelasticity and Structural Dynamics, Aachen, Federal Republic of Germany, Apr. 17-19, 1989, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1989, p. 293-299. refs

Iterative and noniterative methods summarizing current developments in mathematical model updating are presented, with emphasis on the suitability of updated models for launcher/spacecraft coupled analysis, static analysis, and typical spacecraft problems. It is shown that available techniques do not adequately cover the incompatibility between the measured and analytical modes, and that there is a need to establish reliable methods converging correctly to hardware physical characteristics in order to maintain the physical significance of the original model. Criteria for selecting model update parameters and substructures are considered. V.T.

A90-36189*# Alabama Univ., Huntsville.
EXTERIOR SPACECRAFT SUBSYSTEM PROTECTIVE SHIELDING ANALYSIS AND DESIGN
WILLIAM P. SCHONBERG (Alabama, University, Huntsville) and ROY A. TAYLOR (NASA, Marshall Space Flight Center, Huntsville, AL) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, May-June 1990, p. 267-274. refs
Copyright

All spacecraft are susceptible to impacts by meteoroids and pieces of orbiting space debris. 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. It is found that the diameter of the most damaging ricochet debris particle can be as large as 40 percent of the original project tile diameter, and can travel at speeds between 24 and 36 percent of the original projectile impact velocity. Panel dimensions are shown to be strongly dependent on their inclination to the impact velocity vector 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

A90-36198*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADAPTIVE STRUCTURES - AN OVERVIEW
BEN K. WADA (JPL, Pasadena, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, May-June 1990, p. 330-337. Previously cited in issue 12, p. 1795, Accession no. A89-30652. refs
Copyright

A90-36274#
CONCEPT OF THE TENSION TRUSS ANTENNA
KORYO MIURA (Institute of Space and Astronautical Science, Sagamihara, Japan) and YASUYUKI MIYAZAKI AIAA Journal (ISSN 0001-1452), vol. 28, June 1990, p. 1098-1104. refs
Copyright

The concept of the tension truss antenna is proposed. It is shown that a parabolic reflector surface can be formed by a three-dimensional integrated cable lattice system that can be called a tension truss. The tension truss antenna consists of a triangular-faceted cable truss, the RF reflector surface, and a supporting structure which provides support as well as pretension of the cable lattice. The primary feature of the antenna is that its shape is virtually determined by geometric quantities such as the lengths and arrangement of cable members. Because of this feature, the adjustment of antenna surface can be done directly by changing lengths of cable members which form the surface. This adaptive nature of the concept is favorable for controlling reflector surface in orbit. It is also easily deployable and retractable, and varieties of facet sizing and arrangement are possible. Modeling of truss geometry, surface accuracy, analysis on the formation of a parabolic surface, surface adjustment algorithm, and system design are investigated. Author

A90-36275#
EXACT STATIC AND DYNAMIC STIFFNESS MATRICES FOR GENERAL VARIABLE CROSS SECTION MEMBERS
MOSHE EISENBERGER (Carnegie-Mellon University, Pittsburgh, PA) AIAA Journal (ISSN 0001-1452), vol. 28, June 1990, p. 1105-1109. Previously cited in issue 12, p. 1902, Accession no. A89-30743. refs
Copyright

A90-38160
DESIGN OF AN AUTO-DEPLOYABLE TECHNOLOGY DEMONSTRATION SOLAR CONCENTRATOR
A. PINTZ, C. H. CASTLE, R. R. REIMER, and G. D. NAUJOKAS (Cleveland State University, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 867-873. refs
Copyright

A 2-m-diameter prototype solar concentrator has been designed to demonstrate the level of technology required for future space applications. The issues addressed in the design are the attainment of high concentration ratio, high solar reflectivity and low weight. The design was based on the proven concept of the Sunflower solar concentrator of the 1960's because of the latter's advanced development. The design goals are discussed, the concept is described in detail, and the critical technology issues that must be addressed are identified. I.E.

A90-38161* Science Applications International Corp., San Diego, CA.
AN ADVANCED CONCENTRATOR FOR SOLAR DYNAMIC POWER SYSTEMS IN SPACE
KELLY BENINGA and ROGER DAVENPORT (Science Applications International Corp., San Diego, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 875-880. Research supported by NASA. refs
Copyright

Solar concentrators based on rigidized stretched-membrane technology, which have been shown to be a possible alternative to rigid segmented concentrators for solar dynamic power applications in space, are discussed. Membrane concentrators offer an advantage in weight, efficiency of structure use, deployability, and cost. Predeployment packaging and subsequent deployment of a prototype membrane concentrator has been demonstrated. Attractive membrane fabrication techniques have been identified and demonstrated. The concept is described, and materials selection and membrane fabrication are examined. I.E.

A90-38162* Acurex Corp., Mountain View, CA.
CONCEPTUAL DESIGN OF A SELF-DEPLOYABLE, HIGH PERFORMANCE PARABOLIC CONCENTRATOR FOR ADVANCED SOLAR-DYNAMIC POWER SYSTEMS
HANS JOACHIM DEHNE and DONALD R. DUFFY (Acurex Corp., Environmental Systems Div., Mountain View, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 881-886. Research supported by NASA.
Copyright

A summary is presented of the concentrator conceptual design work performed under a NASA-funded project. The design study centers around two basic efforts: conceptual design of a self-deploying, high-performance parabolic concentrator; and materials selection for a lightweight, shape-stable concentrator. The primary structural material selected for the concentrator is PEEK/carbon fiber composite. The deployment concept utilizes rigid gore-shaped reflective panels. The assembled concentrator takes a circular shape with a void in the center. The deployable solar concentrator concept is applicable to a range of solar dynamic power systems of 25 kWe to more than 75 kWe. I.E.

A90-38267* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
UPDATE OF THE SOLAR CONCENTRATOR ADVANCED DEVELOPMENT PROJECT
ROBERT D. CORRIGAN, TODD T. PETERSON (NASA, Lewis Research Center, Cleveland, OH), and DERIK T. EHRESMAN (Harris Corp., Melbourne, FL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2617-2622.
(Contract NAS3-24670)
Copyright

The Solar Concentrator Advanced Development Project, which has achieved the successful design, fabrication, and testing of a full-scale prototypical solar dynamic concentrator, is discussed. The design and fabrication process are summarized, and the test results for the reflective facet optical performance and the concentrator structural repeatability are reported. Initial testing of structural repeatability of a seven panel portion of the concentrator was followed by assembly and testing of the full nineteen-panel structure. The testing, which consisted of theodolite and optical measurements over an assembly-disassembly-reassembly cycle, demonstrated that the concentrator maintained the as-built contour and optical characteristics. The facet development effort, which entailed developing a vapor-deposited reflective facet, produced a viable design with demonstrated optical characteristics that are within the project goals. I.E.

A90-39046
PAMELA - HIGH DENSITY SEGMENTATION FOR LARGE, ULTRA-LIGHT, HIGH-PERFORMANCE MIRRORS
J. D. G. RATHER, B. L. ULICH (Kaman Aerospace Corp., Bloomfield, CT), G. AMES, A. LAZZARINI (Kaman Instrumentation Corp., Colorado Springs, CO), E. K. CONKLIN et al. IN: Reflective optics II; Proceedings of the Meeting, Orlando, FL, Mar. 27-29, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 195-203.
Copyright

The PAMELA (Phased Array Mirror, Extendable Large Aperture) optical technology, which provides important new possibilities for constructing very large telescopes, is described. The PAMELA approach leads directly to the ability to build rugged, diffraction-limited optical telescopes or beam expanders for ground-based or orbital deployment which have unprecedentedly low weight. Such systems will be fault-tolerant, leading to large expected savings in overall system cost and complexity. C.D.

A90-39176
DISCRETIZATION METHODS AND STRUCTURAL OPTIMIZATION - PROCEDURES AND APPLICATIONS; PROCEEDINGS OF THE GAMM SEMINAR, UNIVERSITAET-GESAMTHOCHSCHULE SIEGEN, FEDERAL REPUBLIC OF GERMANY, OCT. 5-7, 1988
H. A. ESCHENAUER, ED. (Siegen, Universitaet-Gesamthochschule, Federal Republic of Germany) and G. THIERAUF, ED. (Universitaet Essen-Gesamthochschule, Federal Republic of Germany) Seminar sponsored by the Gesellschaft fuer angewandte Mathematik und Mechanik, Volkswagen Stiftung, Universitaet-Gesamthochschule Siegen, et al. Berlin and New York, Springer-Verlag (Lecture Notes in Engineering. Volume 42), 1989, 375 p. For individual items see A90-39177 to A90-39190.
Copyright

This conference discusses convex approximation strategies in structural optimization, an optimization method applied to the identification of material parameters, mixed elements in optimal design of plates, and the development and application of an optimization procedure for space and aircraft structures. Particular consideration is given to multilevel optimization of large-scale structures in a parallel computing environment, engineering applications of heuristic multilevel optimization methods, integral equation methods in the internal structure optimization, and multipurpose optimization of vibrating Timoshenko shafts. Attention

is also given to entropy-based minimax applications in shape-optimal design, optimal shape design in contact problems, optimal design of viscoplastic structures under dynamic loading, and knowledge acquisition for expert-system-aided structural optimization by means of transformation methods and primal methods. I.S.

A90-39186
DEVELOPMENT AND APPLICATION OF AN OPTIMIZATION PROCEDURE FOR SPACE AND AIRCRAFT STRUCTURES
GUENTER KNEPPE, WOLFGANG HARTZHEIM, and GEORG ZIMMERMANN (MBB GmbH, Munich, Federal Republic of Germany) IN: Discretization methods and structural optimization - Procedures and applications; Proceedings of the GAMM Seminar, Siegen, Federal Republic of Germany, Oct. 5-7, 1988. Berlin and New York, Springer-Verlag, 1989, p. 194-201. refs

The optimization procedure MBB-LAGRANGE allows the optimization of homogeneous isotropic, orthotropic, or anisotropic structures as well as fiber-reinforced materials with respect to weight, static, dynamic, aeroelastic, and manufacturing requirements. Design variables are the sizing and geometric dimensions. The development is focused on three main topics: optimization algorithms, optimization models, and structural analysis with sensitivity analysis. Important for practical applications is the integration into the CAE-environment by the use of standard interfaces. Author

A90-44425
MEMBER FORCES IN RETICULATED STRUCTURES USING THE EQUIVALENT ENERGY PRINCIPLE
J. A. ALDUAIJ (Kuwait University, Safat) IN: International Symposium on Numerical Methods in Engineering, 5th, Lausanne, Switzerland, Sept. 11-15, 1989, Proceedings. Volume 1. Southampton, England and New York/Berlin, Computational Mechanics Publications/Springer-Verlag, 1989, p. 517-524. refs

The application of the macro-element equivalent-energy method developed by Alduaij (1987) to three-dimensional lattices such as large space structures is described. This approach exploits the fact that the elements of reticulated structures are often arranged in repetitive patterns (repeating cells): the repeating cells are replaced by macro elements to construct a reduced-DOF model of the structure. The derivation of the strain-energy formulation, the macro-element displacement vector, the equivalent stiffness parameters, the displacement expansion, and the member forces is outlined, and numerical results for a simple problem are presented in a table. The member forces by the equivalent-energy method are shown to be in 100-percent agreement with the analytical solution. T.K.

A90-44466
PROLOG APPROACH TO SYSTEM RELIABILITY OF SPACE STRUCTURE
YOSHIRO KOHAMA (Nagoya University, Japan) and ATSUNORI MIYAMURA (Meijo University, Nagoya, Japan) IN: International Symposium on Numerical Methods in Engineering, 5th, Lausanne, Switzerland, Sept. 11-15, 1989, Proceedings. Volume 2. Southampton, England and New York/Berlin, Computational Mechanics Publications/Springer-Verlag, 1989, p. 593-598. refs

The system reliability of space truss structures subjected to combined loading is evaluated by means of PROLOG predicates. This backtracking and nondeterministic capability of PROLOG greatly reduces the burden of software development by greatly narrowing the searching space of optimal parameters using heuristic rules. The description of the connectivity in a network system by graph theory contributes to the easy derivation of the failure load of linear systems like space truss structures. The compact expression of the analytical procedure which this provides consists of a sequence of procedural units particularly suitable for description in PROLOG. The failure modes approach is taken for the evaluation of system failure probability of a space truss structure, and the hierarchically structured predicates are developed. S.A.V.

A90-47114#
EFFECTS OF THE EARTH ORBIT ENVIRONMENT ON THIN-WALL BUBBLES
SCOTT THOMAS (Utah State University, Logan) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, July-Aug. 1990, p. 438-445. Research supported by Morton Thiokol, Inc. refs

An evaluation is made of the effects of the LEO environment's thermal loads, high vacuum, ram pressure, and atomic oxygen ablation on thin-wall bubble space structures blown from curable liquids. The low thermal mass and large area of the structures result in a strong coupling to the thermal environment, so that large temperature gradients and variations can be expected, while these are potentially detrimental, they may be enlisted for satellite thermal control. Because the proposed structures possess very small mass/surface area, atmospheric drag will be significant; the drag problem is also associated with atomic oxygen ablation at orbital velocities. O.C.

A90-48321
A SPACECRAFT PROTECTIVE SCREEN MODEL [MODEL' EKRANIROVANNOSTI KOSMICHESKOGO APPARATA]
V. M. SAKHAROV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, July-Aug. 1990, p. 635-638. In Russian. refs

The paper presents an approach to developing a typical screening model applicable to radiation-sensitive spaces of a spacecraft based on general information about the spacecraft mass and size. This approach was formulated on the basis of an analysis of data on matter distribution functions in equipment units and detector screening functions inside the spacecraft. The proposed approach is verified by an analysis of Prognoz-spacecraft screening characteristics. B.J.

A90-49791*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
REDUCING DISTORTION AND INTERNAL FORCES IN TRUSS STRUCTURES BY MEMBER EXCHANGES
WILLIAM H. GREENE (NASA, Langley Research Center, Hampton, VA) and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) AIAA Journal (ISSN 0001-1452), vol. 28, Sept. 1990, p. 1655-1662. Previously announced in STAR as N89-16194. refs
(Contract NAG1-224)

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

A90-50137
ADVANCED JOINT OF 3-D COMPOSITE MATERIALS FOR SPACE STRUCTURE
T. YAMAMOTO (Mitsubishi Heavy Industries, Ltd., Nagoya, Japan) and T. HIROKAWA (Shikishima Canvas, Co., Ltd., Omihachiman, Japan) IN: International SAMPE Symposium and Exhibition, 35th, Anaheim, CA, Apr. 2-5, 1990, Proceedings. Book 1. Covina, CA, Society for the Advancement of Material and Process Engineering, 1990, p. 1069-1078.

Advanced joint of graphite/epoxy composite materials reinforced by three-dimensional fabrics has been designed,

fabricated, and evaluated. The compressive and tensile strengths of the advanced joint were measured, and fabrication cost was evaluated. Materials and fabrication costs were cut down 28 percent and the weight by 16 percent was compared with unidirectional tape laminated composites. Author

A90-50203
DESIGN AND FABRICATION OF HIGH QUALITY GRAPHITE/EPOXY BRAIDED COMPOSITE TUBES FOR SPACE STRUCTURES
ASHOK K. MUNJAL, DONALD F. SPENCER, ERIC W. RAHNENFUEHRER, BARRY E. PICKETT, and PAUL F. MALONEY (Kaman Aerospace Corp., Bloomfield, CT) IN: International SAMPE Symposium and Exhibition, 35th, Anaheim, CA, Apr. 2-5, 1990, Proceedings. Book 2. Covina, CA, Society for the Advancement of Material and Process Engineering, 1990, p. 1954-1967. refs

The truss structure contemplated for the NASA Space Station is presently evaluated as an application for braided graphite fiber-reinforced graphite tube-based strut members, where they would save 20,000 lbs relative to Al alloy tube-based struts and thereby reduce Space Shuttle launch costs during Space Station construction. The struts must meet such critical design requirements as high axial strength and stiffness; damage tolerance, thermal fatigue cycling, thermal dimensional stability, and long term durability over the course of the envisioned 30-year service life of the Station. The superiority of a braided-reinforcement/resin transfer-molded concept over filament winding and tape-rolling has been demonstrated for damage-tolerance applications, due to braiding's resistance to microcracking. O.C.

A90-50462
OPTIMUM DESIGN BASED ON RELIABILITY FOR A COMPOSITE STRUCTURAL SYSTEM
L. YANG and Z. K. MA (Northwestern Polytechnical University, Xian, People's Republic of China) Computers and Structures (ISSN 0045-7949), vol. 36, no. 5, 1990, p. 785-790. refs

An optimum design methodology based on reliability for a composite structural system has been developed. In this method a two-level optimization technique is adopted. In system level optimization the structural total weight is taken as the design objective, and the requirement of system reliability is the constraint; in member level optimization the laminate reliability is taken as the design objective, and keeping the weight or thickness of laminate unvarying is the constraint. The corresponding optimal criteria and iterative formulae are derived. An illustrative example explains that this method is quite efficient and can be applied to large scale composite structures. Author

A90-50469
FINITE ELEMENT BASED OPTIMIZATION OF COMPLEX STRUCTURES ON A CRAY X-MP SUPERCOMPUTER
E. SIKIOTIS (Simpson Gumpertz and Heger, Inc., Arlington, MA), V. SAOUMA (Colorado, University, Boulder), M. LONG (Cray Research, Inc., Mendota Heights, MN), and W. ROGGER (General Dynamics Corp., Fort Worth, TX) Computers and Structures (ISSN 0045-7949), vol. 36, no. 5, 1990, p. 901-911. Research supported by General Dynamics Corp. refs

The development of an interface between the finite element program ABAQUS and the optimization program ADS, on a CRAY X-MP supercomputer, under both the COS and UNICOS operating systems, is reported. The interface not only links the two programs, but also takes advantage of the uncoupled nature of the constraint gradient computations to perform them in parallel. As such, the execution time of large structural optimization problems can be significantly reduced. The interface is used to perform the design optimization of an aircraft canopy frame with respect to its weight. The formulation of the optimization problem for the canopy and its final solution are presented. Finally, and in light of the design experience gained from this effort, recommendations for the structural optimization procedure of large structures are presented. Author

A90-51052
LARGE APERTURE ANTENNA CONCEPTS FOR MILLIMETER WAVE APPLICATIONS
W. GREGORWICH and H. A. MALLIOT (Lockheed Research Laboratories, Palo Alto, CA) IN: 1989 IEEE Aerospace Applications Conference, Breckenridge, CO, Feb. 12-17, 1989, Conference Digest. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, 9 p. refs

A novel approach that could meet the requirements of up to 220-GHz reception in the severe thermal environment of space is described which relies on a combination of the classical wrapped rib and electrostatic membrane technology. The wrapped rib configuration can be employed to support the membrane and its associated controlling electrodes. Once deployed, the membrane contour can be electrostatically reconfigured to correct for thermal distortion and off-axis beam scan (i.e., change from parabolic to spherical). The wrap-rib, electrostatic-membrane reflector is several orders of magnitude lighter than the nondeployed rigid reflectors and does not have an aperture constrained by the 4.4-m diameter of a launch vehicle envelope. A multipolarization and multiband cluster feed array used to achieve electronic scan over the millimeter-wave frequency spectrum is also described. I.E.

A90-51268
COMPUTATION OF AN ACTIVE CONTROL IN FRACTURE MECHANICS USING FINITE ELEMENTS
P. DESTUYNDER (Ecole Centrale des Arts et Manufactures, Chatenay-Malabry; ONERA, Chatillon-sous-Bagneux, France) European Journal of Mechanics, A/Solids (ISSN 0997-7538), vol. 9, no. 2, 1990, p. 133-141. refs

Using a finite element model of a cracked structure under a dynamic loading, a criterion associated with the growth of the crack evolution is developed. The general theory of the control of a distributed system is then used in order to define an optimal control strategy to prevent crack growth. Author

A90-52072
BALLOONING THROUGH SPACE
EUGENE ROSSEL and ANNE HANDBERRY Space (ISSN 0267-954X), vol. 6, Sept.-Oct. 1990, p. 33-35.

Space inflatable vehicles and a number of ideas which can increase the life and reduce the weight, volume, and cost of such vehicles are discussed. Specialized fabrics and films, improved adhesives, more efficient construction methods, new material coatings to control space radiation can provide solutions to the constantly increasing price for launching a space vehicle. Cost, payload weight, and volume have to be balanced against the value of the mission. Inflatables can be very effective in supporting light and flexible photovoltaic solar cell arrays, as well as in antennas for space communications, in mapping and studying the earth from orbit, and in solar concentrators for either power generation or propulsion. After inflation, both antennas and reflectors have to be rigidized, which eliminates the need for constant repressurization. B.P.

A90-52150#
AN INFLATABLE PARABOLIC REFLECTOR ANTENNA - ITS REALISATION AND ELECTRICAL PREDICTIONS
K. VAN 'T KLOOSTER, W. RITS (ESTEC, Noordwijk, Netherlands), E. PAGANA, P. G. MANTICA (Centro Studi e Laboratori Telecomunicazione S.p.A., Turin, Italy), and M. C. BERNASCONI (Contraves AG, Zurich, Switzerland) ESA Journal (ISSN 0379-2285), vol. 14, no. 2, 1990, p. 211-216. Research supported by ESTEC. refs

An inflatable parabolic reflector antenna almost 6 m in diameter

has been realized. It is a scale model (1:3) of the symmetrical reflector that was being considered for the very-long-baseline interferometry satellite Quasat. The geometry of the model has been evaluated with theodolites and the reflector's geometrical data have been used for electrical predictions at 1.6, 5 and 22 GHz. Measured Quasat-feed patterns have been used as a realistic illumination in the antenna electrical predictions. Author

A90-52584
A LOW MASS, SEALING APERTURE DOOR FOR SPACE APPLICATIONS
C. V. GOODALL (Birmingham, University, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Oct. 1990, p. 451-458. Research supported by SERC.
Copyright

This paper describes the aperture door developed for the UK Wide Field Camera on ROSAT. This door is required not only to provide a good seal against the ingress of contamination on the ground but also to provide the main venting path for the sealed volume during the depressurization experienced in the launch phase. This has lead to the development of a lightweight, flexible door with good sealing properties. Author

A90-52698
ORTOSS - THE ORBITAL TORUS SOLAR-SAIL VEHICLE [ORTOSS - ORBITALER TORUS SONNENSEGLER]
DIETER HAYN (Industrieanlagen-Betriebsgesellschaft, Ottobrunn, Federal Republic of Germany) Luft- und Raumfahrt (ISSN 0173-6264), vol. 11, 3rd Quarter, 1990, p. 34-36. In German. refs
Copyright

The design concept, technological feasibility, and proposed mission profile of Ortoss are discussed. Ortoss is conceived as a 50-m-diameter ring-shaped inflatable orbital vehicle of total mass 440 kg, employing an 1800-sq-m primary solar sail and four symmetrically mounted triangular secondary sails for orbital maneuvers and attitude control. The mission scenario calls for Ariane-4 piggyback launch to GTO, transfer to an orbit with perigee 1200 km, deployment and inflation of the Ortoss spacecraft with N2, and hardening of the chemical adhesives in the shell by UV radiation within about 9 h; the solar-sail configuration is designed to permit complex orbital maneuvers and even lunar flights. It is pointed out that ESA already has the basic technologies required for Ortoss, such as inflatable self-hardening space structures (developed for large antenna systems), a fully decentralized spacecraft bus, and a large telescoping mast to suppport the secondary sails. T.K.

N90-20431*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MODEL DEVELOPMENT IN VISCOPLASTIC RATCHETTING
ALAN D. FREED and KEVIN P. WALKER (Engineering Science Software, Inc., Smithfield, RI.) Apr. 1990 32 p
(NASA-TM-102509; E-5311; NAS 1.15:102509) Avail: NTIS HC A03/MF A01 CSCL 20/11

Space Station Freedom's solar dynamic power modules, like all power plants, contain components that are subjected to conditions which favor thermally driven ratchetting. Existing viscoplastic models tend to overpredict ratchetting behavior, because their back stress (the kinematic variable) seems to stick more than it should during unloading. For this reason, a study was undertaken to compare a variety of possible modifications to the evolution equation for back stress. All models considered herein have a hardening vs. dynamic-recovery format. To remove the stickiness of the back stress, a linear dependence on stress rate is introduced into the evolution equation for back stress in a variety of ways. Several favorable models were screened out of the field of candidates by qualitatively determining their relative ability to fit experimentally observed behavior through six numerical experiments. A final selection must be made by quantitatively correlating the proposed models with experimental data, and then seeing which candidate does the best job of predicting observed ratchetting behavior. This is a subject of future work. Author

N90-21080*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NASA CSI SUSPENSION METHODS OVERVIEW
STANLEY E. WOODARD and VICTOR M. COOLEY *In its* NASA/DOD Controls-Structures Interaction Technology 1989 p 317-333 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

New suspension techniques will be necesary for ground testing the flexible spacecraft anticipated in NASA's future space activity. The most complex spacecraft involve nonlinear maneuvering (i.e., large angle slewing) with articulating substructures such as remote manipulating systems. The NASA control-structure interaction (CSI) ground test method team has begun researching and developing methodology to suspend the future class of spacecraft. This overview describes the work completed thus far. The research objective and technical approach will be presented first. Second, will be a suspension device overview followed by an assessment of existing hardware. Two different mechanical zero-spring-rate mechanisms will be compared for optimal performance. Next, will be a description of how existing hardware can be evolved to meet more general suspension requirements. A comparison of suspending articulating structures overhead vs underneath will follow. After a few experimental results from the zero-spring-rate mechanism/air suspension cart will be concluding remarks and future work. Author

N90-21081*# Martin Marietta Aerospace, Denver, CO.
AN AIR-BEARING WEIGHT OFFLOAD SYSTEM FOR GROUND TEST OF HEAVY LSS STRUCTURES
R. B. RICE *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 335-348 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The capability and use of the Gravity Offload Facility (GOF) are discussed. Briefly explained are the: truss and base casting; carriage assembly; carriage weldment; vertical lift axis control; lifting cylinder; payload gimbal; motion base layout; and control processor. B.G.

N90-21087*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
SPACE TRUSS ZERO GRAVITY DYNAMICS
ANDY SWANSON *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 445-457 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The Structural Dynamics Branch of the Air Force Flight Dynamics Laboratory in cooperation with the Reduced Gravity Office of the NASA Lyndon B. Johnson Space Center (JSC) plans to perform zero-gravity dynamic tests of a 12-meter truss structure. This presentation describes the program and presents all results obtained to date. Author

N90-21089*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
CSI TECHNOLOGY VALIDATION ON AN LSS GROUND EXPERIMENT FACILITY
S. J. WANG and D. B. ELDRED *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 475-496 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 14/2

The test bed developed at JPL for experimental evaluation of new technologies for the control of large flexible space structures is described. The experiment consists of a flexible spacecraft dynamic simulator, sensors, actuators, a microcomputer, and an advanced programming environment. The test bed has been operational for over a year, and thus far nine experiments were completed or are currently in progress. Several of these experiments were reported at the 1987 CSI conference, and several recent ones are documented in this paper, including high order adaptive control, non-parametric system identification, and mu-synthesis robust control. An aggressive program of experiments is planned for the forseeable future. Author

N90-21095*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
GLOBAL NONLINEAR OPTIMIZATION OF SPACECRAFT PROTECTIVE STRUCTURES DESIGN
R. A. MOG, J. N. LOVETT, JR. (Alabama Univ., Huntsville.), and S. L. AVANS Jan. 1990 29 p
(NASA-TM-100387; NAS 1.15:100387) Avail: NTIS HC A03/MF A01 CSCL 22/2

The global optimization of protective structural designs for spacecraft subject to hypervelocity meteoroid and space debris impacts is presented. This nonlinear problem is first formulated for weight minimization of the space station core module configuration using the Nysmith impact predictor. Next, the equivalence and uniqueness of local and global optima is shown using properties of convexity. This analysis results in a new feasibility condition for this problem. The solution existence is then shown, followed by a comparison of optimization techniques. Finally, a sensitivity analysis is presented to determine the effects of variations in the systemic parameters on optimal design. The results show that global optimization of this problem is unique and may be achieved by a number of methods, provided the feasibility condition is satisfied. Furthermore, module structural design thicknesses and weight increase with increasing projectile velocity and diameter and decrease with increasing separation between bumper and wall for the Nysmith predictor. Author

N90-21096*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PRELIMINARY DESIGN APPROACH FOR LARGE HIGH PRECISION SEGMENTED REFLECTORS
MARTIN M. MIKULAS, JR., TIMOTHY J. COLLINS, and JOHN M. HEDGEPETH (Astro Aerospace Corp., Carpinteria, CA.) Feb. 1990 51 p
(NASA-TM-102605; NAS 1.15:102605) Avail: NTIS HC A04/MF A01 CSCL 22/2

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

N90-21099*# DRC Consultants, Inc., Flushing, NY.
HEAVILY LOADED JOINTS FOR ASSEMBLING AEROBRAKE SUPPORT TRUSSES
HANNSKARL BANDEL, NILS OLSSON, and BORIS LEVINTOV Mar. 1990 111 p Prepared for Boeing Co., Seattle, WA
(Contract NAS1-18224)
(NASA-CR-181992; NAS 1.26:181992) Avail: NTIS HC A06/MF A01 CSCL 22/2

The major emphasis was to develop erectable joints for large aerobrake support trusses. The truss joints must be able to withstand the large forces experienced by the truss during the aero-pass, as well as be easily assembled and disassembled on orbit by astronauts or robots. Other important design considerations include; strength, stiffness, and allowable error in strut length. Six mechanical joint designs, as well as a seventh joint design, where a high strength epoxy is injected to make the connection rigid, are presented. Author

N90-22043*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
DEFINITION OF LARGE COMPONENTS ASSEMBLED ON-ORBIT AND ROBOT COMPATIBLE MECHANICAL JOINTS
J. WILLIAMSEN, F. THOMAS, J. FINCKENOR, and B. SPIEGEL Apr. 1990 43 p
(NASA-TM-100395; NAS 1.15:100395) Avail: NTIS HC A03/MF A01 CSCL 13/9

One of four major areas of project Pathfinder is in-space assembly and construction. The task of in-space assembly and construction is to develop the requirements and the technology needed to build elements in space. A 120-ft diameter tetrahedral aerobrake truss is identified as the focus element. A heavily loaded mechanical joint is designed to robotically assemble the defined aerobrake element. Also, typical large components such as habitation modules, storage tanks, etc., are defined, and attachment concepts of these components to the tetrahedral truss are developed. Author

N90-22084*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A SOFT ACTUATION SYSTEM FOR SEGMENTED REFLECTOR ARTICULATION AND ISOLATION
MICHAEL L. AGRONIN and LOUISE JANDURA *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 57-73 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 20/6

Segmented reflectors have been proposed for space based applications such as optical communication and large diameter telescopes. An actuation system for mirrors in a space based segmented mirror array was developed as part of NASA's Precision Segmented Reflector program. The actuation system, called the Articulated Panel Module (APM), provides 3 degrees of freedom mirror articulation, gives isolation from structural motion, and simplifies space assembly of the mirrors to the reflector backup truss. A breadboard of the APM was built and is described. Author

N90-22090*# Fairchild Space Co., Germantown, MD.
THE RESUPPLY INTERFACE MECHANISM RMS COMPATIBILITY TEST
STEWART W. JACKSON and FRANK G. GALLO *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 143-156 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 13/9

Spacecraft on-orbit servicing consists of exchanging components such as payloads, orbital replacement units (ORUs), and consumables. To accomplish the exchange of consumables, the receiving vehicle must mate to the supplier vehicle. Mating can be accomplished by a variety of docking procedures. However, these docking schemes are mission dependent and can vary from shuttle bay berthing to autonomous rendezvous and docking. Satisfying the many docking conditions will require use of an innovative docking device. The device must provide fluid, electrical, pneumatic and data transfer between vehicles. Also, the proper stiffness must be obtained and sustained between the vehicles. A device to accomplish this, the resupply interface mechanism (RIM), was developed. The RIM is a unique device because it grasps the mating vehicle, draws the two vehicles together, simultaneously mates all connectors, and rigidizes the mating devices. The NASA-Johnson Manipulator Development Facility was used to study how compatible the RIM is to on orbit docking and berthing. The facility contains a shuttle cargo bay mockup with a remote manipulator system (RMS). This RMS is used to prepare crew members for shuttle missions involving spacecraft berthing operations. The MDF proved to be an excellant system for testing the RIM/RMS compatibility. The elements examined during the RIM JSC test were: RIM gross and fine alignment; berthing method sequence; visual cuing aids; utility connections; and RIM overall performance. The results showed that the RIM is a good device for spacecraft berthing operations. Mating was accomplished during every test run and all test operators (crew members) felt that the RIM is an effective device. The purpose of the JSC RIM test and its results are discussed. Author

N90-22092*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE CONNECTOR SPACE REDUCTION MECHANISM

M. BRUCE MILAM *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 171-186 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 13/9

The Connector Space Reduction Mechanism (CSRM) is a simple device that can reduce the number of electromechanical devices on the Payload Interface Adapter/Station Interface Adapter (PIA/SIA) from 4 to 1. The device uses simplicity to attack the heart of the connector mating problem for large interfaces. The CSRM allows blind mate connector mating with minimal alignment required over short distances. This eliminates potential interface binding problems and connector damage. The CSRM is compatible with G and H connectors and Moog Rotary Shutoff fluid couplings. The CSRM can be used also with less forgiving connectors, as was demonstrated in the lab. The CSRM is NASA-Goddard exclusive design with patent applied for. The CSRM is the correct mechanism for the PIA/SIA interface as well as other similar berthing interfaces. Author

N90-22094*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
ORBITAL MANEUVERING VEHICLE (OMV) THREE-POINT DOCKING LATCH
W. NEILL MYERS, JOHN C. FORBES, and WAYNE L. BARNES *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 207-212 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 13/9

The primary purpose of the OMV is to dock with orbiting payloads and then either transfer them to a different orbit or return them to the Space Shuttle for servicing. Some such missions will involve docking with payloads equipped with a Flight Support System (FSS) type of interface; an example is the Hubble Space Telescope (HST). The design and development of a mechanism to be used for testing this docking concept on the NASA-Marshall test beds is described. The test results to date are also presented. Author

N90-22591 Aerospatiale Aquitaine, Saint-Medard en Jalles (France). Strategic and Space Div.
STUDY AND SIZING OF BONDED JOINTS IN SPACE STRUCTURES
J. P. MAIGRET, M. MARTIN, and M. LABORIE Feb. 1989 10 p In FRENCH; ENGLISH summary
(REPT-892-430-124; ETN-90-96655) Avail: Aerospatiale, 37 blvd de Montmorency, 75781 Paris, CEDEX 16, France

The industrial and technical context of the strategic and space divisions of Aerospatiale in which bonded structures are studied is presented. The numerous dependances between the variables acting on the quality of bonded joints are summarized. The means developed to increase the reliability of structures and reduce the costs and delays of studies are described. Examples are given to indicate the technical level and field of utilization of these means. LICO software, written to help in rapid analysis of the thermomechanical behavior of bonded joints, is presented. ESA

N90-23048*# Air Force Wright Research and Development Center, Wright-Patterson AFB, OH.
IMPLEMENTATION OF GENERALIZED OPTIMALITY CRITERIA IN A MULTIDISCIPLINARY ENVIRONMENT
R. A. CANFIELD and V. B. VENKAYYA *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 563-576 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 12/1

A generalized optimality criterion method consisting of a dual problem solver combined with a compound scaling algorithm was implemented in the multidisciplinary design tool, ASTROS. This method enables, for the first time in a production design tool, the determination of a minimum weight design using thousands of independent structural design variables while simultaneously considering constraints on response quantities in several disciplines. Even for moderately large examples, the computational efficiency is improved significantly relative to the conventional approach. Author

N90-23462*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
GEOMETRIC PROGRAMMING PREDICTION OF DESIGN TRENDS FOR OMV PROTECTIVE STRUCTURES
R. A. MOG (Science Applications International Corp., Huntsville, AL.) and J. R. HORN Washington Jun. 1990 20 p
(NASA-TM-4206; M-632; NAS 1.15:4206) Avail: NTIS HC A03/MF A01 CSCL 22/2

The global optimization trends of protective honeycomb structural designs for spacecraft subject to hypervelocity meteroid and space debris are presented. This nonlinear problem is first formulated for weight minimization of the orbital maneuvering vehicle (OMV) using a generic monomial predictor. Five problem formulations are considered, each dependent on the selection of independent design variables. Each case is optimized by considering the dual geometric programming problem. The dual variables are solved for in terms of the generic estimated exponents of the monomial predictor. The primal variables are then solved for by conversion. Finally, parametric design trends are developed for ranges of the estimated regression parameters. Results specify nonmonotonic relationships for the optimal first and second sheet mass per unit areas in terms of the estimated exponents. Author

N90-24311# MATRA Espace, Paris-Velizy (France).
DDTF IMPROVEMENTS FOR MORE ACCURATE SPACE DOCKING SIMULATION
D. GRIMBERT, P. NOIRAULT, P. MARCHAL, and L. PETITJEAN (Centre National d'Etudes Spatiales, Toulouse, France) *In* ESA, Second European In-Orbit Operations Technology Symposium p 239-244 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Europe's first confrontation with docking in space will require extensive testing to verify design and performances, and to qualify hardware. To evaluate the docking system dynamic capabilities, a unique Docking Dynamics Test Facility (DDTF) was developed which uses a nine degrees of freedom servo-motion system controlled by a real time computer that simulates the docking spacecraft in zero-g environment. The test system is described and its capabilities summarized. Emphasis is made on all the improvements that were incorporated throughout the system implementation: configuration was reworked to extend the performance range, and significant technology limitations were remedied to enhance the motion accuracy. ESA

N90-24312# MATRA Espace, Toulouse (France).
INVESTIGATIONS ON DOCKING AND BERTHING DYNAMICS
T. BLAIS, C. PAUVERT, W. FEHSE, and A. TOBIAS (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Second European In-Orbit Operations Technology Symposium p 245-257 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Some early results on an ESA comparative study are presented. The investigations of the last meters of the final approach of the rendezvous and the mating process proper are focused on. Final approach problems are presented and discussed. The contact phase for docking and the capture, the transfer and final contact phases for berthing are analyzed. Criteria to assess the reliability of the mating procedures are presented, followed by the trade of docking versus berthing. To illustrate results, realistic cases are considered: Hermes acting as the chaser rendezvousing and mating with a large range of target, from the 4 tones Eureca to the 200 tones Space Station Freedom and including the 20 tones Columbus Free Flyer. ESA

N90-24313# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
DOCKING BERTHING SYSTEMS: FUNCTIONS AND SIMULATION
A. TOBIAS, F. VENDITTI, and NEIL CABLE *In its* Second European In-Orbit Operations Technology Symposium p 259-270 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Investigations made in preparation of the Hermes and Columbus program by the European Space Agency concerning docking berthing systems for pressurized passage of crew and goods are presented. The investigations included the identification of requirements derived from the missions, the scenarios and the characteristics of participating spacecraft, the analysis of functions and operations, the identification of suitable implementation concepts and the preparation and improvement of simulation tools for the analysis of contact dynamics. An on-going plan for further investigations, including extensive computer simulations, manufacturing of models and testing in a motion faciltiy, is presented. ESA

N90-24323# G and H Technology, Inc., Paris (France).
INTERCONNECTING DEVICES CONCEIVED FOR IN-ORBIT OPERATIONS
PIETRO SEQUI and JOE LAFFIN (G and H Technology, Inc., Santa Monica, CA.) *In* ESA, Second European In-Orbit Operations Technology Symposium p 341-350 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Recent work to provide a coordinated approach and standard solutions to major interconnection needs of the Space Transportation System (STS) and the Space Station Freedom is discussed. Among the various connector types reviewed, the following are addressed: rectangular, blind-mate, ORU (Orbital Replacement Unit) electrical interface connectors; rack and panel, D-subminiature size connectors for EVA and robotic end-effector manipulation; connectors for 20 KHz power system; circular connectors for IVA/EVA use; cryogenic family of connectors; various in-flight disconnect type connectors. ESA

N90-24464# Sener S.A., Las Arenas (Spain).
CONCEPT DESIGN FOR HERMES DOCKING/BERTHING MECHANISM
J. J. GONZALEZVALLEJO *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 13-18 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Docking between the Hermes Space Station Freedom or the Columbus Free Flying Laboratory is discussed. The docking mechanism which will both allow Hermes to connect with the target spacecraft and dissipate the impact energy is described. The docking mechanism moves the two vessels closer together and provides a pressurized passageway for crew and goods. The different requirements, needs and strategies involved with such a docking mechanism are discussed. The main structural and mechanical assemblies making up the docking mechanism are described. ESA

N90-24467# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
A COMPACT JOINT FOR THE ROTEX MANIPULATOR
K. PRIESETT and W. BECKERT *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 33-38 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The Robotics Technology Experiment (ROTEX), part of the German D2 Spacelab mission scheduled for February 1992 is described. The rotary joints of the small six axis manipulator arm are presented. Because of the limited space inside the spacelab rack, the joints must be very compact and provide high stiffness and strengh. A summary of the major requirements, a description of two joint configurations, and the basic actuator construction are presented. Component performances and the results of sets conducted on a representative prototype joint are presented. ESA

N90-24483# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
MECHANISMS ADD FOLDABILITY TO ROSAT SOLAR PANELS
H. HEIMERDINGER and P. H. PAWLOWSKI (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne, Germany, F.R.) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 143-148 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Modifications carried out on the ROSAT (x ray satellite) solar panels to adapt them to changes made in the launch carrier are outlined. The requirements, design, assembly, and tests of the new solar panel mechanisms are described. Extensive investigation of the influence of humidity on the friction torque of the MoS2 lubricated ball bearings is carried out. It is concluded that 80 percent air humidity raises the torque to 7 Ncm which corresponds to approximately 275 percent of dry torque. Drying the hinge reduced its torque to 3 Ncm or approximately 110 percent dry torque. ESA

N90-24485# Aerospatiale, Cannes (France).
ADELE: DEPLOYMENT HINGE USING WRAPAROUND STRIPS [ADELE: ARTICULATION DE DEPLOIEMENT A LAMES D'ENROULEMENT]
ERIC BLANC *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 155-158 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The ADELE hinge is described. The hinge is designed to comply with the principles of the appendage deployment concept developed by Aerospatiale. The AMEDE (Amelioration des Mecanismes de Deploiement) concept aims to increase simplicity and functional reliability. The concept allows for deployment without synchronization or speed regulation devices. It calls for the use of hinges such as ADELE with low motor or resistive torques. The conceptual and functional principles behind the ADELE hinge are presented along with the hinge's main characteristics. The Amadeus experiment whose implentation on board the MIR orbital station led to inflight validation of the AMEDE concept is described. ESA

N90-24486# Aeritalia S.p.A., Turin (Italy). Space Systems Group.
SOME REMARKS ON A HINGE ACTUATOR FOR LARGE SPOT ANTENNA ARM DEPLOYERS
EDMONDO TURCI *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 159-166 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Soft and hard mounted ball bearing duplex hinge assemblies are analyzed. Assembly of such hinges with redundant provisions taking vibrational and thermal environments into consideration is discussed. A method is proposed for calculating the friction torque on the ball bearings compared to experimental data. The method is applied to the design of a hinge actuator for a large spot antenna arm deployer. The configuration makes use of an articulated quadrilateral link and spring. The rotation of the arm is actuated without any speed damper. ESA

N90-24489# Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.).
ANALYSIS AND TEST INTERACTION IN THE DEVELOPMENT OF A HOLD DOWN AND RELEASE MECHANISM
H.-J. LUHMANN and C.-CH. ETZLER *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 181-186 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The features of the hold-down and release mechanism used to hold the folded synthetic aperture radar antenna onboard the ESA Remote Sensing Satellite (ERS-1) during launch are described. Six hinged clamps are released in orbit via a system of springs

and cables connected to a pyrotechnical device. Improvements in the mechanism introduced during the early design stage on the basis of analytical investigations and component tests are highlighted. Special emphasis is given to the interaction between analysis and test results. Results from subsystem tests are considered. ESA

N90-24490# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Dept. of Mechanical Systems
THE TETRAHEDRAL WEDGE ATTACHMENT MECHANISM
NEIL CABLE *In its* Fourth European Space Mechanisms and Tribology Symposium p 187-194 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

A device providing precision location of an item by the action of a single locking force is described. It also allows for immediate impedance-free removal of the item in a given direction once the locking force is removed. The joint, a simple re-usable mechanism, can be used for temporary or permanent fixation. Advantages of the device for certain applications are discussed. The replacement of equipment in orbit is one area where it could be useful. It is ideally suited as an end-effector in robotics where use can be made of the self-same joints for attachment of payloads to their storage and working positions. ESA

N90-24494# British Aerospace Public Ltd. Co., Stevenage (England).
DESIGN AND DEVELOPMENT OF A SPACECRAFT STABILITY BOOM
J. ADAMS *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 217-222 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The design and development of a low mass deployable spacecraft stability enhancement mechanism is described. The boom is designed to increase the spin axis stability of the Inmarsat 2 spacecraft for low fuel levels with minimum additional mass. The tip mass of the boom can be varied between two fixed limits in six equal increments. Deployment is achieved with an actuation factor in excess of four using spring assisted centrifugal forces. The developed design will deploy with an actuation factor of four with no spin and could therefore be used as an antenna deployment mechanism. ESA

N90-24504# Sener S.A., Las Arenas (Spain).
A SEQUENTIALLY DEPLOYABLE STRUCTURE FOR SPACE APPLICATIONS. PART 2: ENGINEERING MODEL MANUFACTURING AND TESTING
J. RIVACOBA, M. SIERRA, J. UNDA, and M. EIDEN (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 289-294 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The development, manufacture and testing of a deployable Large Truss Structure (LTS) is described. The LTS is designed to meet the requirements for mid-term applications foreseen within the European scenario. A full scale three bay engineering model of the LTS is manufactured and tested. Advantages of the LTS system over other deployable systems are identified. These include automatic sequential deployment with no need for an external power source, very small volume in stowed configuration and good strength and stiffness during deployment. ESA

N90-25320# State Univ. of New York, Albany. Mechanical Systems Lab.
CONTROL STRUCTURE INTERACTION INSTRUMENTATION Final Technical Report, 1 Dec. 1988 - 30 Nov. 1989
DANIEL J. INMAN 1 Mar. 1990 9 p
(Contract AF-AFOSR-0143-89; AF PROJ. 3842)
(AD-A221375; AFOSR-90-0450TR) Avail: NTIS HC A02/MF A01 CSCL 13/11

This instrumentation award funded the purchase of a strain gauge instrumentation system, piezoelectric actuator system, a pneumatic thruster control system and a digital AD/DA controller system (Systolic System, Inc., Optima 3 nonlinear robotics controller) for use in experiments in identification and control of flexible structures modeled by partial differential equations. This equipment, combined with existing vibration suppression, slewing control and testing facilities provides a unique identification and control facility for flexible structures. The piezoelectric devices combined with existing electric motors, proof mass actuators and accelerometers provide an excellent facility for examining the theory related to active structures. In particular, experiments have been designed and initial testing begun on vibration suppression during slewing control of an active truss. GRA

N90-26058# Aeritalia S.p.A., Turin (Italy). Space Systems Group.
LONG CYCLE PRESSURIZED LOGISTICS MODULE: AN ITALIAN CONTRIBUTION TO THE SPACE STATION FREEDOM LOGISTICS SCENARIO
ERNESTO VALLERANI, LUCIANO BASILE, and GIOVANNI RUM (Italian Space Agency, Rome.) 1989 11 p Presented at 40th IAF Congress, Malaga, Spain, 7-13 Oct. 1989 Previously announced in IAA as A90-13299
(IAF-89-083; ETN-90-97278) Avail: NTIS HC A03/MF A01

The candidate solution for the presence of the Long Cycle Pressurized Logistics Module (LCPLM) within the Freedom Station scenario is presented. It offers advantages for logistics operations management. The LCPLM can be considered user friendly for all the pressurized elements of the Freedom Station and allows use of temporary storage space and increases work space combined with the ability to cycle payloads. Commonality with other Freedom Station pressurized elements reduce the cost and risks of the LCPLM design/development. The need to organize the Freedom Station logistics scenario and to minimize the up/down load for payload maintenance/servicing is evident. The LCPLM represents a suitable means of dealing with these critical areas. ESA

N90-26061*# Astro Aerospace Corp., Carpinteria, CA.
STRUCTURES FOR REMOTELY DEPLOYABLE PRECISION ANTENNAS Final Report
JOHN M. HEDGEPETH 16 Jan. 1989 55 p
(Contract NAS1-18567)
(NASA-CR-182065; NAS 1.26:182065; AAC-TN-1154) Avail: NTIS HC A04/MF A01 CSCL 22/2

There is a need for completely deployable large antenna reflectors capable of efficiently handling millimeter-wave electromagnetic radiation. The structural concepts and technologies that are appropriate to fully automated deployment of dish-type antennas with solid reflector surfaces were studied. First, the structural requirements are discussed. Then, existing concepts for fully deployable antennas are described and assessed relative to the requirements. Finally, several analyses are presented that evaluate the effects of beam steering and segmented reflector design on the accuracy of the antenna. Author

N90-26858*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
HYPERVELOCITY IMPACT SHIELD Patent Application
BURTON G. COUR-PALAIS, inventor (to NASA) and JEANNE LEE CREWS, inventor (to NASA) 30 Apr. 1990 24 p
(NASA-CASE-MSC-21420-1; NAS 1.71:MSC-21420-1; US-PATENT-APPL-SN-516573) Avail: NTIS HC A03/MF A01 CSCL 22/2

A hypervelocity impact shield and method for protecting a wall structure, such as a spacecraft wall, from impact with particles of debris having densities of about 2.7 g/cu cm and impact velocities up to 16 km/s are disclosed. The shield comprises a stack of ultra thin sheets of impactor disrupting material supported and arranged by support means in spaced relationship to one another and mounted to cover the wall in a position for intercepting the particles. The sheets are of a number and spacing such that are impacting particle and the resulting particulates of the impacting particle and sheet material are successively impact-shocked to a thermal state of total melt and/or vaporization to a degree as precludes perforation of the wall. The ratio of individual sheet

thickness to the theoretical diameter of particles of debris which may be of spherical form is in the range of 0.03 to 0.05. The spacing between adjacent sheets is such that the debris cloud plume of liquid and vapor resulting from an impacting particle penetrating a sheet does not puncture the next adjacent sheet prior to the arrival thereat of fragment particulates of sheet material and the debris particle produced by a previous impact. NASA

N90-26859*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
OVERCENTER COLLET SPACE STATION TRUSS FASTENER Patent Application
PHILIP L. SHERIDAN, inventor (to NASA) 30 Apr. 1990 18 p
(NASA-CASE-MSC-21504-1; NAS 1.71:MSC-21504-1; US-PATENT-APPL-SN-516856) Avail: NTIS HC A03/MF A01 CSCL 22/2

A quick-connect fastener is arranged with a tubular body that is arranged to be engaged against the exterior surface of a hollow attachment fitting and coincidentally aligned with an opening in the fitting. A collet having normally-contracted fingers with outwardly-enlarged ends is operatively arranged in the body to be moved forwardly by an expander member mounted in the tubular body for advancing the collet fingers through the opening in the attachment fitting. Biasing means are arranged between the expander member and a toggle linkage in the tubular body which is selectively operated to urge the expander member forwardly into engagement with the collet fingers with an initial biasing force to advance their forward portions through the body opening and then expand them outwardly. The biasing means also provide a subsequent biasing force for retaining the collet members in their expanded positions once their enlarged forward end portions are on the opposite side of the body. NASA

N90-27116*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUSPENSION MECHANISM AND METHOD Patent Application
STANLEY E. WOODARD, inventor (to NASA) and VICTOR M. COOLEY, inventor (to NASA) 31 Jan. 1990 10 p
(NASA-CASE-LAR-14142-1; NAS 1.71:LAR-14142-1; US-PATENT-APPL-SN-473030) Avail: NTIS HC A02/MF A01 CSCL 13/9

The invention is a suspension mechanism and method for suspending a flexible test structure T(sub s) subjected to large horizontal translational and vibratory motions. A zero-spring rate mechanism between air cushions A-1 and A-2 established by air bearings support an end of the test structure T(sub s) on a flat surface of a table permitting up to six degrees of freedom of motion of the suspended test structure T(sub s) substantially unconstrained by the suspension mechanism. NASA

N90-27776*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ENGINEERING TEST RESULTS FOR THE MOOG SINGLE LINE DISCONNECT
SCOTT E. GLUBKE Washington Mar. 1990 37 p
(NASA-TM-100755; REPT-90B00079; NAS 1.15:100755) Avail: NTIS HC A03/MF A01 CSCL 22/2

New and innovative types of disconnects will be required to service, resupply, and maintain future spacecraft subsystems. Efficiently maintaining orbiting scientific instruments, spacecraft support systems, and a manned space station over a long period of time will require the periodic replenishment of consumables and the replacement of components. To accomplish these tasks, the fluid disconnect must be designed to allow the connection and separation of fluid lines and components with minimal hazard to crew and equipment. The capability to simply connect a refueling line or to easily replace a failed component greatly extends the life of a space based fluid system. A test program was initiated to evaluate the Moog Single Line Disconnect. The objective of the test program was to demonstrate the operational characteristics of the disconnect and to verify compliance with current safety regulations. The results of the program are summarized in the referenced document. Author

N90-28061# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Structures and Mechanisms Div.
GUIDELINES FOR THREADED FASTENERS
Dec. 1989 488 p Prepared in cooperation with British Aerospace Public Ltd., Bristol, England
(ESA-PSS-03-208-ISSUE-1; ISSN-0379-4059; ETN-90-96987) Avail: NTIS HC A21/MF A03

The aim of the handbook is to assist the structural design engineer by presenting him in a single document with all the information relevant to the use of threaded fasteners in jointed spacecraft components. Bolted connections represent critical areas within a structure. The need to provide a standardized methodology is addressed. The range of joint geometries covered structural applications, and the range of fastener types and materials for which data is represented reflects emphasis on space structures and related hardware. ESA

N90-28598*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRANSFORMATIONAL PART-COUNT IN LAYERED OCTAHEDRAL-TETRAHEDRAL TRUSS CONFIGURATIONS
HARESH LALVANI (Joint Inst. for Advancement of Flight Sciences, Hampton, VA.) Aug. 1990 20 p
(NASA-TM-102635; NAS 1.15:102635) Avail: NTIS HC A03/MF A01 CSCL 22/2

The number of component part (nodes, struts and panels) termed part count, is an important factor in the design, manufacture, and assembly of modular space structures. Part count expressions are presented for a variety of profiles derived from the layered octahedral-tetrahedral truss configuration. Referred to as the tetrahedral truss in the NASA projects, this specific geometry has been used in several missions. The general expressions presented here transforms to others as one profile changes to another. Such transformational part count relations provide a measure of flexibility and generality, and may be useful when dealing with a wider range of geometric configurations. Author

N90-28879*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
MINIMUM WEIGHT DESIGN OF A LEAF SPRING TAPERED IN THICKNESS AND WIDTH FOR THE HUBBLE SPACE TELESCOPE-SPACE SUPPORT EQUIPMENT
P. I. RODRIGUEZ Washington Sep. 1990 41 p
(NASA-TM-4233; NAS 1.15:4233) Avail: NTIS HC A03/MF A01 CSCL 20/11

A linear elastic solution to the problem of minimum weight design of cantilever beams with variable width and depth is presented. The solution shown is for the specific application of the Hubble Space Telescope maintenance mission hardware. During these maintenance missions, delicate instruments must be isolated from the potentially damaging vibration environment of the space shuttle cargo bay during the ascent and descent phases. The leaf springs are designed to maintain the isolation system natural frequency at a level where load transmission to the instruments in a minimum. Nonlinear programming is used for the optimization process. The weight of the beams is the objective function with the deflection and allowable bending stress as the constraint equations. The design variables are the width and depth of the beams at both the free and the fixed ends. Author

N90-29423*# Boeing Aerospace Co., Seattle, WA. Engineering Technology Organization.
NONLINEAR MODELING OF JOINT DOMINATED STRUCTURES Final Report
J. M. CHAPMAN Washington NASA Sep. 1990 213 p
(Contract NAS1-18864)
(NASA-CR-4324; NAS 1.26:4324) Avail: NTIS HC A10/MF A02 CSCL 22/2

The development and verification of an accurate structural model of the nonlinear joint-dominated NASA Langley Mini-Mast truss are described. The approach is to characterize the structural behavior of the Mini-Mast joints and struts using a test configuration

that can directly measure the struts' overall stiffness and damping properties, incorporate this data into the structural model using the residual force technique, and then compare the predicted response with empirical data taken by NASA/LaRC during the modal survey tests of the Mini-Mast. A new testing technique, referred to as 'link' testing, was developed and used to test prototype struts of the Mini-Masts. Appreciable nonlinearities including the free-play and hysteresis were demonstrated. Since static and dynamic tests performed on the Mini-Mast also exhibited behavior consistent with joints having free-play and hysteresis, nonlinear models of the Mini-Mast were constructed and analyzed. The Residual Force Technique was used to analyze the nonlinear model of the Mini-Mast having joint free-play and hysteresis.
Author

N90-29424*# Dynamic Engineering, Inc., Newport News, VA.
SUSPENSION SYSTEMS FOR GROUND TESTING LARGE SPACE STRUCTURES Final Report
RONALD R. GOLD, INGER P. FRIEDMAN, WILMER H. REED, III, and W. L. HALLAUER (Virginia Polytechnic Inst. and State Univ., Blacksburg.) Washington NASA Oct. 1990 112 p
(Contract NAS1-18798)
(NASA-CR-4325; NAS 1.26:4325; D-377) Avail: NTIS HC A06/MF A01 CSCL 22/2

A research program is documented for the development of improved suspension techniques for ground vibration testing of large, flexible space structures. The suspension system must support the weight of the structure and simultaneously allow simulation of the unconstrained rigid-body movement as in the space environment. Exploratory analytical and experimental studies were conducted for suspension systems designed to provide minimum vertical, horizontal, and rotational degrees of freedom. The effects of active feedback control added to the passive system were also investigated. An experimental suspension apparatus was designed, fabricated, and tested. This test apparatus included a zero spring rate mechanism (ZSRM) designed to support a range of weights from 50 to 300 lbs and provide vertical suspension mode frequencies less than 0.1 Hz. The lateral suspension consisted of a pendulum suspended from a moving cart (linear bearing) which served to increase the effective length of the pendulum. The torsion suspension concept involved dual pendulum cables attached from above to a pivoting support (bicycle wheel). A simple test structure having variable weight and stiffness characteristics was used to simulate the vibration characteristics of a large space structure. The suspension hardware for the individual degrees of freedom was analyzed and tested separately and then combined to achieve a 3 degree of freedom suspension system. Results from the exploratory studies should provide useful guidelines for the development of future suspension systems for ground vibration testing of large space structures. Author

07

VIBRATION & DYNAMIC CONTROLS

Design and analysis of structural dynamics. Includes descriptions of analytical techniques and computer codes, trade studies, requirements and descriptions of orbit maintenance systems, rigid and flexible body attitudesensing systems and controls.

A90-32468*# California Univ., Los Angeles.
CONTROL AUGMENTED STRUCTURAL SYNTHESIS WITH TRANSIENT RESPONSE CONSTRAINTS
R. A. MANNING and L. A. SCHMIT (California, University, Los Angeles) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1, p. 194-204) AIAA Journal (ISSN 0001-1452), vol. 28, May 1990, p. 883-891. Previously cited in issue 14, p. 2166, Accession no. A87-33573. refs
(Contract NSG-1490)
Copyright

A90-32473#
EXPERIMENTAL STUDY OF CHAOTIC VIBRATIONS IN A PIN-JOINTED SPACE TRUSS STRUCTURE
F. C. MOON and G. X. LI (Cornell University, Ithaca, NY) AIAA Journal (ISSN 0001-1452), vol. 28, May 1990, p. 915-921. Research supported by USAF. refs
Copyright

In this paper, the dynamics of a pin-jointed space truss structure is studied. Experimental results demonstrated that the response of the truss, under sinusoidal excitation, exhibited broad-band, chaotic-like vibrations. It is believed that very small gaps in the joints create nonlinearities that lead to the chaos. When a tension cable was added to place the structure under compressive loads, the level of chaos was reduced. Numerical simulation of the truss dynamics including small gaps in the truss joints also showed similar chaotic behavior. Author

A90-32859
AIR FORCE ASTRONAUTICS LABORATORY SMART STRUCTURES AND SKINS PROGRAM OVERVIEW
DOUGLAS W. DEHART (USAF, Astronautics Laboratory, Edwards AFB, CA) IN: Fiber optic smart structures and skins II; Proceedings of the Meeting, Boston, MA, Sept. 5-8, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 11-18.
Copyright

The smart structure/skins systems envisioned by the USAF Astronautics Laboratory for such future spacecraft as the Space Based Radar and Space Based Laser will employ embedded sensors, actuators, and microprocessors to sense, evaluate, and damp, all natural and spurious vibrations; the health-monitoring system also figured by the smart structure will sense any deterioration of structural soundness. Fiber-optics constitutes the sensor technology of choice, due to its lightness, immunity to EM interference, and easy incorporation into composite materials.
O.C.

A90-32862
STRUCTURAL CONSIDERATIONS FOR SENSOR SELECTION AND PLACEMENT
A. S. BICOS and J. J. TRACY (McDonnell Douglas Space Systems Co., Huntington Beach, CA) IN: Fiber optic smart structures and skins II; Proceedings of the Meeting, Boston, MA, Sept. 5-8, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 70-76. refs
Copyright

Over the last few years, a significant amount of work has been conducted on developing fiber-optic sensors that can be used to monitor the performance of structures. At times, the development of sensors seems to have been done without consideration of the specific types of structures for which they are being developed. Typical aerospace structures are composed of strut, beam, plate, and shell components, which can be made of many different kinds of materials. Depending on the types of components used in a structure, the materials used, the expected operating conditions, and expected in-service damage, the requirements for the sensors can vary drastically. Author

A90-32887
PASSIVE AND ACTIVE VIBRATION SUPPRESSION OF LARGE SPACE STRUCTURES
A. S. BICOS, Y. H. PAK, C. L. TRENT, and R. J. UITTO (McDonnell Douglas Space Systems Co., Huntington Beach, CA) IN: Fiber optic smart structures and skins II; Proceedings of the Meeting, Boston, MA, Sept. 5-8, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 359-371. refs
Copyright

Ways to satisfy the settling time requirement of a typical large space structure (LSS) are considered. An attempt is made to determine the amount of vibration suppression or damping

necessary to meet the stringent settling time requirement of a typical LSS and then to design, analyze, and experimentally verify an active control system to meet the damping requirement. A study is also made of the effect of passive damping on the active damping system of an LSS. Author

A90-32888* Virginia Polytechnic Inst. and State Univ., Blacksburg.
MODAL DOMAIN FIBER OPTIC SENSOR FOR CLOSED LOOP VIBRATION CONTROL OF A FLEXIBLE BEAM
D. COX, D. THOMAS, K. REICHARD, D. LINDNER, and R. O. CLAUS (Virginia Polytechnic Institute and State University, Blacksburg) IN: Fiber optic smart structures and skins II; Proceedings of the Meeting, Boston, MA, Sept. 5-8, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 372-383. refs
(Contract NAG1-895; N00014-88-K-0721)
Copyright

The use of a modal domain sensor in a vibration control experiment is described. An optical fiber is bonded along the length of a flexible beam. A control signal derived from the output of the modal domain sensor is used to suppress vibrations induced in the beam. A distributed effect model for the modal domain sensor is developed and combined with models of the beam and actuator dynamics to produce a system suitable for control design. Author

A90-32891
FIBER OPTIC SHAPE SENSING FOR FLEXIBLE STRUCTURES
M. S. MILLER, K. A. MURPHY, A. M. VENGSARKAR, and R. O. CLAUS (Virginia Polytechnic Institute and State University, Blacksburg) IN: Fiber optic smart structures and skins II; Proceedings of the Meeting, Boston, MA, Sept. 5-8, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1990, p. 399-404. Research supported by Virginia Center for Innovative Technology. refs
Copyright

An optical-time-domain-reflectometry based shape sensor is presented. Fibers with air-gap splices at certain known positions are attached to the exterior of a flexible structure. The strain induced in each fiber section due to the bending of the structure is detected by the Optical Time Domain Reflectometer (OTDR) as shifts in the pulses reflected at the splices. The approximate shape of the structure is then determined using the strain information from each fiber section. Experimental results for simple shapes are given, and future directions for determining complex shapes are discussed. Author

A90-33051#
STABILITY OF DYNAMICAL SYSTEMS - AN OVERVIEW
S. PRADEEP and S. K. SHRIVASTAVA (Indian Institute of Science, Bangalore, India) (Space dynamics and celestial mechanics; Proceedings of the International Workshop, Delhi, India, Nov. 14-16, 1985, p. 87-101) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, May-June 1990, p. 385-393. Previously cited in issue 15, p. 2383, Accession no. A87-37135. refs
Copyright

A90-33056*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STRUCTURAL TAILORING AND FEEDBACK CONTROL SYNTHESIS - AN INTERDISCIPLINARY APPROACH
W. KEITH BELVIN (NASA, Langley Research Center, Hampton, VA) and K. C. PARK (Colorado, University, Boulder) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1, p. 1-8) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, May-June 1990, p. 424-429. Previously cited in issue 12, p. 1935, Accession no. A88-32177. refs
(Contract F49620-87-C-0074)
Copyright

A90-33070#
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) (Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987, p. 291-311) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, May-June 1990, p. 545-554. Previously cited in issue 02, p. 203, Accession no. A89-11670. refs
(Contract F33615-86-C-3212)
Copyright

A90-33071*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THREE PARALLEL COMPUTATION METHODS FOR STRUCTURAL VIBRATION ANALYSIS
OLAF STORAASLI, SUSAN BOSTIC (NASA, Langley Research Center, Hampton, VA), MERRELL PATRICK (Duke University, Durham, NC), UMESH MAHAJAN, and SHING MA (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3, p. 1401-1410) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, May-June 1990, p. 555-561. Previously cited in issue 12, p. 1909, Accession no. A88-32323. refs
Copyright

A90-33156
ENERGY OPTIMAL DEGREE OF CONTROLLABILITY AND OBSERVABILITY FOR REGULATOR AND MANEUVER PROBLEMS
RICHARD W. LONGMAN (U.S. Navy, Naval Research Laboratory, Washington, DC; Columbia University, New York) and KYLE T. ALFRIEND (General Research Corp., Arlington, VA) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 38, Jan.-Mar. 1990, p. 87-103. Research supported by the U.S. Navy. refs
Copyright

Motivated by the problem of shape control of large flexible spacecraft, concepts of the degree of controllability (DOC) have been developed for purposes of guiding the control system designer in choosing actuator locations. The concepts depend on the control objective, such as regulation about an equilibrium point, or tracking during a maneuver. A basic framework for the generation of concepts of the DOC and of the degree of observability is used to develop definitions for each based on energy measures. An algorithm is developed to easily determine these quantities for regulator problems, as well as for maneuvering problems (in which the basic objective is to get to a new state) and problems requiring accurate tracking of a maneuver trajectory. The results can serve as a guide for both sensor and actuator location. Author

A90-33157
ORTHOTROPIC PLATES WITH SHEAR ROTATION SUBJECT TO OPTIMAL OPEN-CLOSED LOOP CONTROL
J. C. BRUCH, JR., J. M. SLOSS (California, University, Santa Barbara), S. ADALI (Natal, University, Durban, Republic of South Africa), and I. S. SADEK (North Carolina, University, Wilmington) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 38, Jan.-Mar. 1990, p. 105-119. refs
Copyright

An approach is presented to actively damp excessive vibrations of structural systems governed by systems of partial differential equations. The technique involves the application of a combined open-closed control mechanism to a shear deformable or orthotropic plate undergoing elastic vibrations. The closed-loop control mechanism is assumed to be proportional to displacement and shear rotations. Two performance indices are introduced and minimized with respect to the open-loop control functions and the feedback parameters. The minimization is carried out subject to a constraint on the amount of feedback force that can be spent in the control process. An explicit solution for the open-loop problem is obtained and numerical results are given to indicate the effectiveness of the proposed mechanism. Author

A90-33260
CLOSED-FORM GRAMMIANS AND MODEL REDUCTION FOR FLEXIBLE SPACE STRUCTURES
TREVOR WILLIAMS (Cincinnati, University, OH) IEEE Transactions on Automatic Control (ISSN 0018-9286), vol. 35, March 1990, p. 379-382. refs
Copyright

The author derives analytical expressions for the Grammians of a model given in modal coordinates for the dynamics of a flexible space structure (FSS). These expressions are then used as the basis for a new algorithm to compute a dominant reduced-order model for such a system in an efficient manner. The resulting reduced-order model is obtained directly rather than by truncating a balanced model of the entire system, thus giving rise to significant efficiency gains for the typical FSS case where the reduced-order model is of very much lower order than the original system. I.E.

A90-33392#
ON RIGHT HAND SIDE MODIFICATIONS FOR THE SOLUTION OF INVERSE PROBLEMS IN STRUCTURAL DYNAMIC RESPONSE
H. BAIER, A. RAUSCH, and B. CAESAR (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) IN: European Forum on Aeroelasticity and Structural Dynamics, Aachen, Federal Republic of Germany, Apr. 17-19, 1989, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1989, p. 441-445. refs

A typical problem statement covering design optimization problems in spacecraft structures is considered. Manipulations of the left-hand side of the systems equations, or model sensitivity analysis are briefly summarized, and then right-hand side manipulations are analyzed. A delta right-hand side or control force vector influencing the response in a desired way is introduced. In parallel or subsequent to this step, the optimal control force vector is then related to changes in the design of the left-hand side of the systems equations. Technical applications for the above control force approach are outlined including design of discrete interface structures, discrete design elements of large reflectors critical to dynamic responses, and model parameters update for nonlinear design elements. V.T.

A90-33407#
NEW APPROACHES FOR ACTIVELY CONTROLLING LARGE FLEXIBLE SPACE STRUCTURES
J. MELCHER and E. BREITBACH (DLR, Institut fuer Aeroelastik, Goettingen, Federal Republic of Germany) IN: European Forum on Aeroelasticity and Structural Dynamics, Aachen, Federal Republic of Germany, Apr. 17-19, 1989, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1989, p. 577-583. refs

The paper describes a new active control technology based on structural members which function multiply as structural elements as well as actuators and as sensors and which need adaptive controllers processing digital signals. A new program called ARES (Actively REactiing flexible Structures) is presented which is an attempt to develop systems capable of changing their characteristics in orbit in order to fulfill essential operational requirements. The two main objectives of ARES are shape control (alignment precision, surface accuracy) and vibration suppression by using the advantages of new materials, e.g. piezopolymers or memory alloys. Author

A90-34038* Duke Univ., Durham, NC.
INVERSE DYNAMICS OF ADAPTIVE STRUCTURES USED AS SPACE CRANES
S. K. DAS, S. UTKU (Duke University, Durham, NC), and B. K. WADA (JPL, Pasadena, CA) Journal of Intelligent Material Systems and Structures (ISSN 1045-389X), vol. 1, Jan. 1990, p. 50-75. refs
Copyright

As a precursor to the real-time control of fast moving adaptive structures used as space cranes, a formulation is given for the flexibility induced motion relative to the nominal motion (i.e., the motion that assumes no flexibility) and for obtaining the open loop time varying driving forces. An algorithm is proposed for the computation of the relative motion and driving forces. The governing equations are given in matrix form with explicit functional dependencies. A simulator is developed to implement the algorithm on a digital computer. In the formulations, the distributed mass of the crane is lumped by two schemes, vz., 'trapezoidal' lumping and 'Simpson's rule' lumping. The effects of the mass lumping schemes are shown by simulator runs. Author

A90-34105
DISTRIBUTED PIEZOELECTRIC SENSOR/ACTUATOR DESIGN FOR DYNAMIC MEASUREMENT/CONTROL OF DISTRIBUTED PARAMETER SYSTEMS - A PIEZOELECTRIC FINITE ELEMENT APPROACH
H. S. TZOU and C. I. TSENG (Kentucky, University, Lexington) Journal of Sound and Vibration (ISSN 0022-460X), vol. 138, April 8, 1990, p. 17-34. Research supported by the University of Kentucky. refs
(Contract NSF RII-86-10671)
Copyright

Advanced structures with integrated self-monitoring and control capabilities are becoming very important due to the rapid development of 'intelligent' mechanical systems and space structures. Since the structures are distributed and flexible in nature, distributed dynamic measurement and active vibration suppression are of importance to their performance. In this paper, a new structure (shell or plate) containing an integrated distributed piezoelectric sensor and actuator is proposed. The distributed piezoelectric sensing layer monitors the structural oscillation due to the direct piezoelectric effect and the distributed actuator layer suppresses the oscillation via the converse piezoelectric effect. For modeling flexibility and versatility, a new piezoelectric finite element with internal degrees of freedom is derived. The performance of a plate model with distributed piezoelectric sensor/actuator is evaluated. Applications to distributed dynamic measurement and control of the advanced structures are also demonstrated. Author

A90-34957
CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES
SURESH M. JOSHI Berlin and New York, Springer-Verlag (Lecture Notes in Control and Information Sciences. Volume 131), 1989, 207 p. refs
Copyright

Techniques for the dynamic analysis and control of large flexible space structures are developed analytically. The basic mathematical modeling methods are introduced; a class of dissipative controllers is defined; the robustness properties of these controllers are explored; and an annular momentum-control device is described. Also considered are time-domain and multivariable frequency-domain LQG-type controllers, the effects of actuator nonlinearities, parameter-identifiability studies using Cramer-Rao lower bounds, and an optimal-control approach to the maneuvering problem. T.K.

A90-35350
THIN-WALLED SPACE FRAME ANALYSIS WITH GEOMETRIC AND FLEXIBLE CONNECTION NONLINEARITIES
G. E. BLANDFORD (Kentucky, University, Lexington) Computers and Structures (ISSN 0045-7949), vol. 35, no. 5, 1990, p. 609-617. Research supported by NSF. refs
Copyright

The effect of nonlinear flexible connection behavior on the response of space frames composed of doubly symmetric thin-walled sections including warping deformation and first-order geometric nonlinearity (beam-column and P-delta effects) is considered. The nonlinear flexural connection behavior is modeled using a Ramberg-Osgood moment-rotation relationship. Partial torsion and warping torsion resistance is assumed to respond elastically. Numerical results are presented to examine space frame

behavior, which includes both flexibile connection and first-order geometric nonlinear behaviors. Author

A90-35862* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADAPTIVE STRUCTURES
B. K. WADA, J. L. FANSON (JPL, Pasadena, CA), and E. F. CRAWLEY (MIT, Cambridge, MA) Journal of Intelligent Material Systems and Structures (ISSN 1045-389X), vol. 1, April 1990, p. 157-174. refs
Copyright

Current research in the field of advanced adaptive structures for space applications is reviewed. A classification of adaptive structures is proposed whereby such structures are subdivided into adaptive, sensory, controlled, active, and intelligent structures. The definition and properties of each type of adaptive structures are presented, and methods of structure control are discussed. V.L.

A90-35864
ACTIVE VIBRATION CONTROL USING NITINOL AND PIEZOELECTRIC CERAMICS
ROY IKEGAMI, DAVID G. WILSON, JOHN R. ANDERSON, and GERALD J. JULIEN (Boeing Aerospace and Electronics, Seattle, WA) Journal of Intelligent Material Systems and Structures (ISSN 1045-389X), vol. 1, April 1990, p. 189-206. refs
Copyright

The results of a study to investigate the use of NiTiNOL shape memory metals as the sensor and actuator components of active vibration suppression systems are presented. Two different test set-ups consisting of aluminum cantilever beams with NiTiNOL wires fastened along both sides were developed. The test article for the first set-up was a very flexible, low frequency beam which utilized NiTiNOL wires for both sensing and actuation. The test article for the second set-up was a much stiffer, high frequency beam which utilized NiTiNOL wires for sensing and piezoelectric ceramics for actuation. The settling times of both beams were significantly reduced through the use of the NiTiNOL wire sensors and actuators. Analytical simulations were developed which correlated well with the experimental results. Author

A90-36277#
HIGH-QUALITY APPROXIMATION OF EIGENVALUES IN STRUCTURAL OPTIMIZATION
R. A. CANFIELD (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) AIAA Journal (ISSN 0001-1452), vol. 28, June 1990, p. 1116-1122. refs

A new function for approximating natural frequency constraints during structural optimization is presented. Modern procedures for optimizing a structure typically solve a sequence of approximate subproblems as a means of efficiently finding the solution to the full-design problem. The subproblem is constructed by approximating the response quantities with a first-order Taylor series approximation to the actual functions, using appropriate intermediate design varibles. The nonlinearity of frequency constraint functions has historically required the imposition of strict move limits or the use of a second-order Taylor series approximation. The Rayleigh quotient approximation (RQA) presented here increases the quality of the approximate frequency constraint by approximating the modal strain and kinetic energies instead of the frequency eigenvalue itself. Numerical examples demonstrate that the RQA achieves fast and stable convergence with generous move limits. Author

A90-36278#
SUBMATRIX APPROACH TO STIFFNESS MATRIX CORRECTION USING MODAL TEST DATA
TAE W. LIM (Planning Research Corp., Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 28, June 1990, p. 1123-1130. refs
Copyright

An efficient method for stiffness matrix correction to match modal testing data is presented. The correction is performed while preserving the connectivity of the stiffness matrix and the consistency between the stiffness matrix and the corresponding physical configuration of the structure. Significant reduction of unknown parameters is achieved by grouping the elements of the same stiffness characteristics and representing them as a multiplication of a scaling factor and a submatrix. The correction of the stiffness matrix is performed by adjusting the scaling factors. A concise formulation to identify the scaling factors is found by utilizing a least squares solution. The stiffness matrix identified by this formulation produces the measured mode data accurately. The theoretical development along with a numerical example is presented to illustrate the general procedure and to demonstrate the capability of the method. Author

A90-37651
VIBRATIONAL CHARACTERISTICS OF ASSEMBLIES OF GRAPHITE-REINFORCED POLYETHERSULPHONE TUBES
M. O'NEILL and L. HOLLAWAY (Surrey, University, Guildford, England) Composites (ISSN 0010-4361), vol. 21, Jan. 1990, p. 13-21. Research supported by SERC and Ministry of Defence. refs
Copyright

As part of an investigation into the suitability of graphite fiber-reinforced polyethersulphone as candidate material for terrestrial mobile communication networks, skeletal components have been tested in free-free modal analysis using both experimental and analysis techniques. The results are used to assess the level of agreement that can be obtained from an isotropic approximation for describing the vibrational behavior of composite materials. It is found that the damping of the composite material is exceptionally low and that various types of joints used have not contributed to the damping in the structure. Author

A90-38360* Catholic Univ. of America, Washington, DC.
EXPERIMENTAL IMPLEMENTATION OF THE MODIFIED INDEPENDENT MODAL SPACE CONTROL METHOD
A. BAZ and S. POH (Catholic University of America, Washington, DC) Journal of Sound and Vibration (ISSN 0022-460X), vol. 139, May 22, 1990, p. 133-149. refs
(Contract NAG5-749)
Copyright

An experimental realization of a modified independent modal space control (MIMSC) method to control the vibration of a flexible cantilevered beam is presented. In its operation the method relies on the use of one piezoelectric actuator to control several vibration modes through a time-sharing strategy. The effectiveness of the MIMSC method in damping out the beam vibration is demonstrated by comparing the results with those obtained by other modal control methods. Two methods are considered, the independent modal space control method and the pseudo-inverse method. The feasibility of the MIMSC method as a viable alternative for controlling large flexible structures with a very small number of actuators is emphasized. N.B.

A90-38584
CONTROL OF A ONE-DIMENSIONAL DISTRIBUTED STRUCTURE BASED ON WAVE PROPAGATION ANALYSIS
RAYMOND J. NAGEM (Boston University, MA) and JAMES H. WILLIAMS, JR. (MIT, Cambridge, MA) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 18, no. 1, 1990, p. 33-57. Research supported by USAF. refs
Copyright

Wave propagation in a one-dimensional structure is analyzed. Based on this wave propagation analysis, a control system for the structure is developed. The purpose of the control system is to improve the dynamic response of the structure to an external force. It is shown that the control system can completely isolate a section of the structure from disturbances caused by the external force, or it can add damping to the structure. The effects of two types of errors on the control system are considered. The example given here illustrates the potential importance of control systems based on wave propagation concepts and raises many issues

that are involved in the development of such control systems.
Author

A90-39030
DYNAMICS AND CONTROL OF STRUCTURES
LEONARD MEIROVITCH (Virginia Polytechnic Institute and State University, Blacksburg) New York, Wiley-Interscience, 1990, 438 p. refs
Copyright

The fundamental principles of the dynamical analysis and control of structures are presented in a professional reference work also suitable as a textbook for graduate engineering students. Chapters are devoted to Newtonian mechanics, analytical mechanics, linear system theory, lumped-parameter structures, classical and modern control methods for lumped-parameter systems, exact and approximate methods for distributed-parameter structures, and control of distributed structures. Also provided is a review of the literature on structural control, including applications to aircraft, civil structures, sound-radiation suppression, space structures, launch vehicles, and robotics. T.K.

A90-39331#
ADAPTIVE CONTROL OF LARGE SPACE STRUCTURES
YUZO SHIMADA (Nihon University, Funabashi, Japan) Chinese Society of Astronautics, Journal (ISSN 1000-1328), no. 1, 1990, p. 45-53. refs

This paper deals with the application of a model reference adaptive control theory to the attitude control of large space structures that don't satisfy the conditions of sensor/actuator collocation. The signals from several different positions on the flexible appendages are combined into outputs so that the number of outputs and inputs is the same. As an example, a spacecraft that has flexible solar paddles and a momentum wheel within the rigid central body is studied. Computer simulation results are presented for a situation where the flexural rigidity of the flexible appendages are assumed to vary widely from nominal values.
Author

A90-39334#
STABILITY ROBUSTNESS ANALYSIS OF ATTITUDE CONTROL SYSTEM OF A FLEXIBLE SPACECRAFT IN TIME DOMAIN
SHIJIE XU and YAOHUA WU (Harbin Institute of Technology, People's Republic of China) Chinese Society of Astronautics, Journal (ISSN 1000-1328), no. 1, 1990, p. 77-83. In Chinese, with abstract in English.

The stability robustness of the attitude control system of a flexible spacecraft in the time domain is investigated. As a result of the rotation of solar arrays and the variation of the rotating speed of the momentum wheels, there is uncertainty in the mathematical model of the system. The uncertainty may be solved by the applying perturbation method to the motion equations of the dynamic system. The stability robustness criterion in the time domain is given. A numerical example shows the application of this method.
Author

A90-39793*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
TRUSS SPACE STRUCTURES SYSTEM IDENTIFICATION USING THE MULTIPLE BOUNDARY CONDITION TEST METHOD
C. P. KUO and B. K. WADA (JPL, Pasadena, CA) (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. 172-176) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1246-1249. Previously cited in issue 14, p. 2115, Accession no. A87-33670. refs
(Contract NAS7-918)
Copyright

A90-39794#
DYNAMICS OF COMPLEX TRUSS-TYPE SPACE STRUCTURES
Y. YONG and Y. K. LIN (Florida Atlantic University, Boca Raton) AIAA Journal (ISSN 0001-1452), vol. 28, July 1990, p. 1250-1258. Previously cited in issue 12, p. 1796, Accession no. A89-30787. refs
(Contract AF-AFOSR-88-005)
Copyright

A90-39914
THE POSITIONING OF SENSORS AND ACTUATORS IN THE VIBRATION CONTROL OF FLEXIBLE SYSTEMS
SHINJI KONDOH (Mitsubishi Heavy Industries, Ltd., Nagoya Aircraft Works, Japan), CHIKAYOSHI YATOMI, and KOICHI INOUE (Kyoto University, Japan) JSME International Journal, Series III (ISSN 0914-8825), vol. 33, June 1990, p. 145-152. refs
Copyright

A method is presented for the determination of sensor and actuator positioning and feedback gains for the active vibration control of flexible structures. This method is based on the minimization of the minimum quadratic cost functional in the standard optimal control. The optimal criterion is determined via Riccati equations, and it is minimized with a recursive quadratic programming algorithm with respect to sensor and actuator positioning parameters. The application of this method to a cantilever beam yields several dislocated sensor and actuator locations which are locally optimal. An extension to a case in which modal filters are used is also examined. In this case, the location of the actuator is found to be more sensitive than that of the sensors. This method has clear physical meaning and the flexibility to allow varying of the weighting matrix. Author

A90-40165*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
OPTIMAL MOMENTUM MANAGEMENT CONTROLLER FOR THE SPACE STATION
J. W. SUNKEL (NASA, Johnson Space Center, Houston, TX) and L. S. SHIEH (Houston, University, TX) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 659-668. Previously cited in issue 23, p. 3629, Accession no. A89-52567. refs
(Contract DAAL03-87-K-0001; NAG9-380; NAG9-385)
Copyright

A90-40168*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
POLE/ZERO CANCELLATIONS IN FLEXIBLE SPACE STRUCTURES
TREVOR WILLIAMS and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 684-690. Previously cited in issue 21, p. 3508, Accession no. A88-50165. refs
Copyright

A90-40169#
SIMULATION OF ACTIVELY CONTROLLED SPACECRAFT WITH FLEXIBLE APPENDAGES
R. R. RYAN (Michigan, University, Ann Arbor) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 691-702. Previously cited in issue 02, p. 157, Accession no. A89-12674. refs
Copyright

A90-40170#
DISTRIBUTED FINITE-ELEMENT MODELING AND CONTROL APPROACH FOR LARGE FLEXIBLE STRUCTURES
K. DAVID YOUNG (Lawrence Livermore National Laboratory, Livermore, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 703-713. Previously cited in issue 21, p. 3584, Accession no. A88-50191. refs
(Contract W-7405-ENG-48)
Copyright

A90-40176#
CONTROL FOR ENERGY DISSIPATION IN STRUCTURES

S. P. JOSHI, T. L. VINCENT (Arizona, University, Tucson), and Y. C. LIN (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1, p. 479-490) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 751-753. Previously cited in issue 12, p. 1828, Accession no. A88-32228. refs
Copyright

A90-40177#
OPTIMAL COUPLING RATIO SELECTION FOR FLEXIBLE APPENDAGE ACTUATORS
JOHN B. STETSON, JR. (General Electric Co., Astro-Space Div., Princeton, NJ) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, July-Aug. 1990, p. 754, 755.
Copyright

Articulated and flexible spacecraft appendages requiring precise pointing usually depend on rotary, gear-coupled actuators that are driven by dc servomotors or stepper motors; these are connected to backlashless gear trains with high coupling ratios. Existing methods for selecting gear ratios that minimize the power dissipated in moving a rigid, fixed base load are presently extended to simultaneously minimize both the required actuator power and the vibrational coupling between a rigid-body spacecraft and a flexible load, with one (generally damped) torsional degree-of-freedom. O.C.

A90-40827* University of Southern California, Los Angeles.
BENDING RATE DAMPING IN ELASTIC SYSTEMS
H. T. BANKS, Y. WANG (Southern California, University, Los Angeles, CA), and R. H. FABIANO (Texas A & M University, College Station) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 604-607. refs
(Contract NAG1-517; AF-AFOSR-84-0398; F49620-86-C-0111)
Copyright

Preliminary results of an investigation of the bending rate damping model for elastic structures are presented. A model for which the internal damping term is physically plausible and which can accomodate cantilevered boundary conditions is discussed. The model formulation and mathematical foundations are given, and numerical results are discussed. I.E.

A90-40828
CONTROLLER DESIGN FOR RIGID-FLEXIBLE MULTIBODY SYSTEMS
AHMET S. YIGIT and A. GALIP ULSOY (Michigan, University, Ann Arbor) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 665-673. refs
Copyright

Computed torque-type controllers for rigid-flexible multibody systems are studied using simulations of a two-link system. It is found that a controller design based on uncoupled equations of motion generally provides good performance when evaluated on a fully coupled simulation model. However, evaluating controllers using uncoupled equations in the simulation can give misleading results. Robustness to nonlinearities is investigated, since the computed torque-type control cannot cancel all the nonlinear terms. Uncoupled controllers tend to be more robust than controllers based on linear quadratic design, and of the controllers considered the Corless-Leitmann controller gave the best robustness results for uncancelled nonlinear terms. Spillover and robustness to model parameter uncertainty are also investigated through simulations. I.E.

A90-40834
ON MODELLING OF SEGMENTED MIRRORS MOUNTED ON FLEXIBLE SUPPORTING STRUCTURES
ENRIQUE BARBIERI (Tulane University, New Orleans, LA) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 710, 711. Research supported by Tulane University.
Copyright

The main goals of this research are to formulate a frequency-matching problem as an exact inverse eigenvalue problem for Jacobi matrices, obtain a state-space representation of the mirror/cell structure, and design decentralized controllers for the push-pull mirror actuators. The interconnected mass-spring model used provides an exact match to the frequency distribution of the mirror/cell structure, and the algorithm does not involve any trial-and-error procedure. Preliminary results indicate that the model exhibits a decentralized structural characterization, which can be exploited to design local controllers for next-neighbor disturbance rejection. I.E.

A90-40842
MULTIRATE THREE AXES ATTITUDE STABILIZATION OF SPACECRAFT
S. MONACO (L'Aquila, Universita, Italy), D. NORMAND-CYROT (CNRS, Laboratoire des Signaux et Systemes, Gif-sur-Yvette, France), and S. STORNELLI (ESTEC, Noordwijk, Netherlands) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 797-802. refs
Copyright

A double-rate digital control law is proposed for large-angle attitude maneuvers and stabilization of flexible satellites. Such a control law improves, with respect to the continuous control, the damping of the elastic oscillations. Two sets of equations for modeling the spacecraft dynamics are given, an ideal one for simulation purposes and a simplified one for elaborating the control scheme. Simulation results illustrating two attitude maneuvers of a rigid body with four flexible attached booms, using gas-jet control, are discussed. I.E.

A90-40843
TOWARDS MODELING AND CONTROL OF LARGE SPACE STATIONS
N. U. AHMED and S. S. LIM (Ottawa, University, Canada) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 803-808. Previously announced in STAR as N90-10120. refs
Copyright

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

A90-40844
VARIABLE STRUCTURE ATTITUDE CONTROL AND ELASTIC MODE STABILIZATION OF FLEXIBLE SPACECRAFT
ASHOK IYER and SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 809-814. refs
(Contract DAAL03-87-G-0004)
Copyright

The question of attitude control and elastic mode stabilization of a spacecraft (orbiter) with a beam-tip-mass-type payload is considered. It is assumed that bounded but unknown disturbance torques are acting on the spacecraft. Using variable-structure-system theory, a discontinuous three-axis

moment control law is derived to control the attitude of the spacecraft. Although this control law accomplishes attitude trajectory tracking, it excites the elastic modes of the beam. A modal velocity feedback design that damps the elastic oscillations using additional actuators at the tip of the beam is presented. Simulation results are presented to show that rotational maneuvers and vibration stabilization can be accomplished in the closed-loop system in spite of disturbance torques and uncertainty in the system. I.E.

A90-40906* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LIMITATIONS OF VIBRATION SUPPRESSION IN FLEXIBLE SPACE STRUCTURES
T. W. C. WILLIAMS (NASA, Langley Research Center, Hampton, VA) and P. J. ANTSAKLIS (Notre Dame, University, IN) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2218-2222. refs
Copyright

The uncertainties inherent in the dynamics of flexible spacecraft make robustness questions very important when designing vibration suppression systems for these vehicles. This often leads to the use of sensors and actuators which are collocated on the structure, so as to avoid the potentially destabilizing problem of unknown modal phase differences between noncollocated sensors and actuators. The closed-loop performance attainable is, of course, reduced if only collocated pairs are considered. The object of the present study is to investigate whether the special properties of the transmission zeros of such structures can be used to quantify these performance limitations. The approach is based on recent results concerning the transmission zeros of flexible structures. I.E.

A90-40918
OPTIMAL ROOT LOCI OF FLEXIBLE SPACE STRUCTURES
TREVOR WILLIAMS (Cincinnati, University, OH) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2687, 2688. refs
Copyright

It is shown that simple generic properties can be proved for the optimal root loci of flexible space structures. These results depend on the fundamental second-order nature of such systems and give considerably more insight than is possible a priori for general linear multivariable systems. I.E.

A90-40919* California Inst. of Tech., Pasadena.
VIBRATION DAMPING AND ROBUST CONTROL OF THE JPL/AFAL EXPERIMENT USING MU-SYNTHESIS
GARY J. BALAS, JOHN C. DOYLE (California Institute of Technology, Pasadena), and CHENG-CHIH CHU (JPL, Pasadena, CA) IN: IEEE Conference on Decision and Control, 28th, Tampa, FL, Dec. 13-15, 1989, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2689-2694. Research supported by the California Institute of Technology. refs
Copyright

The technology for controlling elastic deformations of flexible structures is one of the key considerations for future space initiatives. A vital area needed to achieve this objective is the development of a control design methodology applicable to future structures. The mu-synthesis technique is employed to design a high-performance vibration attenuation controller for the JPL/AFAL experimental flexible antenna structure. The results presented deal primarily with the control of first two global flexible modes using only two hub actuators and two hub sensors. Implementation of the multivariable control laws based on a finite-element model is presented. All results are from actual implementation on the JPL/AFAL flexible structure testbed. I.E.

A90-41228#
MODAL SENSORS/ACTUATORS
C.-K. LEE (IBM Almaden Research Center, San Jose, CA) and F. C. MOON (Cornell University, Ithaca, NY) ASME, Transactions, Journal of Applied Mechanics (ISSN 0021-8936), vol. 57, June 1990, p. 434-441. refs
Copyright

A piezoelectric laminate theory that uses the piezoelectric phenomenon to effect distributed control and sensing of structural vibration of a flexible plate has been used to develop a class of distributed sensor/actuators, that of modal sensors/actuators. The one-dimensional modal sensors/actuator equations are first derived theoretically and then examined experimentally. These modal equations indicate that distributed piezoelectric sensors/actuators can be adopted to measure/excite specific modes of one-dimensional plates and beams. If constructed correctly, actuator/ observer spillover will not be present in systems adopting these types of sensors/actuators. A mode 1 and a mode 2 sensor for a one-dimensional cantilever plate were constructed and tested to examine the applicability of the modal sensors/actuators. A modal coordinate analyzer which makes it possible to measure any specific modal-coordinate on-line real-time is proposed. Finally, a way to create a special two-dimensional modal sensor is presented. Author

A90-41823
CONTROL OF SPACECRAFT WITH MULTI-TARGETED FLEXIBLE ANTENNAS
LEONARD MEIROVITCH and MOON K. KWAK (Virginia Polytechnic Institute and State University, Blacksburg) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 38, Apr.-June 1990, p. 187-199. refs
(Contract F49620-88-C-0044)
Copyright

This paper is concerned with the problem of reorienting the line of sight of a given number of flexible antennas in a spacecraft. The maneuver of the antennas is carried out according to a minimum-time policy, which implies bang-bang control. Regarding the maneuver angular motion of the antennas as known, the equations of motion contain time-dependent terms in the form of coefficients and persistent disturbances. The control of the elastic vibration and of the rigid-body motions of the spacecraft caused by the maneuver is implemented by means of a proportional-plus-integral control. The approach is demonstrated by means of a numerical example in which a spacecraft consisting of a rigid platform and two maneuvering flexible antennas is controlled. Author

A90-41961
ATTITUDE CONTROL SYSTEM OF A FLEXIBLE SPACECRAFT WITH A DYNAMIC FILTER [SISTEMA ORIENTATSII DEFORMIRUEMOGO KOSMICHESKOGO APPARATA S DINAMICHESKIM FIL'TROM]
G. IA. LEDENEV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, May-June 1990, p. 329-335. In Russian. refs
Copyright

Sufficient stability conditions are obtained for the attitude control system of a flexible spacecraft with a dynamic filter under the effect of a slowly varying perturbation. This filter substantially attenuates the elastic-vibration signal and excludes the effect of the slowly varying perturbations on the orientation precision. Relationships are obtained which make it possible to choose parameters of the filter that assure the stability of the attitude control system. B.J.

A90-41962
OPTIMAL ALGORITHMS FOR STATE LIMITATIONS OF A SPACECRAFT WITH RELAY CONTROLLERS [OPTIMAL'NYE ALGORITMY OGRANICHENII SOSTOIANIIA KOSMICHESKOGO APPARATA S RELEINYMI ISPOLNITEL'NYMI ORGANAMI]
N. E. ZUBOV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, May-June 1990, p. 336-345. In Russian. refs
Copyright

A new version of a relay controller based on an algorithm with a predictive model is developed which serves as the basis of

state limitation automata for a spacecraft. Particular attention is given to state limitation for a linear stationary spacecraft and to state limitation for a linear nonstationary spacecraft and a nonlinear spacecraft. B.J.

A90-41964
ACCURACY OF THE STABILIZATION OF AN ORBITAL STATION BY A SYSTEM OF GYRODYNES [TOCHNOST' STABILIZATSII ORBITAL'NOI STANTSII SISTEMOI GIRODINOV]
N. N. SHEREMET'EVSKII, D. M. VEINBERG, and V. P. VERESHCHAGIN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, May-June 1990, p. 360-365. In Russian.
Copyright

A mathematical model of a gyroscope-gyrodyne system is described which is used for the ground-based preflight adjustment of the system as well as for the analysis of various orientation regimes during flights of the Mir orbital complex. Based on the variation of certain parameters of the model, attention is given to ways to improve the gyrodynes which allow overall augmentation of the system accuracy. B.J.

A90-42329
ACCOUNTING FOR ELASTIC BODIES IN MULTIBODY LOOPS [BERUECKSICHTIGUNG VON ELASTISCHEN KOERPERN IN MEHRKOERPERSCHLEIFEN]
MANFRED HILLER and PETER SOKOL (Universitaet Duisburg-Gesamthochschule, Federal Republic of Germany) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Karlsruhe, Federal Republic of Germany, Mar. 28-31, 1989) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 70, no. 4, 1990, p. T 28-T 30. In German.
Copyright

A technique for modeling multibody systems with closed kinematic loops containing elastic bodies is developed analytically. The elastic body is treated as a beam element, and its linear-elastic deformation is discretized using ansatz functions. The free elastic body is then integrated into the multibody loop with the help of coupling equations, as described by Woernle (1988), and the equations of motion are obtained in minimal form via the principle of D'Alembert. The applicability of the present approach to problems in large space structures and robotics is indicated. T.K.

A90-42342
SPACE STRUCTURES AND THEIR PLANAR DRAWINGS
A. KAVEH (Iran University of Science and Technology, Teheran) (Gesellschaft fuer angewandte Mathematik und Mechanik, Wissenschaftliche Jahrestagung, Karlsruhe, Federal Republic of Germany, Mar. 28-31, 1989) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 70, no. 4, 1990, p. T 225-T 228. refs
Copyright

A technique based on the polyhedra formula of Euler is developed analytically to transform the topological properties of a three-dimensional rigid-jointed skeletal structure into those of its two-dimensional representation. The aim is to facilitate the counting procedure when determining a structure's degree of statical indeterminancy (DSI) for stability analysis. It is shown that the present method yields a minimal number of DSI countings when an optimal drawing (one having the smallest possible number of crossings) is used; the need for algorithms to construct such drawings is indicated. T.K.

A90-43482* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CONTROLS STRUCTURES INTERACTION, AN INTERDISCIPLINARY CHALLENGE FOR LARGE SPACECRAFT
BRANTLEY R. HANKS (NASA, Langley Research Center, Hampton, VA) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 353-369.
(AAS PAPER 88-231) Copyright

Controls structures interaction (CSI), a phenomenon which occurs when control forces interact with the flexible motion of a structure, can, if improperly treated in design and development, cause reduced performance or control instabilities. Properly applied, it can improve flexible spacecraft performance. In this paper, the NASA CSI technology program for future spacecraft applications is described. The program objectives and organization are outlined, and the nature of individual program tasks is described. The interdisciplinary aspects of CSI are also addressed. C.D.

A90-44846#
PRECISE POINT-TO-POINT POSITIONING CONTROL OF FLEXIBLE STRUCTURES
DENNY K. MIU (California, University, Los Angeles) and SUDARSHAN P. BHAT ASME, Winter Annual Meeting, San Francisco, CA, Dec. 10-15, 1989. 8 p. Research supported by the Digital Equipment Corp., Hewlett-Packard Co., Micropolis Corp., et al. refs
(ASME PAPER 89-WA/DSC-6)

Control strategies to accomplish precise point-to-point positioning of flexible structures are discussed. First, the problem is formulated and solved in closed form using linear quadratic optimal control technique for a simple system with one rigid and one flexible mode; the resulting analytical solutions are examined in both time and frequency domain. In addition, the necessary and sufficient condition for zero residual vibration is derived which simply states that the Laplace transform of the time-bounded control input must have zero contribution at the system poles. This criteria is then used to underline the common features of existing techniques and to devise simple design procedures for precise position control of more complicated structures with multiple flexible modes. Author

A90-45338*# Ford Aerospace Corp., Palo Alto, CA.
APPROACH TO LARGE SPACE STRUCTURE CONTROL SYSTEM DESIGN USING TRADITIONAL TOOLS
P. Y. CHU, B. WIE, B. GRETZ, and C. PLESCIA (Ford Aerospace Corp., Palo Alto, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Sept.-Oct. 1990, p. 874-880. refs
(Contract NAS8-36422)
Copyright

This paper illustrates how traditional analysis and design tools can be successfully applied, with insights derived from recent research on control-structure interaction, to preliminary control system design for a large space structure such as the Space Station Freedom. The control system regulates attitude during construction, normal on-orbit operation, reboost, and docking using control-moment gyros and thrusters. The tools include finite-element modeling, model reduction based on modal truncation, single-input/single-output Bode plot design, position and rate feedback, roll-off and phase filter, and simulation. The resulting system is characterized by simple architecture and moderate bandwidth. The large configuration changes during the construction period are handled by gain scheduling. Author

A90-45339#
TRANSFER FUNCTION ANALYSIS OF A FLEXIBLE TOROIDAL STRUCTURE
BONG WIE (Arizona State University, Tempe) and ARTHUR E. BRYSON, JR. (Stanford University, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 13, Sept.-Oct. 1990, p. 881-886. refs
Copyright

This paper is concerned with the modeling of a flexible toroidal structure for attitude and structural control studies. A two-dimensional elastic system, consisting of a flexible toroid and a pretensioned membrane, is analyzed in terms of the transfer function from a control torque input to the collocated sensor output. The critical tension for out-of-plane buckling is also determined. The models considered in the paper are simple enough to treat analytically, yet complicated enough to demonstrate the dynamical

characteristics of future space structures with a toroidal configuration. It is shown that for such structures, the coupling between two elastic systems results in a transfer function expressed as a combination of an infinite product expansion and an infinite partial fraction expansion. Such a representation should be useful in future studies in reduced-order modeling of flexible toroidal structures. Author

A90-45416
IDENTIFICATION OF FLEXIBLE STRUCTURES FOR ROBUST CONTROL
GARY J. BALAS (Minnesota, University, Minneapolis) and JOHN C. DOYLE (California Institute of Technology, Pasadena) (1989 American Control Conference, Pittsburgh, PA, June 21-23, 1989) IEEE Control Systems Magazine (ISSN 0272-1708), vol. 10, June 1990, p. 51-58. Research supported by the California Institute of Technology. refs
Copyright

Documentation is provided of the authors' experience with modeling and identification of an experimental flexible structure for the purpose of control design, with the primary aim being to motivate some important research directions in this area. A multi-input/multi-output (MIMO) model of the structure is generated using the finite element method. This model is inadequate for control design, due to its large variation from the experimental data. Chebyshev polynomials are employed to fit the data with single-input/multi-output (SIMO) transfer function models. Combining these SIMO models leads to a MIMO model with more modes than the original finite element model. To find a physically motivated model, an ad hoc model reduction technique which uses a priori knowledge of the structure is developed. The ad hoc approach is compared with balanced realization model reduction to determine its benefits. Descriptions of the errors between the model and experimental data are formulated for robust control design. Plots of select transfer function models and experimental data are included. I.E.

A90-46034
VIBRATION CONTROL IN SPACECRAFT
D. J. INMAN and A. SOOM (New York, State University, Buffalo) IN: Modern practice in stress and vibration analysis; Proceedings of the Conference, Liverpool, England, Apr. 3-5, 1989. Oxford, England and Elmsford, NY, Pergamon Press, 1989, p. 11-16. refs
Copyright

This paper examines both passive and active vibration control for use in vibration suppression in spacecraft. Proposed spacecraft designs are very lightweight and hence extremely flexible when compared with earthbound structures. To further complicate matters, spacecraft are intended to function in a vacuum void of external viscous damping mechanisms. For these reasons, the vibration suppression problem for spacecraft presents new challenges to the vibration community. The unique problems of controlling the structural vibration in flexible spacecraft are examined and discussed in this paper. Author

A90-46047
MULTICRITERIA DESIGN OF SPACECRAFT STRUCTURES WITH SPECIAL EMPHASIS ON MASS AND STIFFNESS
H. BAIER (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Multicriteria design optimization: Procedures and applications. Berlin and New York, Springer-Verlag, 1990, p. 244-259.
Copyright

The optimal design problem of spacecraft structures is defined, including objective functions, constraints, design variables, system equations, and loads. Considerations on optimality criteria are discussed, and different strategies for multicriteria problems are classified by dividing them into 'a priori' and 'ad hoc' methods. Optimal design of fiber laminates, optimization of a precision reflector, mass and dynamic stiffness optimization, and shape optimization of axisymmetric shell structures are analyzed. It is concluded that many design optimization problems are multicriteria problems, and the solution algorithms for these problems stipulate transformation into single-criteria problems. Flexibility in applying various algorithmic approaches and problem statements is emphasized. V.T.

A90-46070* Drexel Univ., Philadelphia, PA.
A MODIFIED FINITE ELEMENT-TRANSFER MATRIX FOR CONTROL DESIGN OF SPACE STRUCTURES
T.-M. TAN, A. YOUSUFF, L. Y. BAHAR, and M. KONSTANDINIDIS (Drexel University, Philadelphia, PA) Computers and Structures (ISSN 0045-7949), vol. 36, no. 1, 1990, p. 47-55. refs
(Contract NAG1-622)
Copyright

The Finite Element-Transfer Matrix (FETM) method was developed for reducing the computational efforts involved in structural analysis. While being widely used by structural analysts, this method does, however, have certain limitations, particularly when used for the control design of large flexible structures. In this paper, a new formulation based on the FETM method is presented. The new method effectively overcomes the limitations in the original FETM method, and also allows an easy construction of reduced models that are tailored for the control design. Other advantages of this new method include the ability to extract open loop frequencies and mode shapes with less computation, and simplification of the design procedures for output feedback, constrained compensation, and decentralized control. The development of this new method and the procedures for generating reduced models using this method are described in detail and the role of the reduced models in control design is discussed through an illustrative example. Author

A90-46176
MATHEMATICAL MODELING OF ACTUATOR - FLEXIBLE BEAM DYNAMIC SYSTEMS
M. J. PANZA and R. W. MAYNE (New York, State University, Buffalo) IN: Structural vibration and acoustics; Proceedings of the Twelfth Biennial ASME Conference on Mechanical Vibration and Noise, Montreal, Canada, Sept. 17-21, 1989. New York, American Society of Mechanical Engineers, 1989, p. 91-98. refs
(Contract F49620-88-C-0018)
Copyright

A mathematical representation is developed for the fully coupled system dynamics of a hinged flexible beam driven by an actuator along its length. The derivation includes a distributed beam model discretized by the application of modal analysis and interacting dynamic models for hydraulic and electromagnetic actuators. Flexible actuator transmission members are also included. The beam and actuator equations are combined to obtain a state variable representation of the overall system. The system equations are solved numerically to demonstrate possible effects of actuator and beam parameter selection on the system dynamics and the beam vibration. Author

A90-46249
AN APPROACH TO DYNAMICS AND CONTROL OF A CLASS OF INTERCONNECTED RIGID/FLEXIBLE ORBITING BODIES
Y. MORITA and V. J. MODI (British Columbia, University, Vancouver, Canada) IN: Machinery dynamics - Applications and vibration control problems; Proceedings of the Twelfth Biennial ASME Conference on Mechanical Vibration and Noise, Montreal, Canada, Sept. 17-21, 1989. New York, American Society of Mechanical Engineers, 1989, p. 347-353. refs
Copyright

A general formulation for studying dynamics of flexible systems characterized by interconnected beam-type members forming a chain geometry is presented. As applied to NASA's proposed SCOLE (Spacecraft Control Laboratory Experiment) system, the study is approached utilizing the Lagrangian procedure with the generalized forces accounting for the environmental effects, damping, and control. The infinite time linear state feedback regulator, employing the Shuttle's primary and vernier thrusters, is designed to suppress the vibrations as well as control the attitude motion of the Shuttle. It is shown that the optimal linear regulator,

utilizing the Shuttle's attitude control thrusters, considerably reduces the mast's undesireable vibrations during the mast pitch maneuver, resulting in a quick return to the desired pointing accuracy of the antenna. R.E.P.

A90-46353
BEHAVIOR OF A SINGLE-DEGREE-OF-FREEDOM SYSTEM WITH A GENERALIZED FRICTION LAW
J. R. ANDERSON and A. A. FERRI (Georgia Institute of Technology, Atlanta) Journal of Sound and Vibration (ISSN 0022-460X), vol. 140, July 22, 1990, p. 287-304. refs
(Contract NSF MSM-87-07846)
Copyright

Although single-degree-of-freedom systems with classical dry (Coulombic) friction have been studied extensively, the properties of systems damped with generalized friction laws have not been thoroughly examined. This paper is concerned with the properties of a system damped by a combination of viscous damping, dry friction with constant normal force, dry friction with amplitude-dependent normal force, and dry friction with rate-dependent normal force. This system is studied first by using an 'exact' time domain method and then by using first order harmonic balance. The stick-slip behavior of the system is also studied. It is seen that amplitude-dependent normal force gives rise to a viscous-like damping characteristic. It is also seen that the response amplitude can be decreased or increased by the addition of amplitude-dependent friction. Author

A90-46774 Ford Aerospace and Communications Corp., Palo Alto, CA.
SLEW DISTURBANCE COMPENSATION FOR MULTIPLE SPACECRAFT PAYLOADS
PETER Y. CHU (Ford Aerospace and Communications Corp., Palo Alto, CA) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 1. San Diego, CA, Univelt, Inc., 1990, p. 301-311. Research sponsored by NASA and NOAA.
(AAS PAPER 89-369) Copyright

Multiple slewing spacecraft payloads such as mirrors and antennas cause dynamic disturbances to the spacecraft and themselves. A centralized compensation logic uses the payload slew commands to calculate these interactions, or essentially runs a mini-simulation of spacecraft response in real-time, and modifies the lines-of-sight accordingly. No sensor is used. From the payload designers and users point of view, the spacecraft bus appears not disturbed. The scheme is readily expanded to any number of payloads. The implementation on the new geo-stationary GOES weather satellites with two double-gimballed scanners is described. The pointing error reduction ratio is about 15:1. Together with the baseline spacecraft feedback control system, the effective spectral band is from DC to about 1 Hz. Author

A90-46801
NOVEL SENSING AND STRUCTURAL IDENTIFICATION METHODS - PRELIMINARY ANALYTICAL AND EXPERIMENTAL RESULTS
G. H. JAMES and J. L. JUNKINS (Texas A & M University, College Station) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 807-823. refs
(AAS PAPER 89-425) Copyright

A process called structural identification was developed for upgrading the mathematical models that predict the dynamical response of large flexible structures on orbit. The method is an extension of the Creamer (1987) and Creamer and Junkins approach which scales contributions of user-defined substructures to the model matrices to fit the experimentally determined free and forced response of the system. Using vibration frequency data from experiments in which an optical imaging system, together with conventional strain gages, was used to measure inertial deflections of 20 active targets mounted on an aluminum grid cantilevered in the vertical plane, the frequency response functions, mode shapes, damping ratios, and frequency response functions were obtained. I.S.

A90-46802
DYNAMICS AND CONTROL OF THE SHUTTLE BASED SCOLE TYPE LARGE ANTENNA SYSTEM
V. J. MODI (British Columbia, University, Vancouver, Canada) and Y. MORITA IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 825-840. refs
(AAS PAPER 89-436) Copyright

A general formulation for studying dynamics of a large class of interconnected flexible and/or rigid bodies forming a chain-type system is developed using the Lagrangian procedure with the generalized forces accounting for the environmental effects, damping, and control. The formulation is used to investigate complex dynamics of the antenna system proposed for the Shuttle-based Spacecraft Control Laboratory Experiment. The results clearly emphasize interactions between librational and vibrational degrees of freedom and demonstrate the effectiveness of the optimal linear regulator in regaining the fine pointing accuracy. I.S.

A90-46803 Howard Univ., Washington, DC.
USE OF OPTIMALITY CRITERION TECHNIQUES IN THE COMBINED DESIGN AND CONTROL OF LARGE SPACE STRUCTURES
K. SATYANARAYANA and PETER M. BAINUM (Howard University, Washington, DC) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 841-854. Research supported by NASA and Howard University. refs
(AAS PAPER 89-437) Copyright

A combined structural and control optimization problem for large space structures is formulated using an optimality criteria approach for the orientation and shape control of a free-free beam in orbit. Optimality criteria for minimizing the combined cost function of the structure are derived. The obtained configuration of the structure is used to derive control laws, and a closed-loop dynamic performance is evaluated for the structures. A comparison with two other methods shows that the configurations obtained by the combined cost approach require least control efforts for the shape and orientation control of the orbiting beam. I.S.

A90-46804* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SELECTION OF COMPONENT MODES FOR THE SIMULATION OF FLEXIBLE MULTIBODY SPACECRAFT
JOHN T. SPANOS and WALTER S. TSUHA (JPL, Pasadena, CA) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 855-877. refs
(AAS PAPER 89-438) Copyright

This paper describes a procedure for the selection of component modes employed in discretization of component deformation in a flexible multibody spacecraft. The emphasis is placed on the selection of modes which adequately represent the interaction of the various on-board control systems with the vehicle structural flexibility. The method combines the component mode synthesis approaches of Craig-Bampton (1968), MacNeal (1971) and Rubin (1975), and Benfield-Hruda (1971) with the modal balancing method of Moore (1981) and Gregory (1984). The procedure, which is applicable to both articulating and nonarticulating systems, was used to develop a low-order model of the three-body articulating Galileo spacecraft. I.S.

A90-46805* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SENSITIVITY OF THE TRANSMISSION ZEROS OF FLEXIBLE SPACE STRUCTURES
TREVOR WILLIAMS and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe,

VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 879-895. refs
(AAS PAPER 89-439) Copyright

The new pole/zero cancellation technique developed for the problem of sensitivity and robustness in vibration isolation systems for flexible spacecraft requires an analysis of the sensitivity of transmission zeros. This paper analyzes the sensitivity of the transmission zeros of flexible structures with compatible sensors and actuators, in terms of partial derivatives and condition numbers. It is shown that, in both measures, the sensitivities of the zeros of such a system are closely related to those of its poles. It is also shown that the closed-loop poles produced by applying the pole/zero cancellation to the structure have sensitivities approaching those of the zeros, so that these are given by the sensitivities of the open-loop poles. Examples are presented that illustrate these points. I.S.

A90-46806
OPTIMIZATION OF ACTUATORS/SENSORS PLACEMENT AND DERIVATION OF REDUCED ORDER MODELS FOR THE OPTIMAL CONTROL OF FLEXIBLE STRUCTURES
PAULO T. M. LOURENCAO and ATAIR RIOS-NETO (Embraer - Empresa Brasileira de Aeronautica, S.A., Sao Jose dos Campos, Brazil) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 897-908. refs
(AAS PAPER 89-441) Copyright

This paper presents a systematic approach to the dynamics and control of large flexible structures, which is based on optimal control techniques. This approach can simultaneously handle both the model order reduction and placement of actuators and sensors. Two methods are presented. In the first method, actuators and sensors are placed in order to minimize spillover effects and the reduced model is obtained by simple truncation. In the second method, an optimization problem is formulated and the reduced model and the positions of the actuators and sensors are obtained so as to minimize the difference between the responses of the original and the reduced systems. I.S.

A90-46808
CONTROL OF FLEXIBLE SPACECRAFT WITH TIME-VARYING CONFIGURATION
LEONARD MEIROVITCH and MOON KYU KWAK (Virginia Polytechnic Institute and State University, Blacksburg) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 927-949. refs
(Contract F49620-89-C-0049)
(AAS PAPER 89-470) Copyright

This paper is concerned with the dynamics and control of articulated flexible spacecraft. The mathematical model consists of a rigid platform and a given number of retargeting flexible antennas. The mission consists of maneuvering the antennas so as to coincide with preselected lines of sight while stabilizing the platform in an inertial space and suppressing the elastic vibration of the antennas. A perturbation technique permits the derivation of a new control law for systems with time-varying configuration, in which the time-varying terms are relatively small. According to the proposed perturbation method, the control gains consist of zero-order time-invariant gains obtained from the solution of a matrix algebraic Riccati equation (MARE) for the postmaneuver state and first-order time-varying gains obtained from the solution of a matrix differential Lyapunov equation (MDLE). The approach is illustrated by means of a numerical example. Author

A90-47322#
STRUCTURAL MODEL VERIFICATION WITH LINEAR QUADRATIC OPTIMIZATION THEORY
HELENE LAPIERRE and GERMAIN OSTIGUY (Ecole Polytechnique, Montreal, Canada) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3, p. 1194-1201) AIAA Journal (ISSN 0001-1452), vol. 28, Aug. 1990, p. 1497-1503. Research supported by CDC and Supply and Services Canada. Previously cited in issue 12, p. 1940, Accession no. A88-32300. refs
Copyright

A90-47323*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
STATISTICAL ANALYSIS OF STATIC SHAPE CONTROL IN SPACE STRUCTURES
RICARDO A. BURDISSO and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) AIAA Journal (ISSN 0001-1452), vol. 28, Aug. 1990, p. 1504-1508. refs
(Contract NAG1-224)

The article addresses the problem of efficient analysis of the statistics of initial and corrected shape distortions in space structures. Two approaches for improving efficiency are considered. One is an adjoint technique for calculating distortion shapes: the second is a modal expansion of distortion shapes in terms of pseudo-vibration modes. The two techniques are applied to the problem of optimizing actuator locations on a 55 m radiometer antenna. The adjoint analysis technique is used with a discrete-variable optimization method. The modal approximation technique is coupled with a standard conjugate-gradient continuous optimization method. The agreement between the two sets of results is good, validating both the approximate analysis and optimality of the results. Author

A90-47576
AIAA GUIDANCE, NAVIGATION AND CONTROL CONFERENCE, PORTLAND, OR, AUG. 20-22, 1990, TECHNICAL PAPERS. PARTS 1 & 2
Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. Pt. 1, 899 p.; pt. 2, 950 p. For individual items see A90-47577 to A90-47607, A90-47609 to A90-47699, A90-47701 to A90-47762.
Copyright

Recent advances in aircraft and spacecraft guidance, navigation, and control (GNC) technology are discussed in reviews and reports. Sections are devoted to control systems for the Space Station Freedom, control of flexible structures, guidance algorithms and analysis, aircraft control, missile guidance and control, computational dynamics and control, navigation algorithms and analysis, GNC for the ESA Columbus program, and space robotics. Consideration is given to tracking and estimation algorithms, launch-vehicle guidance and control, GNC components, spacecraft slewing and pointing control, AI applications, optimization and optimal control, differential games, space-vehicle GNC, actuator placement and structural identification, linear-system control, man-in-the-loop flight control, spacecraft attitude dynamics and control, structural control experiments, and the analysis and synthesis of robust controllers. T.K.

A90-47578*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MULTI-STAGE DESIGN OF AN OPTIMAL MOMENTUM MANAGEMENT CONTROLLER FOR THE SPACE STATION
J. W. SUNKEL (NASA, Johnson Space Center, Houston, TX) and L. S. SHIEH (Houston, University, TX) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 12-22. refs
(Contract DAAL03-87-K-0001; NAG9-380; NAG9-385)
(AIAA PAPER 90-3316) Copyright

This paper presents a multistage design scheme for determining an optimal control-moment-gyro momentum-management and attitude-control system for the Space Station Freedom. The Space Station equations of motion are linearized and block-decomposed into two block-decoupled subsystems using the matrix-sign algorithm. A sequential procedure is utilized for designing a linear-quadratic regulator for each subsystem, which optimally places the eigenvalues of the closed-loop subsystem in the region of an open sector, bounded by lines inclined at + or - pi/2k (for

k = 2 or 3) from the negative real axis, and the left-hand side of a line parallel to the imaginary axis in the s-plane. Simulation results are presented to compare the resultant designs. Author

A90-47579#
AN INNOVATIVE APPROACH TO THE MOMENTUM MANAGEMENT CONTROL FOR SPACE STATION FREEDOM
JALAL MAPAR (Grumman Corp., Space Station Program Support Div., Reston, VA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 23-28. refs
(AIAA PAPER 90-3317) Copyright

A new approach to the control-moment-gyro (CMG) momentum-management and attitude-control of the Space Station Freedom is presented. The nonlinear equations of motion are developed in terms of body attitude and attitude rate with respect to the local horizontal local vertical (LVLH) and linearized about any arbitrary stable point via the use of perturbation techniques. It is shown that, for some assembly flights, linearization of equations of motion about the LVLH may not be valid, and that a better choice would be to linearize about a torque equilibrium attitude. Next, a three-axis-coupled control law is used, and the controller gains are determined via a combination of the optimal-control and regional-pole-placement techniques. It is shown that the proposed linearization process, together with the coupled control laws, can stabilize a previously uncontrollable Space Station assembly flight. Author

A90-47580*# Analytical Mechanics Associates, Inc., Hampton, VA.
PREDICTED TORQUE EQUILIBRIUM ATTITUDE UTILIZATION FOR SPACE STATION ATTITUDE CONTROL
RENJITH R. KUMAR, MICHAEL L. HECK (Analytical Mechanics Associates, Inc., Hampton, VA), and BRENT P. ROBERTSON (McDonnell Douglas Space Systems Co., Seabrook, MD) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 29-41. refs
(Contract NAS1-18246)
(AIAA PAPER 90-3318) Copyright

An approximate knowledge of the torque equilibrium attitude (TEA) is shown to improve the performance of a control moment gyroscope (CMG) momentum management/attitude control law for Space Station Freedom. The linearized equations of motion are used in conjunction with a state transformation to obtain a control law which uses full state feedback and the predicted TEA to minimize both attitude excursions and CMG peak and secular momentum. The TEA can be computationally determined either by observing the steady state attitude of a 'controlled' spacecraft using arbitrary initial attitude, or by simulating a fixed attitude spacecraft flying in desired orbit subject to realistic environmental disturbance models. Author

A90-47581*# Arizona State Univ., Tempe.
ROBUST H(INFINITY) CONTROL DESIGN FOR THE SPACE STATION WITH STRUCTURED PARAMETER UNCERTAINTY
KUK-WHAN BYUN, BONG WIE (Arizona State University, Tempe), DAVID GELLER, and JOHN SUNKEL (NASA, Johnson Space Center, Houston, TX) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 42-52. refs
(AIAA PAPER 90-3319) Copyright

A robust H(infinity) control design methodology and its application to a Space Station attitude and momentum control problem are presented. This new approach incorporates nonlinear multiparameter variations in the state-space formulation of H(infinity) control theory. An application of this robust control synthesis technique tothe Space Station control problem yields a remarkable result in stability robustness with respect to the moments-of-inertia variation of about 73 percent in one of the structured uncertainty directions. The performance and stability of this new robust H(infinity) controller for the Space Station are compared to those of other controllers designed using a standard linear-quadratic-regulator synthesis technique. Author

A90-47582*# Texas Univ., Austin.
A GAME THEORETIC CONTROLLER FOR A LINEAR TIME-INVARIANT SYSTEM WITH PARAMETER UNCERTAINTY AND ITS APPLICATION TO THE SPACE STATION
IHNSEOK RHEE and JASON L. SPEYER (Texas, University, Austin) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 53-63. Research supported by NASA. refs
(AIAA PAPER 90-3320) Copyright

A game theoretic controller is developed for a linear time-invariant system with parameter uncertainties in system and input matrices. The input-output decomposition modeling for the plant uncertainty is adopted. The uncertain dynamic system is represented as an internal feedback loop in which the system is assumed forced by fictitious disturbance caused by the parameter uncertainty. By considering the input and the fictitious disturbance as two noncooperative players, a differential game problem is constructed. It is shown that the resulting time invariant controller stabilizes the uncertain system for a prescribed uncertainty bound. This game theoretic controller is applied to the momentum management and attitude control of the Space Station in the presence of uncertainties in the moments of inertia. Inclusion of the external disturbance torque to the design procedure results in a dynamical feedback controller which consists of conventional PID control and cyclic disturbance rejection filter. It is shown that the game theoretic design, comparing to the LQR design or pole placement design, improves the stability robustness with respect to inertia variations. Author

A90-47583#
A CONTROL SYSTEM DESIGN AND EVALUATION PROCEDURE FOR A POTENTIAL FLIGHT EXPERIMENT - CASES
MICHAEL A. SCOTT, DIRK WARNAAR, DAVE GHOSH, and RAYMOND C. MONTGOMERY (Lockheed Engineering and Sciences Co., Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 64-72. refs
(AIAA PAPER 90-3321)

This paper addresses active vibration suppression for large flexible space structures. A procedure has been developed which can be used to design control systems for proposed flight structures. The proposed method includes on-orbit system identification, followed by a control system design, implementation, and evaluation of the structural response due to a given set of disturbances. This process was successfully applied to the Mini-Mast ground test facility. These results are presented. They indicate excellent agreement between simulations and the actual Mini-Mast test. The method is applied to a spacecraft configuration currently being considered for flight test by NASA: the Controls, Astrophysics, and Structures Experiment in Space (CASES). Simulation results for control law design are presented. Results indicate that increased damping can be achieved for CASES. Author

A90-47584#
MODAL ANALYSIS AND ACTIVE VIBRATION CONTROL OF A SYSTEM OF A CANTILEVER BEAM AND A REACTION-MASS ACTUATOR
HUNG V. VU (California State University, Long Beach) and GWOCHEANG O. SHAW IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 73-78. refs
(AIAA PAPER 90-3322) Copyright

In this paper the dynamics and control of a system of a cantilever beam and a reaction-mass actuator are solved. By solving the eigenvalue problem, the frequency equation and mode shapes are derived. The orthogonality condition is also obtained for the system. Lagrange's equation is used to derive the differential equations for both undamped and damped cases. The closed-form solution of the undamped system subjected to external forces is obtained. While a numerical method is needed for calculating the forced response of the damped system. The differential equation in terms of generalized coordinates has to be transformed back into that of physical coordinates which need to be measured for feedback in control loop. The optimal feedback gains for the closed-loop system are calculated in case study. Author

A90-47585*# Case Western Reserve Univ., Cleveland, OH.
CONTROL/STRUCTURE INTERACTIONS OF FREEDOM'S SOLAR DYNAMIC MODULES
R. D. QUINN (Case Western Reserve University, Cleveland, OH) and I. YUNIS (Analex Corp., Cleveland, OH) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 79-88. Research supported by NASA. refs
(AIAA PAPER 90-3323) Copyright

The purpose of this paper is to address potential control/structures interaction (CSI) problems of large flexible multibody structures in the presence of pointing and tracking requirements. A control approach is introduced for the simultaneous tracking and vibration control of multibody space structures. The application that is discussed is Space Station Freedom configured with solar dynamic (SD) modules. The SD fine-pointing and tracking requirements may necessitate controller frequencies above the structural natural frequencies of Freedom and the SD modules. It is well known that this can give rise to CSI problems if the controller is designed without due consideration given to the structural dynamics of the system. In this paper, possible CSI problems of Freedom's solar dynamic power systems are demonstrated using a simple lumped mass model. A NASTRAN model of Freedom developed at NASA Lewis is used to demonstrate potential CSI problems and the proposed tracking and vibration control approach. Author

A90-47588#
OPTIMAL COMPENSATOR DESIGN WITH ONE RICATTI EQUATION
KRISTIN M. STRONG and JOHN R. SESAK (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 105-113.
(AIAA PAPER 90-3326) Copyright

This paper presents a newly observed functional relationship between the algebraic Riccati equations of optimal control and estimation theory employed in the control of flexible structures. This new relationship termed modal reciprocity shows that the matrix elements of the respective controller and estimator Riccati equations are directly related through simple algebraic gains that are proportional to powers of the modal frequencies or are unity. Modal reciprocity holds for collocated systems employing all velocity or all position feedback sensors. Consequently for systems of this class, one may completely eliminate one Riccati equation from the optimal compensator design process: the second Riccati equation solution is calculated algebraically from the first via a singular transformation matrix whose elements are known functions of the modal frequencies. This matrix can be calculated from open-loop data prior to solving the Riccati equation. Author

A90-47609#
PARAMETER SELECTION FOR MODEL REDUCTION USING MODIFIED COMPONENT COST ANALYSIS
JEFFREY D. BOOHER, JAYANT RAMAKRISHNAN (Dynacs Engineering Co., Inc., Clearwater, FL), and DAVID S. CHANG (Honeywell, Inc., Avionics Div., Clearwater, FL) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 316-327. refs
(AIAA PAPER 90-3349) Copyright

Large scale mechanical systems are composed of interconnected dynamic components. This paper seeks to simplify the model of each dynamic component so that the overall system is of manageable size. Models of components are reduced so as to approximate the response of all components and the nonworking constraint forces acting on all components. The modified component cost method seeks to decompose the norm of the response vector (in this case the response and the vector of nonworking constraint forces) into contributions of each coordinate of each component. The reduction methodology requires the selection of some parameters which emphasize quantities such as the steady state response to a step input. This paper deals with the parameters selection process and presents the best set of parameters for the specific problem and objective considered. Using these parameter values, the coordinates can be ranked according to their contribution and deleted accordingly. Author

A90-47610#
IDENTIFICATION OF A PRECISION SEGMENTED REFLECTOR
ERIC K. PARSONS (Lockheed Research Laboratories, Palo Alto, CA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 328-338. refs
(AIAA PAPER 90-3350) Copyright

A major example of control/structure interaction in future active optics occurs in precision segmented reflectors. The Advanced Structures/Controls Integrated Experiment (ASCIE) is designed as a testbed for controls/structures technology for such systems. The desire for greater performance motivates this research to model and verify the ASCIE dynamics. First, an analytical model of the open-loop dynamics of the segment alignment system is constructed from an FEM. This model predicts the modes that the alignment control would destabilize, which are critical for the control design. Subsequently, comparison of predicted and measured transfer functions indicates errors in the analytical model that adjustments to the FEM and system identification need to correct. Finally, the paper gives a brief description of a systematic approach for improving the ASCIE structural dynamic model.
Author

A90-47612*# Texas A&M Univ., College Station.
ATTITUDE CONTROL/MOMENTUM MANAGEMENT OF THE SPACE STATION FREEDOM FOR LARGE ANGLE TORQUE-EQUILIBRIUM-ATTITUDE CONFIGURATIONS
ALEXANDER G. PARLOS (Texas A & M University, College Station) and JOHN W. SUNKEL (NASA, Johnson Space Center, Houston, TX) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 348-358. refs
(Contract NAG9-347)
(AIAA PAPER 90-3352) Copyright

An attitude-control and momentum-management (ACMM) system for the Space Station in a large-angle torque-equilibrium-attitude (TEA) configuration is developed analytically and demonstrated by means of numerical simulations. The equations of motion for a rigid-body Space Station model are outlined; linearized equations for an arbitrary TEA (resulting from misalignment of control and body axes) are derived; the general requirements for an ACMM are summarized; and a pole-placement linear-quadratic regulator solution based on scheduled gains is proposed. Results are presented in graphs for (1) simulations based on configuration MB3 (showing the importance of accounting for the cross-inertia terms in the TEA estimate) and (2) simulations of a stepwise change from configuration MB3 to the 'assembly complete' stage over 130 orbits (indicating that the present ACCM scheme maintains sufficient control over slowly varying Space Station dynamics). T.K.

A90-47613#
SPACE STATION ATTITUDE CONTROL AND MOMENTUM MANAGEMENT - A NONLINEAR LOOK
S. R. VADALI (Texas A & M University, College Station) and H.-S. OH IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 360-368. Research supported by the Texas Advanced Research and Technology Program. refs
(AIAA PAPER 90-3353) Copyright

Nonlinear design procedures are presented for obtaining attitude and angular momentum control laws for the Space Station. These are based on Liapunov's second method for stability analysis. Various forms of attitude-control laws are derived using the fully coupled dynamic equations of motion, which include gravity-gradient torques. Next, the coupled attitude control and momentum management problem is addressed for a Station configuration that is gravity-gradient stable. Two methods are developed to control gravity-unstable configurations. The first method, called the successive stabilization method, stabilizes the attitude first and then combinations of attitude and momentum variables. The second method is based on system decomposition into two connected subsystems, the attitude controller and the momentum manager. Simulation results are presented for the Phase-1 configuration in the presence of constant disturbances. It is shown that the space station can be stabilized about a torque-equilibrium-attitude and the momentum of the control-moment gyroscopes is bounded in the presence of constant disturbances. Author

A90-47614#
FEEDBACK LINEARIZATION AND NONLINEAR ULTIMATE BOUNDNESS CONTROL OF THE SPACE STATION USING CMG
SAHJENDRA N. SINGH and THEODORE C. BOSSART (Nevada, University, Las Vegas) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 369-376. refs
(Contract DAAL03-87-G-0004)
(AIAA PAPER 90-3354) Copyright

Based on feedback linearization and ultimate boundedness theory, a new approach to attitude control of the Space Station using control-moment gyros (CMGs) is presented. A linearizing transformation is derived to obtain a simple linear representation of the nonlinear pitch-axis dynamics. A feedback control law for trajectory tracking is derived when there is no disturbance torque acting on the Space Station. For attitude control in the presence of uncertain torque input, an additional control signal is superimposed such that in the closed-loop system; attitude responses are uniformly ultimately bounded and tend to a small set of ultimate boundedness. Extension of this approach to linearization of the coupled yaw- and roll-axis dynamics and control is presented. Simulation results for the pitch-axis control are obtained to show that, in the closed-loop system, precise attitude control is achieved. Author

A90-47616#
BOUNDS ON PARAMETER UNCERTAINTY FOR PRESERVING A MINIMUM DAMPING RATIO OF A VIBRATION SUPPRESSION SYSTEM
TERRY R. ALT (McDonnell Douglas Space Systems Co., Huntington Beach, CA) and FARYAR JABBARI (California, University, Irvine) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 388-393. refs
(AIAA PAPER 90-3357) Copyright

Liapunov stability theory may be used to determine stability robustness bounds for linear systems with multiple uncertain parameters. Recently, this theory has been used to determine performance robustness bounds; e.g., preserving a minimum damping ratio. This theory is applied to evaluate performance robustness bounds for a vibration suppression system of a dual keel Space Station. Bounds on the variation of the modal frequencies are presented which guarantee a minimum damping ratio in all the bending modes included in the design model. Optimization over a positive definite matrix is carried out to remove as much conservatism as the technique allows. Also, upper bounds are calculated by a search method in order to show possible conservatism. Author

A90-47619*# Texas A&M Univ., College Station.
A NONLINEAR OPTIMIZATION APPROACH FOR DISTURBANCE REJECTION IN FLEXIBLE SPACE STRUCTURES
ALEXANDER G. PARLOS (Texas A & M University, College Station) and JOHN W. SUNKEL (NASA, Johnson Space Center, Houston, TX) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 414-424. refs
(Contract NAG9-275)
(AIAA PAPER 90-3361) Copyright

In this paper the design of an active control law for the rejection of persistent disturbances in large space structures is presented. The control system design approach is based on a deterministic model of the disturbances, with a model-based-compensator (MBC) structure, optimizing the magnitude of the disturbance that the structure can tolerate without violating certain predetermined constraints. In addition to closed-loop stability, the explicit treatment of state, control and control rate constraints, such as structural displacement, control actuator effort, and compensator time guarantees that the final design will exhibit desired performance characteristics. The technique is applied for the vibration damping of a simple two bay truss structure which is subjected to persistent disturbances, such as shuttle docking. Preliminary results indicate that the proposed control system can reject considerable persistent disturbances by utilizing most of the available control, while limiting the structural displacements to within desired tolerances. Further work, however, for incorporating additional design criteria, such as compensator robustness to be traded-off against performance specifications, is warranted. Author

A90-47639*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE STATION FREEDOM DISTURBANCE SIMULATION AND MANAGEMENT TOOL
SIMA S. LISMAN and DAVID B. RATHBUN (JPL, Pasadena, CA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 623-633. refs
(AIAA PAPER 90-3384) Copyright

The design and functions of the Disturbance Simulation and Management Tool, (DMST), a software package developed to evaluate the effects of design changes and disturbance inputs on the Space Station dynamic environment, are described. DMST is a menu-driven interactive package, written in the PRO-MATLAB, which incorporates methods such as FEM model reduction, mode synthesis, and discrete-time numerical simulation. Particular attention is given to the main-menu options, including building a payload and payload-pointing-system (PPS) configuration, selecting disturbance inputs, running PPS and lab-module microgravity-environment (MGE) simulations, calculating limits to meet PPS and MGE requirements, and performing MGE spectral analyses using power-spectral density or shock spectra. Typical numerical results are presented in graphs. T.K.

A90-47648#
EUROPEAN SPACE AGENCY ACTIVITIES ON SPACECRAFT CONTROL STRUCTURE INTERACTION
S. STORNELLI (ESTEC, Noordwijk, Netherlands) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug.

20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 698-706. refs
(AIAA PAPER 90-3393) Copyright

ESA spacecraft control structure interaction (SCSI) for future space vehicles is addressed in this paper. The objective is to give a brief control technology overview in SCSI with reference to guidance, navigation, and control systems for the past and future ESA missions. The discussion concentrates on those research and development activities related to control system design tools, with examples of application to multiarticulated payload platforms.
Author

A90-47677*# Illinois Univ., Urbana-Champaign.
ROBUST TRACKING OF A FLEXIBLE SPACECRAFT SUBJECT TO INDUCED DISTURBANCES AND PARAMETRIC UNCERTAINTIES
FAKHREDDINE KARRAY, THOMAS A. DWYER, III, and JINHO KIM (Illinois, University, Urbana) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 988-995. Research supported by SDIO. refs
(Contract F49620-87-C-0103; NAG1-613)
(AIAA PAPER 90-3423) Copyright

A variable structure control technique combined with an operator spline for bilinear systems is implemented to a fast moving deformable structure for purposes of achieving robust tracking performance. The control torque applied to the structure is based on estimates of the structure parameters and on upper bounds of the model errors. For a rapid rotation of the deformable structure, the elastic response can be modeled by oscillators driven by angular acceleration, where stiffness and damping coefficients are also angular velocity and acceleration dependent. By transforming this 'slew-driven' elastic dynamics into a bilinear form, an operator spline can be constructed, that gives a low order estimate of the induced disturbance. An upper bound between the estimated deformation and the unknown exact deformation is also generated, which can be used where required in the sliding control correction.
Author

A90-47679# Ford Aerospace Corp., Palo Alto, CA.
ON-ORBIT PARAMETER TUNING OF A DISTURBANCE COMPENSATOR
PETER Y. CHU (Ford Aerospace Corp., Palo Alto, CA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1006-1010. Research sponsored by NASA and NOAA. refs
(AIAA PAPER 90-3425) Copyright

Multiple slewing spacecraft payloads cause dynamic disturbances to the spacecraft and themselves. A centralized compensator uses the payload slew commands to calculate these interactions and moves the lines-of-sight of the payloads accordingly. This paper describes an on-orbit parameter identification procedure and algorithm that tunes the parameters of such a controller. The algorithm is a nonlinear least square fit based on the Levenberg-Marquardt algorithm. The scheme has been implemented for the GOES I-M satellites. Annual tunings are expected to reduce the residual errors by a factor of two.
Author

A90-47681*# Arizona State Univ., Tempe.
ACTIVE CONTROL SYNTHESIS FOR FLEXIBLE SPACE STRUCTURES EXCITED BY PERSISTENT DISTURBANCES
BONG WIE (Arizona State University, Tempe) and MARCELO GONZALEZ IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1022-1031. Research supported by NASA. refs
(AIAA PAPER 90-3427) Copyright

Both classical and state-space synthesis methods for active control of flexible space structures in the presence of persistent disturbances are presented. The methods exploit the so-called internal model principle for asymptotic disturbance rejection. A generic example of flexible space structures is used to illustrate the simplicity of the proposed design methodologies. The concept of a disturbance rejection filter dipole is introduced from a classical control viewpoint. It is shown that the proposed design methods will invariably make use of non-minimum-phase compensation for a class of noncolocated control problems. The need for tradeoffs between performance and parameter robustness is discussed.
Author

A90-47682*# Texas A&M Univ., College Station.
ACTIVE REJECTION OF PERSISTENT DISTURBANCES IN FLEXIBLE SPACE STRUCTURES
CHENG-NENG HWANG, SUHADA JAYASURIYA, ALEXANDER G. PARLOS (Texas A & M University, College Station), and JOHN W. SUNKEL (NASA, Johnson Space Center, Houston, TX) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1032-1041. refs
(Contract NAG9-347)
(AIAA PAPER 90-3428) Copyright

A dynamic compensator for active rejection of persistent disturbances in flexible space structures is designed on the principle of the H(infinity)-optimization of the sensitivity transfer function matrix. A general state space solution is formulated to the multiinput multioutput H(infinity)-optimal control problem, allowing the use of the H(infinity)-optimal synthesis algorithm for the state-space models of space structures that result from model order reduction. Disturbances encountered in flexible space structures, such as shuttle docking, are investigated using the high-mode and the reduced-order models of a cantilevered two-bay truss, demonstrating the applicability of the H(infinity)-optimal approach.
I.S.

A90-47714#
A MEASURE OF CONTROLLABILITY FOR ACTUATOR PLACEMENT
YOUDAN KIM and JOHN L. JUNKINS (Texas A & M University, College Station) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1329-1339. Research supported by Texas Advanced Technology Program. refs
(Contract F49620-87-C-0078)
(AIAA PAPER 90-3464) Copyright

A new measure of controllability for linear time invariant dynamical systems is introduced. The controllability measure is designed especially to guide the placement of actuators to control vibrating structures. An example is presented and the design of optimal feedback control laws for each of several actuator configurations supports the practical value of the new controllability measure.
Author

A90-47715#
ACTUATOR PLACEMENT IN STRUCTURAL CONTROL
K. CHOE and H. BARUH (Rutgers University, New Brunswick, NJ) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1340-1351. refs
(AIAA PAPER 90-3465) Copyright

The placement of force and torque actuators for structural control problems is considered. Objective functions are defined based on the elements of the actuator influence matrix and optimization studies are conducted. The performance of the control is compared. The results indicate that a relatively even distribution of the actuators gives satisfactory results, while a close spacing of the actuators leads to excessive fuel and energy use. In all cases, several evenly spaced actuator distributions are found to be suitable. In addition, torque actuators are found to be less desirable than force actuators, because they excite the higher

modes to a greater degree. The efficiency of piecewise-continuous actuators is analyzed. While piecewise-continuous actuators are more realistic models than point actuators and they reduce stress levels, if their contact area is too large they use more fuel.
Author

A90-47716*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A METHOD FOR OPTIMAL ACTUATOR AND SENSOR PLACEMENT FOR LARGE FLEXIBLE STRUCTURES
K. B. LIM (NASA, Langley Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1352-1360. refs
(AIAA PAPER 90-3466) Copyright
A method of finding the optimal sensor and actuator locations for the control of flexible structures has been developed. The method is based on the orthogonal projection of structural modes into the intersection subspace of the controllable and observable subspaces. The controllability and observability grammians are then used to weight the projections to reflect the degrees of controllability and observability. This method produces a three-dimensional design space wherein sets of optimal actuator and sensors may be selected. Author

A90-47717*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTEGRATION OF SYSTEM IDENTIFICATION AND ROBUST CONTROLLER DESIGNS FOR FLEXIBLE STRUCTURES IN SPACE
JER-NAN JUANG and JIANN-SHIUN LEW (NASA, Langley Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1361-1375. refs
(AIAA PAPER 90-3467) Copyright
A novel approach is developed using experimental data from the structural testing of a physical system to identify a reduced-order model and its error for a robust controller design. There are three steps involved in the approach. First, an approximately balanced model is identified using the eigensystem realization algorithm, which is an identification algorithm. Second, the model error is calculated and described in frequency domain in terms of the H(infinity) norm. Third, a pole-placement technique in combination with an H(infinity) control method is applied to design a controller for the system. A set of experimental data from an existing setup, namely the Mini-Mast system, is used to illustrate and verify the approach development in this paper.
Author

A90-47718*# Texas Univ., Austin.
APPLICATION OF A PERIODIC LATTICE FILTER FOR IDENTIFYING A FLEXIBLE STRUCTURE
YOUNG JAE LEE and JASON L. SPEYER (Texas, University, Austin) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1376-1386. Research supported by NASA. refs
(AIAA PAPER 90-3468) Copyright
Lattice filters have properties which make them attractive for the application to the identification of the parameters of flexible structures. Here, the problem of both order and parameter estimation is addressed, where the numerical difficulties of an embedded lattice filter are avoided by applying a periodic lattice filter. With this formulation, it is quite natural to estimate system order by applying Akaike's (1976) information criterion to each channel of the periodic lattice filter. Several examples including nonstationary cases are simulated to demonstrate these facts.
Author

A90-47719*# Old Dominion Univ., Norfolk, VA.
DISTRIBUTED PARAMETER ESTIMATION FOR LARGE BEAM-LIKE STRUCTURES FOR GENERAL INPUTS
JI-YAO SHEN, JEN-KUANG HUANG (Old Dominion University, Norfolk, VA), and LAWRENCE W. TAYLOR, JR. (NASA, Langley Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1387-1395. refs
(AIAA PAPER 90-3469) Copyright
In this paper, maximum likelihood estimation for distributed parameter models of large flexible structures has been formulated. Distributed parameter models involve far fewer unknown parameters than independent modal characteristics of finite element models. The closed-form solutions for the partial differential equations with general forced inputs have been derived. The closed-form expressions of the sensitivity functions lead to highly efficient algorithms for analyzing ground or on-orbit test results. Numerical simulations with impulse and step inputs to the NASA Mini-MAST trust have been demonstrated. The estimations of modal properties involve its longitudinal elongation modes, lateral bending modes and torsional modes. The results show that distributed parameter models are promising in the parameter estimation of large flexible structures. Author

A90-47720*# Old Dominion Univ., Norfolk, VA.
INTEGRATED SYSTEM IDENTIFICATION AND MODAL STATE ESTIMATION FOR CONTROL OF FLEXIBLE SPACE STRUCTURES
CHUNG-WEN CHEN, JEN-KUANG HUANG (Old Dominion University, Norfolk, VA), MINH PHAN, and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1396-1404. refs
(AIAA PAPER 90-3470)
A novel approach of integrated system identification and modal state estimation is proposed for control of linear dynamical systems including flexible space structures. There are four steps involved in this approach. First, the relation between a stochastic state space model of a dynamical system and the coefficients of its autoregressive model with exogenous input is derived. Second, an adaptive least-squares transversal predictor is used to estimate the coefficients of the model. Third, a state space model and a steady state Kalman filter gain of the dynamical system are then identified from the coefficients of the model by using the eigensystem realization algorithm. Fourth, a modal state estimator is constructed using the modal parameters of the identified model. On-line implementation of this algorithm can continually improve the modal parameters and the filter gain. It can also gradually update the system model when the system characteristics are slowly changing. A numerical example is used to illustrate the feasibility of the new approach. Author

A90-47724*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST EIGENSYSTEM ASSIGNMENT FOR STATE ESTIMATORS USING SECOND-ORDER MODELS
JER-NAN JUANG and PEIMAN G. MAGHAMI (NASA, Langley Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1428-1438. refs
(AIAA PAPER 90-3474) Copyright
A novel design of a state estimator is presented using second-order dynamic equations of mechanical systems. The eigenvalues and eigenvectors of the state estimator are assigned by solving the second-order eigenvalue problem of the structural system. Three design method for the state estimator are given in this paper. The first design method uses collocated sensors to measure the desired signals and their derivatives. The second design method uses prefilters to shift signal phases to obtain

estimates of the signal derivatives. These two methods are used to build a second-order state estimator model. The third design method is the conventional one which converts a typical second-order dynamic model to a first-order model, and then builds a state estimator based on the first-order model. It is shown that all the three designs for state estimation are similar. A numerical example representing a large space structure is given for illustration of the design methods presented in this paper. Author

A90-47742*# Harris Corp., Melbourne, FL.
FOUR EXPERIMENTAL DEMONSTRATIONS OF ACTIVE VIBRATION CONTROL FOR FLEXIBLE STRUCTURES
DOUG PHILLIPS and EMMANUEL G. COLLINS, JR. (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1625-1633. refs
(Contract F49620-87-C-0108; NAS1-18872)
(AIAA PAPER 90-3496) Copyright

Laboratory experiments designed to test prototype active-vibration-control systems under development for future flexible space structures are described, summarizing previously reported results. The control-synthesis technique employed for all four experiments was the maximum-entropy optimal-projection (MEOP) method (Bernstein and Hyland, 1988). Consideration is given to: (1) a pendulum experiment on large-amplitude LF dynamics; (2) a plate experiment on broadband vibration suppression in a two-dimensional structure; (3) a multiple-hexagon experiment combining the factors studied in (1) and (2) to simulate the complexity of a large space structure; and (4) the NASA Marshall ACES experiment on a lightweight deployable 45-foot beam. Extensive diagrams, drawings, graphs, and photographs are included. The results are shown to validate the MEOP design approach, demonstrating that good performance is achievable using relatively simple low-order decentralized controllers. T.K.

A90-47743#
STRUCTURAL CONTROL EXPERIMENTS USING AN H(INFINITY) POWER FLOW APPROACH
DOUGLAS G. MACMARTIN and STEVEN R. HALL (MIT, Cambridge, MA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1634-1644. refs
(Contract AF-AFOSR-88-0029)
(AIAA PAPER 90-3497) Copyright

Experimental results are presented comparing velocity feedback with a new technique for designing guaranteed stable control laws for uncertain modally dense structures with collocated sensors and actuators. A dereverberated mobility model is used, which is similar in many respects to a wave-based model but can treat more general structures. The power dissipated by the controller can be maximized in either an H2 or an H(infinity) sense. The H(infinity) approach guarantees that the controller is positive real, and thus that the system will remain stable for any uncertainty, provided that the power flow is correctly modeled. The experimental results indicate that the controllers designed with this approach are much more effective than simple collocated rate feedback. Author

A90-47744*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
EXPERIMENTAL STUDY OF ROBUSTNESS IN ADAPTIVE CONTROL FOR LARGE FLEXIBLE STRUCTURES
CHE-HANG CHARLES IH, DAVID S. BAYARD, ASIF AHMED, and SHYH JONG WANG (JPL, Pasadena, CA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1645-1656. Research sponsored by USAF. refs
(AIAA PAPER 90-3498) Copyright

An experimental study is performed to investigate the robustness of model reference adaptive control for the large flexible structures control application. The main nonidealities of concern are unmodeled dynamics, input saturation, and time delay effects (here, actuator and sensor dynamics are lumped into the last item for convenience). This study focuses on the robustness with respect to input saturation and time delay effects, since robustness to unmodeled dynamics is inherent to the basic algorithm and has been demonstrated experimentally elsewhere. Author

A90-47745#
OPTIMAL PASSIVE CONTROL OF MULTI-DEGREE OF FREEDOM SYSTEMS USING A VIBRATION ABSORBER
JOHN P. DUKE, STEVEN WEBB (USAF, Frank J. Seiler Research Laboratory, Boulder, CO), and HUNG VU (California State University, Long Beach) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1657-1663. Research supported by USAF. refs
(AIAA PAPER 90-3499)

This paper presents two approaches for the optimal design of a vibration absorber for use on multi-degree of freedom systems. The first approach directly extends a well-known vibration absorber theory by treating the critical mode of vibration as a sigle-degree-of-freedom system provided that mode is dominate in one of the degrees of freedom. In the second approach, a more general view is taken using numerical optimization to account for the fact that several modes can contribute to the oscillations of some critical point in the system. Both methods provide effective means of determining optimal passive vibration absorbers for multi-degree of freedom systems. Author

A90-47746#
ANALYSIS OF A PASSIVELY TUNED ACTUATOR ON A LOW-ORDER STRUCTURE
STEVEN WEBB and JEFFREY S. TURCOTTE (U.S. Air Force Academy, Colorado Springs, CO) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1664-1672. Research sponsored by USAF. refs
(AIAA PAPER 90-3500)

The interactions between a passively-tuned-reaction mass actuator and a low-order structure to which the actuator was attached are studied analytically and experimentally. The extent to which a passively tuned actuator reduces structure vibrations is studied as well as the sensitivity of the structure to a mistuned actuator. The question of whether or not a tuned actuator dampens the vibrations throughout the entire structure or just at particular locations on the structure is addressed. It is concluded that a reaction mass actuator, which is passively tuned to the optimum frequency and damping ratio of the structure's first resonant mode, does in fact reduce the peak amplitude ratios of the structure's first few resonant modes. K.K.

A90-47760*# Columbia Univ., New York, NY.
OPTIMIZATION OF ACTUATOR AND SENSOR PLACEMENT FOR ON-ORBIT IDENTIFICATION IN LARGE FLEXIBLE SPACECRAFT
MARTIN BERGMANN, RICHARD W. LONGMAN (Columbia University, New York), and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1785-1793. refs
(Contract NAG1-649)
(AIAA PAPER 90-3516) Copyright

There has been considerable research on choosing actuator and sensor locations in large flexible spacecraft in order to optimize the controllability and observability of the system, or to maximize some objective function of control system performance. Future large flexible spacecraft may require on-orbit identification of the structure to tune the control system, because such tests cannot

be performed in a one-g environment before launch. This indicates that the choice of actuator and sensor locations must serve a dual purpose, for control and for identification. This paper develops concepts for a degree of identifiability and studies placement of actuators and sensors on a free-free beam to optimize such objective functions. The results in this simple situation suggest that in free-free spacecraft structures in orbit, placement for control and placement for identification may often be consistent objectives rather than conflicting objectives. Author

A90-49793#
CORRECTING FINITE ELEMENT MODELS USING A SYMMETRIC EIGENSTRUCTURE ASSIGNMENT TECHNIQUE
D. C. ZIMMERMAN (Florida, University, Gainesville) and M. WIDENGREN (Kungliga Tekniska Hogskolan, Stockholm, Sweden) AIAA Journal (ISSN 0001-1452), vol. 28, Sept. 1990, p. 1670-1676. refs
Copyright

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

A90-49794#
INTEGRATED DIRECT OPTIMIZATION OF STRUCTURE/REGULATOR/OBSERVER FOR LARGE FLEXIBLE SPACECRAFT
JUNJIRO ONODA and NAOYUKI WATANABE (Institute of Space and Astronautical Science, Kanagawa, Japan) AIAA Journal (ISSN 0001-1452), vol. 28, Sept. 1990, p. 1677-1685. Previously cited in issue 12, p. 1796, Accession no. A89-30792. refs
Copyright

A90-50410
THE INFLUENCE OF LUMPED ROTARY INERTIA IN FLEXIBLE MULTIBODY DYNAMICS
HAO-JAN LAI and BERNHARD DOPKER (Iowa, University, Iowa City) Mechanics of Structures and Machines (ISSN 0890-5452), vol. 18, no. 2, 1990, p. 197-210. refs
(Contract DAAE07-85-CR-05)
Copyright

A computational method for dynamic analysis of flexible multibody mechanisms is presented that extends lumped mass models to account for the influence of lumped rotary inertia. In order to account for the effect of lumped rotary inertia, a diagonal mass matrix is evaluated and the equations of motion are derived for a general diagonal mass matrix. The system equations of motion of a constrained mechanism are systematically assembled. Numerical results for a hollow pipe are compared to a finite element solution to demonstrate the accuracy of the approach. A wheeled vehicle example is presented to demonstrate the influence of lumped rotary inertia in a large-scale dynamic system. Author

A90-50504
OPTIMUM DESIGN OF SPACE STRUCTURES WITH ACTIVE AND PASSIVE DAMPING
RAMANA V. GRANDHI (Wright State University, Dayton, OH) Engineering with Computers (ISSN 0177-0667), vol. 6, Summer 1990, p. 177-183. refs
(Contract F33615-88-C-3204)
Copyright

This paper investigates the effects of passive damping on the optimum structural design with active controllers. An integrated design of structure and active control system is performed. The minimum weight design is obtained by imposing constraints on the closed-loop damping and the imaginary part of the closed-loop eigenvalues of the active control system. The mathematical optimization problem is solved by using the NEWSUMT-A program, which is based on quadratic extended interior penalty function method. The ACOSS-FOUR model is selected for the numerical studies. The active control effort, performance index, and optimum weights are presented as a function of the passive damping. Author

A90-50541* Catholic Univ. of America, Washington, DC.
ACTIVE CONTROL OF A FLEXIBLE STRUCTURE USING A MODAL POSITIVE POSITION FEEDBACK CONTROLLER
S. POH and A. BAZ (Catholic University of America, Washington, DC) Journal of Intelligent Material Systems and Structures (ISSN 1045-389X), vol. 1, July 1990, p. 273-288. Previously announced in STAR as N90-17371. refs
(Contract NAG5-749)
Copyright

The feasibility of a new Modal Positive Position Feedback (MPPF) strategy in controlling the vibration of a complex flexible structure using a single piezo-electric active structural member is demonstrated. The control strategy generates its control forces by manipulating only the modal position signals of the structure to provide a damping action to undamped modes. This is in contrast to conventional modal controllers that rely in their operation on negative feedback of both the modal position and velocity. The proposed strategy is very simple to design and implement as it designs the controller at the uncoupled modal level and utilizes simple first order filters to achieve the Positive Position Feedback effect. The performance of the new strategy is enhanced by augmenting it with a time sharing strategy to share a small number of actuators between larger number of modes. The effectiveness of the new strategy is validated experimentally on a flexible box-type structure that has four bays and its first two bending modes are 2.015 and 6.535 Hz, respectively. A single piezo-electric actuator is utilized as an active structural member to control several transverse bending modes of the structure. The performance of the active control system is determined in the time and the frequency domains. The results are compared with those obtained when using the Independent Modal Space Control (IMSC) of Meirovitch. The experimental results suggest the potential of the proposed strategy as a viable means for controlling the vibration of large flexible structures in real time. Author

A90-50542* Duke Univ., Durham, NC.
EFFECT OF JOINT IMPERFECTIONS ON STATIC CONTROL OF ADAPTIVE STRUCTURES AS SPACE CRANES
A. V. RAMESH, SENOL UTKU (Duke University, Durham, NC), B. K. WADA, and G. S. CHEN (JPL, Pasadena, CA) Journal of Intelligent Material Systems and Structures (ISSN 1045-389X), vol. 1, July 1990, p. 309-326. refs
(Contract NAS7-100)
Copyright

Effect of imperfections in the joints of an adaptive structure on its slow (no inertia forces) motion along a prescribed trajectory as a space crane is studied. Two mathematical models to predict the effect of joint imperfections are proposed. The two models are used to obtain estimates of the deviations of the node of the space crane to which the end-effector is attached, from its prescribed trajectory. An application of the models to a two-section space crane is given. Author

A90-52009
TRANSIENT FINITE ELEMENT COMPUTATIONS ON 65536 PROCESSORS - THE CONNECTION MACHINE
C. FARHAT, N. SOBH, and K. C. PARK (Colorado, University, Boulder) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 30, July 1990, p. 27-55. refs
(Contract N00014-87-K-2018; NSF ASC-87-17773)
Copyright

The parallel implementation of FEM mechanical analysis programs on the Connection Machine (CM-2) is described and demonstrated. The hardware architecture of the CM-2 is characterized and illustrated with diagrams; benchmark performance data are summarized; the parallel data structures encountered in FEM problems are reviewed; and the

decomposition/mapping strategy is outlined. The flow chart of a massively parallel transient simulation is then given, and results are presented graphically for sample problems involving (1) the transient response of a cracked Al plate, (2) wave propagation in a three-dimensional bar, (3) the vibrations induced in the Space Station by Space Shuttle docking, and (4) wave propagation in a three-dimensional glassy bar on an elastic foundation. It is found that the MIMD programming features which arise as a result of mesh irregularities have a detrimental effect on performance because the CM-2 is an SIMD machine. T.K.

A90-52010
DYNAMICS OF GENERAL FLEXIBLE MULTIBODY SYSTEMS
RAY P. S. HAN and ZHI CHENG ZHAO (Manitoba, University, Winnipeg, Canada) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 30, July 1990, p. 77-97. Research supported by NSERC. refs
Copyright

A general treatment is presented for modeling the dynamics of a flexible multibody system, using a lumped-mass FEM approach. The system topology is defined as an arbitrary combination of both rigid and flexible bodies, connected together by joints that permit translation and compliance, in a general tree configuration. An extension to handle closed-loop kinematic chains is also indicated. Kane's theory of generalized speeds is used to derive the equations of motion, and this results in a very efficient computer-oriented methodology for solving the dynamics of such large mechanical systems. The dynamical equations are transformed into a system of first-order differential equations for an explicit formulation of the problem. Results for three examples with known solutions indicate that the method is accurate, efficient, and versatile for the analysis of a general flexible multibody system. Author

A90-52752
MOTION CONTROL OF SPACE STRUCTURES
LARRY SILVERBERG (North Carolina State University, Raleigh) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 3, Oct. 1990, p. 223-234. refs
Copyright

A new area of civil engineerng is emerging as we begin to establish a permanent presence in space. The new area of civil engineering is the motion control of space structures. This paper describes why the motion control of space structures is fundamentally a civil engineering problem. Author

A90-52755
SPACE STRUCTURES - ISSUES IN DYNAMICS AND CONTROL
H. BENAROYA (Rutgers University, Piscataway, NJ) and M. L. NAGURKA (Carnegie-Mellon University, Pittsburgh, PA) Journal of Aerospace Engineering (ISSN 0893-1321), vol. 3, Oct. 1990, p. 251-270. refs
Copyright

A selective technical overview is presented on the vibration and control of large space structures, the analysis, design, and construction of which will require major technical contributions from the civil/structural, mechanical, and extended engineering communities. The immediacy of the U.S. Space Station makes the particular emphasis placed on large space structures and their control appropriate. The Space Station is but one part of the space program, and includes the lunar base, which the Space Station is to service. This paper attempts to summarize some of the key technical issues and hence provide a starting point for further involvement. The first half of this paper provides an introduction and overview of large space structures and their dynamics; the latter half discusses structural control, including control-system design and nonlinearities. A crucial aspect of the large space structures problem is that dynamics and control must be considered simultaneously; the problems cannot be addressed individually and coupled as an afterthought. Author

A90-52998#
VIBRATION CONTROL OF SPACECRAFT APPENDAGES THROUGH BASE MOTION
A. K. MISRA (McGill University, Montreal, Canada) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 431-437. Research supported by NSERC and McGill University.
(AIAA PAPER 90-2917) Copyright

The paper explores the possibility of suppressing the vibrations of spacecraft appendages by applying a translatory motion at its point of attachment (or base). Both constant length appendages as well as appendages during extension or retraction are considered. The base acceleration plays the role of a single input to the system. If it is comprised of an appropriate feedback of the generalized velocities, the appendage vibrations can be suppressed. Author

A90-52999#
ACTIVE VIBRATION CONTROL OF AN INVERTED CANTILEVER BEAM WITH END MASS
ROBERT A. CALICO, JR. (USAF, Institute of Technology, Wright-Patterson AFB, OH) and DAVID R. JACQUES IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 438-448.
(AIAA PAPER 90-2918) Copyright

An experiment is described for active control of structural vibrations. It consists of an inverted cantilever beam with rectangular cross section. Proof mass actuators mounted on the free end of the beam, and a structural dynamics shaker mounted at a midpoint on the beam provide the control force inputs. The integrated output of beam mounted accelerometers provide velocity feedback, and a programmable controller allows different control algorithms to be easily implemented. Several optimal controllers were implemented, and modal suppression techniques were demonstrated. Experimental results are compared to analytical predictions. Author

A90-53000#
TRANSMISSION ZEROS AND HIGH-AUTHORITY/LOW-AUTHORITY CONTROL OF FLEXIBLE SPACE STRUCTURES
TREVOR WILLIAMS (Cincinnati, University, OH) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 449-454. refs
(AIAA PAPER 90-2919) Copyright

Flexible space structures generally have very low levels of inherent damping. This makes the problem of controlling such systems quite challenging; for instance, unmodelled modes can easily be made unstable by spillover effects. One way of avoiding these difficulties is to use a low-authority control loop to simply increase structural damping, typically to 5-10 percent of critical, and then use a more sophisticated high-authority control loop to achieve the desired control objectives. A very important design question that then arises is: where should the dampers which are used to implement the low-authority controller be placed in order to give the best possible overall closed-loop performance? This question is studied here, and it is shown that it is more important to increase the damping of the zeros of the damping-augmented structure than that of the poles. A simple algorithm is then derived for determining the damper locations which make the zeros as heavily damped as possible. Finally, the operation of this algorithm is illustrated by application to a simple cantilever beam example. Author

A90-53001*# Illinois Univ., Urbana.
APPLICATION OF THE OPERATOR SPLINE TECHNIQUE TO NONLINEAR ESTIMATION AND CONTROL OF MOVING ELASTIC SYSTEMS
FAKHREDDINE KARRAY and THOMAS A. W. DWYER, III (Illinois, University, Urbana) IN: AIAA/AAS Astrodynamics Conference,

Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 455-460. Research supported by SDIO. refs
(Contract F49620-87-C-0103; NAG1-613)
(AIAA PAPER 90-2920) Copyright

A bilinear model of the vibrational dynamics of a deformable maneuvering body is described. Estimates of the deformation state are generated through a low dimensional operator spline interpolator of bilinear systems combined with a feedback linearized based observer. Upper bounds on error estimates are also generated through the operator spline, and potential application to shaping control purposes is highlighted. Author

A90-53012#
COLLABORATIVE ATTITUDE CONTROL FOR MULTI-BODY PLATFORMS
NORMAN G. FITZ-COY (Control Dynamics Co., Huntsville, AL) and JOHN E. COCHRAN, JR. (Auburn University, AL) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 552-559. refs
(AIAA PAPER 90-2929) Copyright

A method for determining control strategies for decentralized control of multi-body spacecraft is presented. The method is based on a 2-player, linear, nonzero-sum, differential game. A Nash strategy is used to obtain necessary conditions under which each of the two controllers minimize a quadratic performance index using output feedback of information on the system state and knowledge of the other controller's current activity. The control action for linear dynamics and linear control is determined by the solutions to two coupled matrix, algebraic Riccati equations. An algorithm for finding the required solution is given. The method is illustrated by applying it to obtain control strategies for two controllers of a multi-body system representative of a platform with multiple pointing payloads. Author

A90-53013#
DYNAMICS AND CONTROL OF MULTIBODY SYSTEMS - AN APPROACH TO FORMULATION AND IMPLEMENTATION
V. J. MODI, A. SULEMAN, and A. NG (British Columbia, University, Vancouver, Canada) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 560-570. refs
(Contract NSERC-STR-32682)
(AIAA PAPER 90-2985) Copyright

A relatively general formulation for studying the dynamics of an arbitrary spacecraft with interconnected flexible bodies is developed accounting for transient system inertias, shift in the center of mass, shear deformations, rotary inertias and geometric nonlinearities. The computer implementation has been carried out through symbolic manipulation of the equations of motion. Versatility of the formulation is illustrated through simulation of the dynamics of one of the evolving Space Station configurations. Author

A90-53014#
ON THE CONTROL OF THE SCOLE TYPE FLEXIBLE MULTIBODY SYSTEM
Y. MORITA and V. J. MODI (British Columbia, University, Vancouver, Canada) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 571-579.
(AIAA PAPER 90-2930) Copyright

For studying dynamics of space based multilink structures, a relatively general formulation has been developed in an efficient fashion. It is applied to the Shuttle-based large reflector antenna system as proposed in the NASA design challenge. The Shuttle attitude and the antenna mast vibration are controlled through the Shuttle's primary and vernier thrusters, a set of actuators located on the mast, and joint rotation. Three different control strategies of centralized and decentralized forms are developed in which the optimal linear quadratic regulator theory and the direct velocity feedback principle are employed. The results reveal the complex system dynamics and effectiveness of the proposed controllers. Author

A90-53015*# Howard Univ., Washington, DC.
THE EFFECT OF ADDITIONAL DESIGN PARAMETERS ON THE LQR BASED DESIGN OF A CONTROL/STRUCTURAL SYSTEM
PETER M. BAINUM and JIANKE XU (Howard University, Washington, DC) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 580-586. refs
(Contract NSG-1414)
(AIAA PAPER 90-2931) Copyright

A multiobjective cost function that includes a form of the standard LQR regulator cost and its partial variation with respect to the additional design parameters is presented in connection with the design of an orbiting control/structural system. Simple models of uniform solid and tubular beams are demonstrated with two typical additional payload masses, i.e., symmetrically distributed and asymmetrically distributed, with respect to the center of the beam. By regarding the transient response of pitch angle and free-free beam deformations in the orbital plane, the optimal outer diameter of the beam and all feedback control can be determined by numerical analysis with this multicriterial approach. It is concluded that the multicriteria design approach should give better results from both the structural designer's and the control designer's standpoints. R.E.P.

A90-53029#
TRANSFORM METHODS FOR PRECISION CONTINUUM AND CONTROL MODELS OF FLEXIBLE SPACE STRUCTURES
VICTOR D. LUPI (MIT, Cambridge, MA), JAMES D. TURNER, and HON M. CHUN (Photon Research Associates, Inc., Cambridge, MA) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 680-689. refs
(Contract F49620-89-C-0082)
(AIAA PAPER 90-2946) Copyright

An open loop optimal control algorithm is developed for general flexible structures, based on Laplace transform methods. A distributed parameter model of the structure is first presented, followed by a derivation of the optimal control algorithm. The control inputs are expressed in terms of their Fourier series expansions, so that a numerical solution can be easily obtained. The algorithm deals directly with the transcendental transfer functions from control inputs to outputs of interest, and structural deformation penalties, as well as penalties on control effort, are included in the formulation. The algorithm is applied to several structures of increasing complexity to demonstrate its generality. Author

A90-53032#
DYNAMICS OF THE ANTENNA POINTING CONTROL SYSTEM WITH FLEXIBLE STRUCTURES
MASAZUMI UEBA (NTT, Radio Communication Systems Laboratories, Yokosuka, Japan) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 704-711. refs
(AIAA PAPER 90-2951) Copyright

This paper describes the dynamics of the antenna pointing control system with flexible structures of onboard large antennas for multibeam communication satellites. A method is clarified for deriving the dynamics of a 3.5-m-diameter flexible large antenna reflector and a flexible support boom with a driven mechanism on its tip. Two important coupling coefficients, between a rigid-satellite main body and a flexible main reflector and between a driven subreflector and a support boom, are shown. The effect of the critical structural parameters on the antenna pointing control system is also evaluated. Author

N90-20119 Virginia Polytechnic Inst. and State Univ., Blacksburg.
DISCRETE-TIME CONTROL OF A SPACECRAFT WITH RETARGETABLE FLEXIBLE ANTENNAS Ph.D. Thesis
MARTIN ERNEST BARTEA FRANCE 1989 132 p
Avail: Univ. Microfilms Order No. DA8922350

The discrete-time control of a spacecraft consisting of a rigid-platform with retargetable flexible antennas is considered. The mission consists of independent minimum-time manuevers of each antenna to coincide with predetermined lines of sight, while the platform is stabilized in an inertial space and elastic vibration of the antennas is suppressed., A discrete-time approach permits consideration of the time-varying nature of the system in designing the control law. Both global and decentralized controls are proposed for a noise-free system with full-state feedback. Initially, a time-varying linear quadratic regulator (LQR) is implemented, followed by two types of decentralized controllers. First, a collocated control law is devised in which actuator forces are based on the position and velocity at the actuator locations. Next, a new method called Substructure Decentralized Control (SDC) is proposed, where each flexible substructure is controlled based on state measurements associated with the substructure modes of the separately modeled appendages. In both global and decentralized cases, a linear control law is first implemented coupled with an open-loop disturbance-accommodating control based on the known inertial disturbances caused by the maneuver. Elastic motion is next controlled using non-linear (on-off) antenna controllers for each decentralized case. For SDC, the controls translate into quantized actual controls. Lastly, nonlinear (on-off) control laws are also used to control the rigid-body motion for each case. The problem of controlling the time-varying system in the presence of noisy actuators and sensors is also examined.
Dissert. Abstr.

N90-20123# Michigan Univ., Ann Arbor. Dept. of Electrical Engineering and Computer Science.
AIMING CONTROL: THEORY AND APPLICATIONS TO DYNAMIC CONTROL OF SPACE STRUCTURES Annual Report, 1 Aug. 1988 - 31 Jul. 1989
SEMYON M. MEERKOV 15 Jul. 1989 90 p
(Contract F49620-87-C-0079; AF PROJ. 2304)
(AD-A217877; AFOSR-90-0035TR) Avail: NTIS HC A05/MF A01 CSCL 22/1

The goal of the project as a whole is the investigation of fundamental bounds on the maximal achievable precision of aiming of dynamical systems with random perturbations and application of these bounds to control of space structures. To this end, during the second year of the project the following results were obtained: it has been shown that linear systems with small additive noise can be pointed with any desired accuracy by output feedback if and only if the system is invertable and minimum phase in an approximate sense; when the measurements noise is present, the maximal achievable precision of aiming is bounded, even if the conditions mentioned above are satisfied; thus, the measurement noise has a more severe effect on the pointability of dynamical system than the input noise. In addition, the problem of residence probability control has been investigated and its relation to the problem of residence time control was analyzed. GRA

N90-20125# Air Force Inst. of Tech., Wright-Patterson AFB, OH.
DISCRETE-TIME CONTROL OF A SPACECRAFT WITH RETARGETABLE FLEXIBLE ANTENNAS Ph.D. Thesis
MARTIN E. FRANCE 25 May 1989 134 p
(AD-A218345; AFIT/CI/CIA-89-070) Avail: NTIS HC A07/MF A01 CSCL 22/2

The discrete time control of a spacecraft consisting of a rigid platform with retargetable flexible antennas is considered. The mission consists of independent minimum time maneuvers of each antenna to coincide with predetermined lines of sight, while the platform is stabilized in an inertial space and elastic vibration of the antennas is suppressed. The system is governed by a set of linearized time varying equations of motion. A discrete time approach permits consideration of the time varying nature of the system in designing the control law. Both global and decentralized controls are proposed for a noise free system with full state feedback. Initially, a time varying linear quadratic regulator (LQR) is implemented, followed by two types of decentralized controllers. GRA

N90-20433# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.
SENSOR AND ACTUATOR SELECTION FOR FAULT-TOLERANT CONTROL OF FLEXIBLE STRUCTURES Ph.D. Thesis
WILLIAM NEIL MCCASLAND Feb. 1989 194 p Sponsored by AFIT Prepared in cooperation with Draper (Charles Stark) Lab., Inc., Cambridge, MA
(AD-A217384; AFIT/CI/CIA-88-227; CSDL-T-1010) Avail: NTIS HC A09/MF A01 CSCL 20/11

Control system design for structural dynamics requires instrumenting the structure with sensors and actuators, the effectiveness of which depends strongly on spatial position. For the long duration missions typical of spacecraft, the possibility of failures must be considered and coverage provided for with redundancy and a reconfiguration strategy. To support these, it is mandatory that sensors and actuators be located such that sufficient controllability and observability of the flexible dynamics is assured in the presence of failures. A systematic procedure is developed for finding such configurations of sensors and actuators for large scale systems. Norms on the controllability and observability open loop Gramian are taken as an index for optimization. The control objectives are reflected by truncating the time interval over which the Gramian is defined, and by scaling the state basis with respect to a normalizing, or reference, signal path. GRA

N90-21062*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NASA/DOD CONTROLS-STRUCTURES INTERACTION TECHNOLOGY 1989
JERRY R. NEWSOM, comp. Washington Aug. 1989 543 p Conference held in San Diego, CA, 29 Jan. - 2 Feb. 1989; sponsored by NASA Langley Research Center, Hampton, VA and Wright Research Development Center, Wright-Patterson AFB, OH
(NASA-CP-3041; L-16602; NAS 1.55:3041) Avail: NTIS HC A23/MF A03 CSCL 22/2

The purpose of this conference was to report to industry, academia, and government agencies on the current status of controls-structures interaction technology. The agenda covered ground testing, integrated design, analysis, flight experiments, and concepts.

N90-21065*# Martin Marietta Aerospace, Denver, CO.
PACOSS PROGRAM STATUS AND RESULTS
K. E. RICHARDS, JR. *In* NASA, Langley Research Center, NASA/DOD Controls-Structure Interaction Technology 1989 p 31-65 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

Future large space systems (LSS), both civilian and military, will have performance objectives which require stringent pointing accuracies, relatively fast retargeting times, short settling times, accurate dynamic shape requirements, or combinations thereof. Many of these structures will be large but lightweight and will exhibit a dense, low-frequency modal spectrum with significant content within the control bandwidth. Although it is possible in principle to achieve structural vibration control with purely active means, experience with complex structures has shown that the realities of plant model inaccuracies and real sensor and actuator dynamics frequently combine to produce disappointing results. It was shown that a combination of passive and active control will result in a simpler system which can be expected to be more reliable and less expensive than a corresponding system utilizing active control exclusively. The goals of the Passive and Active Control of Space Structures (PACOSS) program consist of a thorough investigation of the relative roles of passive active

vibration control, and the development of validated means of vibration control. The program approach, representative system article, dynamic test article, and test status and results are outlined. Author

N90-21066*# *Jet Propulsion Lab., California Inst. of Tech.,* Pasadena.
VIBRATION ISOLATION VERSUS VIBRATION COMPENSATION ON MULTIPLE PAYLOAD PLATFORMS
S. W. SIRLIN *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 67-81 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

There are many future science instruments with high performance pointing (sub microradian) requirements. To build a separate spacecraft for each payload is prohibitively expensive, especially as not all instruments need to be in space for a long duration. Putting multiple payloads on a single basebody that supplies power, communications, and orbit maintenance is cheaper, easier to service, and allows for the spacecraft bus to be reused as new instruments become available to replace old instruments. Once several payloads are mounted together, the articulation of one may disturb another. The situation is even more extreme when the basebody serves multiple purposes, such as space station which has construction, satellite servicing, and man motion adding to the disturbance environment. The challenge then is to maintain high performance at low cost in a multiple payload environment. The goal is to supply many future science instruments with high performance pointing (sub microradian). The options are independent spacecraft for each payload (expensive); or multiple payloads on a single basebody (cheaper, easier to service, basebody reusable for several short duration payloads). The problems are one payload can disturb another, and other activities create large disturbances (construction, satellite servicing, and man motion). Author

N90-21068*# *National Aeronautics and Space Administration.* Langley Research Center, Hampton, VA.
CONTROLLED MULTIBODY DYNAMICS SIMULATION FOR LARGE SPACE STRUCTURES
J. M. HOUSNER, S. C. WU, and C. W. CHANG (Comtek Co., Yorktown, VA.) *In its* NASA/DOD Controls-Structures Interaction Technology 1989 p 91-109 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

Multibody dynamics discipline, and dynamic simulation in control structure interaction (CSI) design are discussed. The use, capabilities, and architecture of the Large Angle Transient Dynamics (LATDYN) code as a simulation tool are explained. A generic joint body with various types of hinge connections; finite element and element coordinate systems; results of a flexible beam spin-up on a plane; mini-mast deployment; space crane and robotic slewing manipulations; a potential CSI test article; and multibody benchmark experiments are also described. B.G.

N90-21069*# Mechanical Dynamics, Inc., Ann Arbor, MI.
ELEMENT-SPECIFIC MODAL FORMULATIONS FOR LARGE-DISPLACEMENT MULTIBODY DYNAMICS
R. R. RYAN and H. H. YOO (Michigan Univ., Ann Arbor.) *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 111-129 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

Large dispacement assumed-mode modeling techniques are examined in the context of multibody elastodynamics. The range of both general and element-specific approaches are studied with the aid of examples involving beams, plates, and shells. For systems undergoing primarily structural bending and twisting with little or no membrane distortion, it is found that fully-linear, element-specific, modal formulations provide the most accurate time history solutions at the least expense. When membrane effects become dominant in structural problems due to loading and boundary conditions, one must naturally resort to a formulation involving a nonlinear stress-strain relationship in addition to nonlinear terms associated with large overall system motion. Such nonlinear models were investigated using assumed modes and found to lead to modal convergence difficulties when standard free-free structural modes are employed. A constrained mode formulation aimed at addressing the convergence problem is proposed. Author

N90-21070*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NONLINEAR AND DISTRIBUTED PARAMETER MODELS OF THE MINI-MAST TRUSS
LAWRENCE W. TAYLOR, JR. *In its* NASA/DOD Controls-Structures Interaction Technology 1989 p 131-150 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

Large spacecraft such as Space Station Freedom employ large trusses in their construction. The structural dynamics of such trusses often exhibit nonlinear behavior and little damping which can impact significantly the performance of control systems. The Mini-MAST truss was constructed to research such structural dynamics and control systems. The Mini-MAST truss is an object of study for the guest investigator program as part of NASA's controls-structures interaction program. The Mini-MAST truss is deployable and about 65 ft long. Although the bending characteristics of the Mini-MAST truss are essentially linear, the angular deflection under torsional loading has exhibited significant hysteresis and nonlinear stiffness. It is the purpose to develop nonlinear and distributed parameter models of the truss and to compare the model dynamics with actual measurements. Distributed parameter models have the advantage of requiring fewer model parameters. A tangent function is used to describe the nonlinear stiffness in torsion, partly because of the convenience of its easily expressed inverse. Hysteretic slip elements are introduced and extended to a continuum to account for the observed hysteresis in torsion. The contribution of slipping to the structural damping is analyzed and found to be strongly dependent on the applied loads. Because of the many factors which affect the damping and stiffness in a truss, it is risky to assume linearity. Author

N90-21071*# Lawrence Livermore National Lab., CA.
A DISTRIBUTED FINITE-ELEMENT MODELING AND CONTROL APPROACH FOR LARGE FLEXIBLE STRUCTURES
K. D. YOUNG *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 151-161 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

An unconventional framework is described for the design of decentralized controllers for large flexible structures. In contrast to conventional control system design practice which begins with a model of the open loop plant, the controlled plant is assembled from controlled components in which the modeling phase and the control design phase are integrated at the component level. The developed framework is called controlled component synthesis (CCS) to reflect that it is motivated by the well developed Component Mode Synthesis (CMS) methods which were demonstrated to be effective for solving large complex structural analysis problems for almost three decades. The design philosophy behind CCS is also closely related to that of the subsystem decomposition approach in decentralized control. Author

N90-21072*# Alabama Univ., Huntsville. Dept. of Electrical and Computer Engineering.
EFFECTIVE TECHNIQUES FOR THE IDENTIFICATION AND ACCOMMODATION OF DISTURBANCES
C. D. JOHNSON *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 163-180 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The successful control of dynamic systems such as space stations, or launch vehicles, requires a controller design methodology that acknowledges and addresses the disruptive effects caused by external and internal disturbances that inevitably act on such systems. These disturbances, technically defined as

uncontrollable inputs, typically vary with time in an uncertain manner and usually cannot be directly measured in real time. A relatively new non-statistical technique for modeling, and (on-line) identification, of those complex uncertain disturbances that are not as erratic and capricious as random noise is described. This technique applies to multi-input cases and to many of the practical disturbances associated with the control of space stations, or launch vehicles. Then, a collection of smart controller design techniques that allow controlled dynamic systems, with possible multi-input controls, to accommodate (cope with) such disturbances with extraordinary effectiveness are associated. These new smart controllers are designed by non-statistical techniques and typically turn out to be unconventional forms of dynamic linear controllers (compensators) with constant coefficients. The simplicity and reliability of linear, constant coefficient controllers is well-known in the aerospace field. Author

N90-21073*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MODELING AND CONTROL OF FLEXIBLE SPACE PLATFORMS WITH ARTICULATED PAYLOADS
PHILIP C. GRAVES (Vigyan Research Associates, Inc., Hampton, VA.) and SURESH M. JOSHI *In its* NASA/DOD Controls-Structures Interaction Technology 1989 p 181-210 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The first steps in developing a methodology for spacecraft control-structure interaction (CSI) optimization are identification and classification of anticipated missions, and the development of tractable mathematical models in each mission class. A mathematical model of a generic large flexible space platform (LFSP) with multiple independently pointed rigid payloads is considered. The objective is not to develop a general purpose numerical simulation, but rather to develop an analytically tractable mathematical model of such composite systems. The equations of motion for a single payload case are derived, and are linearized about zero steady-state. The resulting model is then extended to include multiple rigid payloads, yielding the desired analytical form. The mathematical models developed clearly show the internal inertial/elastic couplings, and are therefore suitable for analytical and numerical studies. A simple decentralized control law is proposed for fine pointing the payloads and LFSP attitude control, and simulation results are presented for an example problem. The decentralized controller is shown to be adequate for the example problem chosen, but does not, in general, guarantee stability. A centralized dissipative controller is then proposed, requiring a symmetric form of the composite system equations. Such a controller guarantees robust closed loop stability despite unmodeled elastic dynamics and parameter uncertainties. Author

N90-21074*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DETECTION OF POTENTIAL SPACE STATION CONTROL/STRUCTURE INTERACTION WITH CO-ST-IN
KELLY CARNEY, RON GRAHAM, DOUG KYR, and PAUL ANDREW BLELLOCH (SDRC, Inc., San Diego, CA.) *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 211-228 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The NASA Lewis Research Center is concerned with the potential of interaction between space station controllers and the solar PV array structures. The models required to handle this problem are very large, and automated methods were developed for the transfer of data between structural dynamic and control system analysis software. These methods emphasize the need to achieve accurate coupled analysis results while using as small a model as possible. Specific tools which help the analyst in this regard include modal order techniques, the use of mode acceleration to calculate internal loads and stresses and the transfer of Craig-Bampton components to reduce problems associated with modal sufficiency. These techniques were applied to a space station model with 366 modes below 1 Hz. Attitude control, and alpha and beta joint control were simulated. The inclusion of alpha and beta joint controllers is important when examining overall space station dynamics. An initial choice of control parameters does indicate a potential for control/structure interaction during reboost. As expected this is exacerbated by increasing the rate gain and decreasing the hysteresis of the reaction control system (RCS) in order to improve rigid body performance. Author

N90-21075*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
OPTIMIZATION OF THE STRUCTURAL AND CONTROL SYSTEM FOR LSS WITH REDUCED-ORDER MODEL
N. S. KHOT *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 229-239 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The objective is the simultaneous design of the structural and control system for space structures. The minimum weight of the structure is the objective function, and the constraints are placed on the closed loop distribution of the frequencies and the damping parameters. The controls approach used is linear quadratic regulator with constant feedback. A reduced-order control system is used. The effect of uncontrolled modes is taken into consideration by the model error sensitivity suppression (MESS) technique which modified the weighting parameters for the control forces. For illustration, an ACOSS-FOUR structure is designed for a different number of controlled modes with specified values for the closed loop damping parameters and frequencies. The dynamic response of the optimum designs for an initial disturbance is compared. Author

N90-21076*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPUTATIONAL ARCHITECTURE FOR INTEGRATED CONTROLS AND STRUCTURES DESIGN
W. KEITH BELVIN and K. C. PARK (Colorado Univ., Boulder.) *In its* NASA/DOD Controls-Structures Interaction Technology 1989 p 241-260 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

To facilitate the development of control structure interaction (CSI) design methodology, a computational architecture for interdisciplinary design of active structures is presented. The emphasis of the computational procedure is to exploit existing sparse matrix structural analysis techniques, in-core data transfer with control synthesis programs, and versatility in the optimization methodology to avoid unnecessary structural or control calculations. The architecture is designed such that all required structure, control and optimization analyses are performed within one program. Hence, the optimization strategy is not unduly constrained by cold starts of existing structural analysis and control synthesis packages. Author

N90-21077*# Colorado Univ., Boulder. Dept. of Aerospace Engineering Sciences.
CONTROLLER REDUCTION FOR EFFECTIVE INTERDISCIPLINARY DESIGN OF ACTIVE STRUCTURES
MARK J. BALAS and RALPH QUAN *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 261-270 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

Control problems of large aerospace structures are intrinsically interdisciplinary and require strategies which address the complete interaction between flexible structures, electromechanical actuators and sensors, and feedback control algorithms. Current research and future directions which will require an interdisciplinary team effort in dynamics, control and optimization of such structures are being surveyed. It is generally agreed that the dynamics of space structures require large scale discrete modeling, resulting in thousands of discrete unknowns. Proven control strategies, on the other hand, employ a low order controller that is based on a reduced order model of structures. Integration of such low order controllers and large scale dynamics models often leads to serious deterioration of the closed loop stability margin and even instability. To alleviate this stability deterioration while low order controllers

remain effective, the following approach was investigated: (1) retain low order controllers based on reduced order models of structures as the basic control strategy; (2) introduce a compensator that will directly account for the deterioration of stability margin due to controller-structure integration; and (3) assess overall performance of the integrated control structure system by developing measures of suboptimality in the combination of (1) and (2). The benefits include: simplicity in the design of basic controllers, thus facilitating the optimization of structure control interactions; increased understanding of the roles of the compensator so as to modify the structure as well as the basic controller, if necessary, for improved performance; and adaptability to localize controllers by viewing the compensator as a systems integration filter. Author

N90-21078*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
RECENT EXPERIENCE IN SIMULTANEOUS CONTROL-STRUCTURE OPTIMIZATION
M. SALAMA, R. RAMAKER, and M. MILMAN *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 271-283 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

To show the feasibility of simultaneous optimization as design procedure, low order problems were used in conjunction with simple control formulations. The numerical results indicate that simultaneous optimization is not only feasible, but also advantageous. Such advantages come at the expense of introducing complexities beyond those encountered in structure optimization alone, or control optimization alone. Examples include: larger design parameter space, optimization may combine continuous and combinatoric variables, and the combined objective function may be nonconvex. Future extensions to include large order problems, more complex objective functions and constraints, and more sophisticated control formulations will require further research to ensure that the additional complexities do not outweigh the advantages of simultaneous optimization. Some areas requiring more efficient tools than currently available include: multiobjective criteria and nonconvex optimization. Efficient techniques to deal with optimization over combinatoric and continuous variables, and with truncation issues for structure and control parameters of both the model space as well as the design space need to be developed. Author

N90-21079*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A SURVEY OF EXPERIMENTS AND EXPERIMENTAL FACILITIES FOR ACTIVE CONTROL OF FLEXIBLE STRUCTURES
DEAN W. SPARKS, JR., GARNETT C. HORNER, JER-NAN JUANG, and GERHARD KLOSE (Jet Propulsion Lab., California Inst. of Tech., Pasadena.) *In its* NASA/DOD Controls-Structures Interaction Technology 1989 p 285-315 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

A brief survey of large space structure control related experiments and facilities was presented. This survey covered experiments performed before and up to 1982, and those of the present period (1982-...). Finally, the future planned experiments and facilities in support of the control-structure interaction (CSI) program were reported. It was stated that new, improved ground test facilities are needed to verify the new CSI design techniques that will allow future space structures to perform planned NASA missions. Author

N90-21082*# Lockheed Missiles and Space Co., Palo Alto, CA.
ASCIE: AN INTEGRATED EXPERIMENT TO STUDY CSI IN LARGE SEGMENTED OPTICAL SYSTEMS
JEAN-NOEL AUBRUN and KENNETH R. LORELL *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 349-362 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 20/6

A description of the advanced structures/control integrated experiment (ASCIE) experimental setup, a generic test bed for several essential technologies was presented. In particular its multi-input, multi-output, non-collocated control system and its complex structural dynamics, characteristic of large segmented systems make it an ideal test bed for Control-Structure Interaction (CSI) experiments. The high accuracy of its measurement system will make it possible to investigate the dynamics of microvibrations and its implication for the CSI phenomenon. Author

N90-21083*# Texas A&M Univ., College Station.
CSI SENSING AND CONTROL: ANALYTICAL AND EXPERIMENTAL RESULTS
J. L. JUNKINS, T. C. POLLOCK, and Z. H. RAHMAN *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 363-385 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

Recent work on structural identification and large-angle maneuvers with vibration suppression was presented. The recent work has sought to balance structural and controls analysis activities by involving the analysts directly in the validation and experimental aspects of the research. Some new sensing, actuation, system identification, and control concepts were successfully implemented. An overview of these results is given. Author

N90-21084*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
EXPERIMENTAL EVALUATION OF ACTIVE-MEMBER CONTROL OF PRECISION STRUCTURES
JAMES FANSON, GARY BLACKWOOD, and CHENG-CHIH CHU *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 387-410 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The results of closed loop experiments that use piezoelectric active-members to control the flexible motion of a precision truss structure are described. These experiments are directed toward the development of high-performance structural systems as part of the Control/Structure Interaction (CSI) program at JPL. The focus of CSI activity at JPL is to develop the technology necessary to accurately control both the shape and vibration levels in the precision structures from which proposed large space-based observatories will be built. Structural error budgets for these types of structures will likely be in the sub-micron regime; optical tolerances will be even tighter. In order to achieve system level stability and local positioning at this level, it is generally expected that some form of active control will be required. Author

N90-21085*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
CONTROLS, ASTROPHYSICS, AND STRUCTURES EXPERIMENT IN SPACE (CASES)
HENRY B. WAITES and JOHN P. SHARKEY *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 411-425 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

As the size and performance requirements of future NASA and DOD spacecrafts and payloads tend to increase, the associated control systems that must effect these requirements tend to interact with the vehicle's structural dynamics. Some of the Control Structure Interaction (CSI) issues are being addressed in a flight experiment which is entitled CASES (Controls, Astrophysics and Structures Experiment in Space). As one of the first CSI flight experiments, the main emphasis for CASES is to provide a test bed for validating CSI developments and simultaneously, to pave the way for subsequent CSI experiments and science missions by establishing precedents for flight qualifying Large Space Structures (LSS)-class spacecraft. In addition, CASES provides an opportunity to obtain data bases for in-space controls and structures experiments and, at the same time, to gather hard x ray data from pertinent galactic sources. Author

N90-21086*# Naval Research Lab., Washington, DC.
LACE FLIGHT DYNAMICS EXPERIMENT
SHALOM FISHER *In* NASA, Langley Research Center,

NASA/DOD Controls-Structures Interaction Technology 1989 p 427-443 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The Low Power Atmospheric Compensation Experiment (LACE) is scheduled for launch in late 1989 into a 556 km altitude circular orbit of 43 deg inclination. The LACE flight dynamics experiment is an experiment secondary to the primary LACE mission. The purpose of the experiment is to provide on-orbit systems identification of the LACE spacecraft. The structure of the LACE spacecraft is of special interest to the CSI community. It incorporates 3 deployable/retractable booms of maximum length 45.72 m (150 ft) mounted on a rectangular parallelepiped bus of mass 1,200 kg. The zenith directed gravity gradient boom is mounted on the top of the bus; the retroreflector boom is mounted forward and deployed along the velocity vector, the balance boom is mounted and pointed aft. Attitude stabilization is accomplished by means of gravity gradient torques and by a momentum wheel. The LACE flight dynamics experiment is designed to measure modal frequencies, damping ratios, and oscillation amplitudes of the LACE spacecraft, as well as the vibration intensity generated by boom deployments and retractions. It is anticipated that this experiment will provide an opportunity for improvements in the accuracy of computer simulations of flexible structures and multibody dynamics. Author

N90-21090*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STRAIN AND DYNAMIC MEASUREMENTS USING FIBER OPTIC SENSORS EMBEDDED INTO GRAPHITE/EPOXY TUBES
D. W. DEHART, T. DOEDERLEIN, J. KOURY (Air Force Astronautics Lab., Edwards AFB, CA.), R. S. ROGOWSKI, J. S. HEYMAN, and M. S. HOLBEN, JR. *In its* NASA/DOD Controls-Structures Interaction Technology 1989 p 497-506 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 20/6

Graphite/epoxy tubes were fabricated with embedded optical fibers to evaluate the feasibility of monitoring strains with a fiber optic technique. Resistance strain gauges were attached to the tubes to measure strain at four locations along the tube for comparison with the fiber optic sensors. Both static and dynamic strain measurements were made with excellent agreement between the embedded fiber optic strain sensor and the strain gauges. Strain measurements of 10(exp -7) can be detected with the optical phase locked loop (OPLL) system using optical fiber. Because of their light weight, compatibility with composites, immunity to electromagnetic interference, and based on the static and dynamic results obtained, fiber optic sensors embedded in composites may be useful as the sensing component of smart structures. Author

N90-21091*# Air Force Astronautics Lab., Edwards AFB, CA.
INITIAL OPERATIONAL CAPABILITY OF THE ASTREX LARGE SPACE STRUCTURES TEST BED
G. A. NORRIS *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 507-522 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

Future DOD, NASA, and SDI space systems will be larger than any spacecraft flown before. The economics of placing these large space systems (LSS) into orbit dictates that they be as low in mass as possible. The combination of very large size and relatively low mass produces systems which possess little structural rigidity. This flexibility causes severe technical problems when combined with the precise shape and pointing requirements associated with many future LSS missions. Development of new control technologies which can solve these problems and enable future LSS missions is under way, but a test bed is needed for demonstration and evaluation of the emerging control hardware (sensors and actuators) and methodologies. In particular, the need exists for a facility which enables both large angle slewing and subsequent pointing/shape control of a variety of flexible bodies. The Air Force Astronautics Laboratory (AFAL) has conceived the Advanced Space Structures Technology Research Experiments (ASTREX) facility to fill this need. An overview of the ASTREX facility is given. Author

N90-21092*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
IN-HOUSE EXPERIMENTS IN LARGE SPACE STRUCTURES AT THE AIR FORCE WRIGHT AERONAUTICAL LABORATORIES FLIGHT DYNAMICS LABORATORY
ROBERT W. GORDON, UMIT OZGUNER, and STEVEN YURKOVICH (Ohio State Univ., Columbus.) *In* NASA, Langley Research Center, NASA/DOD Controls-Structures Interaction Technology 1989 p 523-541 Aug. 1989
Avail: NTIS HC A23/MF A03 CSCL 22/2

The Flight Dynamics Laboratory is committed to an in-house, experimental investigation of several technical areas critical to the dynamic performance of future Air Force large space structures. The advanced beam experiment was successfully completed and provided much experience in the implementation of active control approaches on real hardware. A series of experiments is under way in evaluating ground test methods on the 12 meter trusses with significant passive damping. Ground simulated zero-g response data from the undamped truss will be compared directly with true zero-g flight test data. The performance of several leading active control approaches will be measured and compared on one of the trusses in the presence of significant passive damping. In the future, the PACOSS dynamic test article will be set up as a test bed for the evaluation of system identification and control techniques on a complex, representative structure with high modal density and significant passive damping. Author

N90-21412*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTEGRATED MODELING AND ANALYSIS OF A SPACE-TRUSS ARTICLE
ALAN E. STOCKWELL (Lockheed Engineering and Sciences Co., Hampton, VA.), SHARON E. PEREZ, and RICHARD S. PAPPA Mar. 1990 28 p Presented at the MSC World Users' Conference, Los Angeles, CA, 26-30 Mar. 1990
(NASA-TM-102615; NAS 1.15:102615) Avail: NTIS HC A03/MF A01 CSCL 20/11

MSC/NASTRAN is being used in the Controls-Structures Interaction (CSI) program at NASA Langley Research Center as a key analytical tool for structural analysis as well as the basis for control law development, closed-loop performance evaluation, and system safety checks. Guest investigators from academia and industry are performing dynamics and control experiments on a flight-like deployable space truss called Mini-Mast to determine the effectiveness of various active-vibration control laws. MSC/NASTRAN was used to calculate natural frequencies and mode shapes below 100 Hz to describe the dynamics of the 20-meter-long lightweight Mini-Mast structure. Gravitational effects contribute significantly to structural stiffness and are accounted for through a two-phase solution in which the differential stiffness matrix is calculated and then used in the eigensolution. Reduced modal models are extracted for control law design and evaluation of closed-loop system performance. Predicted actuator forces from controls simulations are then applied to the extended model to predict member loads and stresses. These pre-test analyses reduce risks associated with the structural integrity of the test article, which is a major concern in closed-loop control experiments due to potential instabilities. Author

N90-21770 Texas Univ., Austin.
A DECENTRALIZED LINEAR QUADRATIC CONTROL DESIGN METHOD FOR FLEXIBLE STRUCTURES Ph.D. Thesis
TZU-JENG SU 1989 204 p
Avail: Univ. Microfilms Order No. DA9005673

A decentralized suboptimal linear quadratic control design procedure which combines substructural synthesis, model reduction, decentralized control design, subcontroller synthesis, and controller reduction is proposed for the design of reduced-order controllers for flexible structures. The procedure starts with a

definition of the continuum structure to be controlled. An evaluation model of finite dimension is obtained by the finite element method. Then, the finite element model is decomposed into several substructures by using a natural decomposition called substructuring decomposition. Each substructure, at this point, still has too large a dimension and must be reduced to a size that is Riccati-solvable. A Krylov model reduction algorithm is proposed to reduce the spillover of control energy. The Krylov reduced model has the property of matching low-frequency moments of the full-order system. Then, based on the reduced substructure model, a subcontroller is designed by an Linear Quadratic (LQ) optimal control method for each substructure independently. After all subcontrollers are designed, a controller synthesis method called Substructural Controller Synthesis is employed to synthesize all subcontrollers into a global controller. The assembling scheme used is the same as that employed for the structure matrices. Finally, a controller reduction scheme, called the Equivalent Impulse Response Energy Controller (EIREC) reduction algorithm, is used to reduce the global controller to a reasonable size for implementation. The EIREC reduced controller preserves the impulse response energy of the full-order controller and has the property of matching low-frequency moments and low-frequency power moments. Dissert. Abstr.

N90-21784 Colorado Univ., Boulder.
ROBUST CONTROL OF FLEXIBLE STRUCTURES Ph.D. Thesis
NASSIM MOHAMMED ARBOUZ 1989 101 p
Avail: Univ. Microfilms Order No. DA8923474

The control of flexible mechanical systems has application to control of space systems, aircraft, robotics and active optics, to name a few. These systems have distributed-parameter dynamics; their natural damping is very small; they have many densely packed low-frequency modes; and their model parameters are uncertain. Moreover, performance requirements such as pointing accuracy, shape control, and bandwidth are very stringent and make the problem of structural vibration more acute. Another important application of flexible structural control is in robotics. The goal is to develop lighter and faster robots capable of moving larger payloads with low energy requirements. The single-input, single-output control of flexible structures is first examined. Important time and frequency-domain properties that characterize elastic systems were established. Particularly, an interesting pattern of movement of the plant zeros was demonstrated as a function of the sensor location. This zero motion has a considerable implication on control design. A compensation method was then presented based on a frequency minimax technique, and a search procedure which always converges to the optimal controller. The concept of generalized lead-lag compensation was proposed. This method is intended for the noncollocated control of flexible structures. A theorem giving necessary and sufficient conditions for the existence of such a stabilizing controller is proved, and a systematic design procedure is given. The multi-output control of flexible structures was also investigated. An optimal sensor placement procedure, based on eigenstructure assignment, is developed for the robust control of elastic systems. Dissert. Abstr.

N90-21878 Illinois Univ., Urbana-Champaign.
NONLINEAR SPLINE OPERATOR INTERPOLATION AND SLIDING CONTROL OF DEFORMABLE MANEUVERING BODIES Ph.D. Thesis
FAKHREDDINE KARRAY 1989 132 p
Avail: Univ. Microfilms Order No. DA9010910

For purposes of achieving high performances of tracking, and precision pointing of a flexible structure subject to large angular maneuvers (such as the slewing maneuver of a large space structure), a newly developed off-line modeling procedure combined with a robust control technique is investigated and then implemented to the moving structure. The modeling issue is first discussed, and two different procedures for dealing with the nonlinear dynamics of a given deformable structure are described. The coupled dynamic of vibration, translation, and rotation are derived for a completely decretized model and then for a hybrid model. Deformation estimates are then computed through two types of observers: the well-known extended Kalman filter and the feedback linearized based observer. Knowing that hardware costs, as well as on-time computational problems arise whenever dealing with such observers, especially for high dimensional systems, another alternative is then to be sought. An off-line modeling technique is developed using the nonlinear optimal interpolator theory. This interpolator is used basically to reduce the dimension of the original system to the one determined by the number of applied test inputs. Estimates of the deformations, as well as error bounds on their measurements are then computed. Finally, and in order to insure a robust performance of the moving structure subject to induced deformations, and structural parameters variations, a procedure based on the sliding manifolds technique is used. Combination of such a technique, with the outputs of the optimal interpolator constitutes an excellent alternative for the system to achieve robust tracking performances in presence of disturbances and parameter uncertainties. Dissert. Abstr.

N90-21882*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE DETERMINATION OF MAXIMUM DEEP SPACE STATION SLEW RATES FOR A HIGH EARTH ORBITER
J. A. ESTEFAN n its The Telecommunications and Data Acquisition Report p 13-20 15 Feb. 1990
Avail: NTIS HC A15/MF A02 CSCL 17/2

As developing national and international space ventures, which seek to employ NASA's Deep Space Network (DSN) for tracking and data acquisition, evolve, it is essential for navigation and tracking system analysts to evaluate the operational capability of Deep Space Station antennas. To commission the DSN for use in tracking a highly eccentric Earth orbiter could quite possibly yield the greatest challenges in terms of slewing capability; certainly more so than with a deep-space probe. The focus here is on the determination of the maximum slew rates needed to track a specific high Earth orbiter, namely the Japanese MUSES-B spacecraft of the Very Long Baseline Interferometry Space Observatory Program. The results suggest that DSN 34-m antennas are capable of meeting the slew rate requirements for the nominal MUSES-B orbital geometries currently being considered. Author

N90-21949 Duke Univ., Durham, NC.
PASSIVE SHAPE CONTROL OF SPACE ANTENNAS WITH DETERMINATE TRUSS SUPPORT STRUCTURES Ph.D. Thesis
AHMET BULENT TRAK 1989 130 p
Avail: Univ. Microfilms Order No. DA9010373

The shape control of space antennas by a passive method is investigated. The application of the passive approach to the shape control of determinate trusses is emphasized. The passive control is achieved by modifying the nodal coordinates of the structure such that the modified structure deforms to the original (unmodified) geometry under the given loading. The modified geometry is obtained by changing the coordinates iteratively. Mathematically, the technique can be represented as the simple iteration method for solving nonlinear equations. The technique was illustrated in four cases. Two loading conditions and a tetrahedral truss were considered. In Case 1, a modified geometry, which would deform to the original geometry, was sought. In Case 2, a modified surface geometry, which would deform to the original surface geometry, was sought. In Case 3, a single modified geometry, which would satisfy both loading conditions, was sought. In Case 4, an indeterminate truss was investigated under a single loading condition. Dissert. Abstr.

N90-22719# Aerospace Corp., El Segundo, CA. Electronics Research Lab.
THE EFFECT OF MECHANICAL DEFORMATION ON THE RADIATION PATTERNS OF LARGE SPACE-BASED ARRAYS
GWENDOLYN M. SHAW 30 Apr. 1988 65 p
(Contract F04701-85-C-0086)
(AD-A219288; TR-0086A(2925-05)-1; SD-TR-88-49) Avail: NTIS HC A04/MF A01 CSCL 20/14

Large phased arrays for space applications require light-weight

deployable structures. As these structures are not completely rigid, they undergo dynamic deformations in orbit that are typically expressed as mechanical modes of surface position. In contrast with conventional antenna tolerance theory, which is based on a random Gaussian representation of manufacturing tolerance, these deformations follow a deterministic function. The effects of these mechanical deformations on the radiation performance of the phased array are analyzed. Closed-form solutions are presented for uniformly illuminated array, and results are shown for various mechanical modes. Tapered-amplitude array excitation is then treated numerically and contrasted with uniformly excited arrays. The array patterns resulting from modal errors and random errors are compared. DOE

N90-22787 Pennsylvania State Univ., University Park.
ROBUST CONTROL OF VIBRATION IN FLEXIBLE STRUCTURES Ph.D. Thesis
CHI-KUAN KAO 1989 154 p
Avail: Univ. Microfilms Order No. DA9007877

Robust algorithms are developed for the control of vibration in flexible structures. These algorithms are based on the sliding mode control theory and can be designed to yield a satisfactory performance if the bounds on the parameters' errors are known. The algorithms were developed for both the independent modal space control system and the coupled modal space control system when the bounds on the system parameters' errors are known. An explicit method to construct the desired sliding hyperplanes for coupled modal sliding mode control is formulated. Boundary layers are used around the sliding hyperplanes to eliminate the chattering phenomenon. Three types of steady state solutions for the closed loop system inside the boundary layers are found: the zero solution, the constant nonzero solution and the limit cycle. The amplitude and frequency of the limit cycle were estimated by the describing function approach. Thus, the steady state vibration in the controlled modes and in the residual modes can be evaluated. Numerical examples with a simply supported beam and a flexible tetrahedral truss structure are presented to verify the theoretical analyses. The sliding mode control algorithm was also formulated when states are estimated using an observer. Singular-value approach is used to study the robustness of this control system to observation spillover. For the simply supported beam structure, the natural frequencies are well separated. To have a robust system in this case, the desired sliding manifold and the Luenberger's observer gain matrix can be found by the pole-placement method. However, to have a robust system for the flexible tetrahedral truss structure with closely lumped natural frequencies, it is necessary to use the linear quadratic method for the construction of the desired sliding manifold and the Kalman filter with fictitious noises for the observer design. Dissert. Abstr.

N90-22988*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
AN ASSESSMENT OF MULTIBODY SIMULATION TOOLS FOR ARTICULATED SPACECRAFT
GUY K. MAN and SAMUEL W. SIRLIN *In its* Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 12-25 15 Dec. 1989
Avail: NTIS HC A21/MF A03 CSCL 09/2

A survey of multibody simulation codes was conducted in the spring of 1988, to obtain an assessment of the state of the art in multibody simulation codes from the users of the codes. This survey covers the most often used articulated multibody simulation codes in the spacecraft and robotics community. There was no attempt to perform a complete survey of all available multibody codes in all disciplines. Furthermore, this is not an exhaustive evaluation of even robotics and spacecraft multibody simulation codes, as the survey was designed to capture feedback on issues most important to the users of simulation codes. We must keep in mind that the information received was limited and the technical background of the respondents varied greatly. Therefore, only the most often cited observations from the questionnaire are reported here. In this survey, it was found that no one code had both many users (reports) and no limitations. The first section is a report on multibody code applications. Following applications is a discussion of execution time, which is the most troublesome issue for flexible multibody codes. The representation of component flexible bodies, which affects both simulation setup time as well as execution time, is presented next. Following component data preparation, two sections address the accessibility or usability of a code, evaluated by considering its user interface design and examining the overall simulation integrated environment. A summary of user efforts at code verification is reported, before a tabular summary of the questionnaire responses. Finally, some conclusions are drawn. Author

N90-22992*# Arizona Univ., Tucson. Computer-Aided Engineering Lab.
SYSTEMATIC GENERATION OF MULTIBODY EQUATIONS OF MOTION SUITABLE FOR RECURSIVE AND PARALLEL MANIPULATION
PARVIZ E. NIKRAVESH, GWANGHUM GIM, ARA ARABYAN, and UDO REIN *In* JPL, Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 43-56 15 Dec. 1989
Avail: NTIS HC A21/MF A03 CSCL 09/2

The formulation of a method known as the joint coordinate method for automatic generation of the equations of motion for multibody systems is summarized. For systems containing open or closed kinematic loops, the equations of motion can be reduced systematically to a minimum number of second order differential equations. The application of recursive and nonrecursive algorithms to this formulation, computational considerations and the feasibility of implementing this formulation on multiprocessor computers are discussed. Author

N90-23003*# Cincinnati Univ., OH. Dept. of Aerospace Engineering and Engineering Mechanics.
A DISTURBANCE BASED CONTROL/STRUCTURE DESIGN ALGORITHM
MARK D. MCLAREN and GARY L. SLATER *In* JPL, Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 122-139 15 Dec. 1989 Sponsored in part by AFOSR, Wright-Patterson AFB, OH and CRAY Research, Inc.
Avail: NTIS HC A21/MF A03 CSCL 09/2

Some authors take a classical approach to the simultaneous structure/control optimization by attempting to simultaneously minimize the weighted sum of the total mass and a quadratic form, subject to all of the structural and control constraints. Here, the optimization will be based on the dynamic response of a structure to an external unknown stochastic disturbance environment. Such a response to excitation approach is common to both the structural and control design phases, and hence represents a more natural control/structure optimization strategy than relying on artificial and vague control penalties. The design objective is to find the structure and controller of minimum mass such that all the prescribed constraints are satisfied. Two alternative solution algorithms are presented which have been applied to this problem. Each algorithm handles the optimization strategy and the imposition of the nonlinear constraints in a different manner. Two controller methodologies, and their effect on the solution algorithm, will be considered. These are full state feedback and direct output feedback, although the problem formulation is not restricted solely to these forms of controller. In fact, although full state feedback is a popular choice among researchers in this field (for reasons that will become apparent), its practical application is severely limited. The controller/structure interaction is inserted by the imposition of appropriate closed-loop constraints, such as closed-loop output response and control effort constraints. Numerical results will be obtained for a representative flexible structure model to illustrate the effectiveness of the solution algorithms. Author

N90-23014*# Massachusetts Inst. of Tech., Cambridge.
NONLINEAR STRAIN-DISPLACEMENT RELATIONS AND FLEXIBLE MULTIBODY DYNAMICS
CARLOS E. PADILLA and ANDREAS H. VONFLOTOW *In* JPL,

Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 230-245 15 Dec. 1989
Sponsored by NSF, Washington, DC
Avail: NTIS HC A21/MF A03 CSCL 09/2

Dynamics of chains of flexible bodies undergoing large rigid body motions, but small elastic deflections are considered. The role of nonlinear strain-displacement relations in the development of the motion equations correct to first order in elastic deflections is investigated. The general form of these equations linearized only in the small elastic deflections is presented, and the relative significance of various nonlinear terms is studied both analytically and through the use of the numerical simulations. Numerical simulations are performed for a two link chain constrained to move in the plane, subject to hinge torques. Each link is modeled as a thin beam. Slew maneuver simulation results are compared for models with and without properly modeled kinematics of deformation. The goal of this case study is to quantify the importance of the terms in the equations of motion which arise from the inclusion of nonlinear strain-displacement relations. It is concluded that unless the consistently linearized equations in elastic deflections and speeds are available and necessary, the inconsistently (prematurely) linearized equations should be replaced in all cases by ruthlessly linearized equations: equations in which all nonlinear terms involving the elastic deflections and speeds are ignored. Author

N90-23021*# Techno-Sciences, Inc., Greenbelt, MD.
FREQUENCY RESPONSE MODELING AND CONTROL OF FLEXIBLE STRUCTURES: COMPUTATIONAL METHODS
WILLIAM H. BENNETT *In* JPL, Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 277-291 15 Dec. 1989
(Contract F33615-88-C-3215)
Avail: NTIS HC A21/MF A03 CSCL 09/2

The dynamics of vibrations in flexible structures can be conventiently modeled in terms of frequency response models. For structural control such models capture the distributed parameter dynamics of the elastic structural response as an irrational transfer function. For most flexible structures arising in aerospace applications the irrational transfer functions which arise are of a special class of pseudo-meromorphic functions which have only a finite number of right half place poles. Computational algorithms are demonstrated for design of multiloop control laws for such models based on optimal Wiener-Hopf control of the frequency responses. The algorithms employ a sampled-data representation of irrational transfer functions which is particularly attractive for numerical computation. One key algorithm for the solution of the optimal control problem is the spectral factorization of an irrational transfer function. The basis for the spectral factorization algorithm is highlighted together with associated computational issues arising in optimal regulator design. Options for implementation of wide band vibration control for flexible structures based on the sampled-data frequency response models is also highlighted. A simple flexible structure control example is considered to demonstrate the combined frequency response modeling and control algorithms. Author

N90-23024*# University of Southern California, Los Angeles. *Dept. of Electrical Engineering - Systems.*
MODERN CACSD USING THE ROBUST-CONTROL TOOLBOX
RICHARD Y. CHIANG and MICHAEL G. SAFONOV *In* JPL, Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 294-311 15 Dec. 1989
Avail: NTIS HC A21/MF A03 CSCL 09/2

The Robust-Control Toolbox is a collection of 40 M-files which extend the capability of PC/PRO-MATLAB to do modern multivariable robust control system design. Included are robust analysis tools like singular values and structured singular values, robust synthesis tools like continuous/discrete H(exp 2)/H infinity synthesis and Linear Quadratic Gaussian Loop Transfer Recovery methods and a variety of robust model reduction tools such as Hankel approximation, balanced truncation and balanced stochastic truncation, etc. The capabilities of the toolbox are described and illustated with examples to show how easily they can be used in practice. Examples include structured singular value analysis, H infinity loop-shaping and large space structure model reduction. Author

N90-23035*# *State Univ. of New York, Buffalo. Dept. of* Mechanical and Aerospace Engineering.
CONTROL OF A FLEXIBLE PLANAR TRUSS USING PROOF MASS ACTUATORS
CONSTANTINOS MINAS, EPHRAHIM GARCIA, and DANIEL J. INMAN *In* JPL, Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 434-445 15 Dec. 1989
(Contract F49620-88-C-00018; F49620-86-C-60111; AF-AFOSR-0119-85; AF-AFOSR-0390-88)
Avail: NTIS HC A21/MF A03 CSCL 13/9

A flexible structure was modeled and actively controlled by using a single space realizable linear proof mass actuator. The NASA/UVA/UB actuator was attached to a flexible planar truss structure at an optimal location and it was considered as both passive and active device. The placement of the actuator was specified by examining the eigenvalues of the modified model that included the actuator dynamics, and the frequency response functions of the modified system. The electronic stiffness of the actuator was specified, such that the proof mass actuator system was tuned to the fourth structural mode of the truss by using traditional vibration absorber design. The active control law was limited to velocity feedback by integrating of the signals of two accelerometers attached to the structure. The two lower modes of the closed-loop structure were placed further in the LHS of the complex plane. The theoretically predicted passive and active control law was experimentally verified. Author

N90-23037*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ON TRAJECTORY GENERATION FOR FLEXIBLE SPACE CRANE: INVERSE DYNAMICS ANALYSIS BY LATDYN
G.-S. CHEN, J. M. HOUSNER, S.-C. WU, and C.-W. CHANG (Comtek Co., Yorktown, VA.) *In* JPL, Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 447-448 15 Dec. 1989
Avail: NTIS HC A21/MF A03 CSCL 13/9

For future in-space construction facility, one or more space cranes capable of manipulating and positioning large and massive spacecraft components will be needed. Inverse dynamics was extensively studied as a basis for trajectory generation and control of robot manipulators. The focus here is on trajectory generation in the gross-motion phase of space crane operation. Inverse dynamics of the flexible crane body is much more complex and intricate as compared with rigid robot link. To model and solve the space crane's inverse dynamics problem, LATDYN program which employs a three-dimensional finite element formulation for the multibody truss-type structures will be used. The formulation is oriented toward a joint dominated structure which is suitable for the proposed space crane concept. To track a planned trajectory, procedures will be developed to obtain the actuation profile and dynamics envelope which are pertinent to the design and performance requirements of the space crane concept. Author

N90-23041*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
CONCURRENT PROCESSING SIMULATION OF THE SPACE STATION
R. GLUCK, A. L. HALE (Supercomputing Solutions, Inc., San Diego, CA.), and JOHN W. SUNKEL *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 477-491 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

The development of a new capability for the time-domain simulation of multibody dynamic systems and its application to the study of a large angle rotational maneuvers of the Space Station is described. The effort was divided into three sequential

tasks, which required significant advancements of the state-of-the art to accomplish. These were: (1) the development of an explicit mathematical model via symbol manipulation of a flexible, multibody dynamic system; (2) the development of a methodology for balancing the computational load of an explicit mathematical model for concurrent processing; and (3) the implementation and successful simulation of the above on a prototype Custom Architectured Parallel Processing System (CAPPS) containing eight processors. The throughput rate achieved by the CAPPS operating at only 70 percent efficiency, was 3.9 times greater than that obtained sequentially by the IBM 3090 supercomputer simulating the same problem. More significantly, analysis of the results leads to the conclusion that the relative cost effectiveness of concurrent vs. sequential digital computation will grow substantially as the computational load is increased. This is a welcomed development in an era when very complex and cumbersome mathematical models of large space vehicles must be used as substitutes for full scale testing which has become impractical. Author

N90-23047*# DYNACS Engineering Co., Inc., Clearwater, FL.
ENHANCED MODELING FEATURES WITHIN TREETOPS
R. J. VANDERVOORT and MANOJ N. KUMAR *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 548-562 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 12/1

The original motivation for TREETOPS was to build a generic multi-body simulation and remove the burden of writing multi-body equations from the engineers. The motivation of the enhancement was twofold: (1) to extend the menu of built-in features (sensors, actuators, constraints, etc.) that did not require user code; and (2) to extend the control system design capabilities by linking with other government funded software (NASTRAN and MATLAB). These enhancements also serve to bridge the gap between structures and control groups. It is common on large space programs for the structures groups to build hi-fidelity models of the structure using NASTRAN and for the controls group to build lower order models because they lack the tools to incorporate the former into their analysis. Now the controls engineers can accept the hi-fidelity NASTRAN models into TREETOPS, add sensors and actuators, perform model reduction and couple the result directly into MATLAB to perform their design. The controller can then be imported directly into TREETOPS for non-linear, time-history simulation. Author

N90-23049*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
NEW MULTIVARIABLE CAPABILITIES OF THE INCA PROGRAM
FRANK H. BAUER, JOHN P. DOWNING, and CHRISTOPHER J. THORPE (Fairchild Space Co., Germantown, MD.) *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 577-584 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

The INteractive Controls Analysis (INCA) program was developed at NASA's Goddard Space Flight Center to provide a user friendly, efficient environment for the design and analysis of control systems, specifically spacecraft control systems. Since its inception, INCA has found extensive use in the design, development, and analysis of control systems for spacecraft, instruments, robotics, and pointing systems. The (INCA) program was initially developed as a comprehensive classical design analysis tool for small and large order control systems. The latest version of INCA, expected to be released in February of 1990, was expanded to include the capability to perform multivariable controls analysis and design. Author

N90-23053*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
CONTROL/STRUCTURE INTERACTION DESIGN METHODOLOGY
HUGH C. BRIGGS and WILLIAM E. LAYMAN *In its* Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 606-619 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

The Control Structure Interaction Program is a technology development program for spacecraft that exhibit interactions between the control system and structural dynamics. The program objectives include development and verification of new design concepts (such as active structure) and new tools (such as a combined structure and control optimization algorithm) and their verification in ground and possibly flight test. The new CSI design methodology is centered around interdisciplinary engineers using new tools that closely integrate structures and controls. Verification is an important CSI theme and analysts will be closely integrated to the CSI Test Bed laboratory. Components, concepts, tools and algorithms will be developed and tested in the lab and in future Shuttle-based flight experiments. The design methodology is summarized in block diagrams depicting the evolution of a spacecraft design and descriptions of analytical capabilities used in the process. The multiyear JPL CSI implementation plan is described along with the essentials of several new tools. A distributed network of computation servers and workstations was designed that will provide a state-of-the-art development base for the CSI technologies. Author

N90-23054*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MODEL REDUCTION FOR FLEXIBLE SPACECRAFT WITH CLUSTERED NATURAL FREQUENCIES Abstract Only
T. W. C. WILLIAMS (National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.) and W. K. GAWRONSKI *In its* Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 620 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 22/2

Two approaches to the problem of model reduction for flexible spacecraft that have proved very useful are balancing and model truncation. Furthermore, it is well known that a model representation of a lightly damped flexible structure with widely spaced natural frequencies is approximately balanced. Consequently, reduction in either coordinate system gives similar results for this case. It is important to note, however, that flexible space structures typically have clusters of closely spaced frequencies. In such cases, reduction in model coordinates can give large errors, while the error obtained using balancing is generally much smaller. A new reduction procedure which combines the best features of model and balanced reduction is therefore developed. It is more efficient than balanced reduction of the full system, as it only involves balancing those subsystems of close modes that are highly correlated, yet is shown to yield results which are essentially as good. Author

N90-23055*# Texas Univ., Austin. Dept. of Aerospace Engineering and Engineering Mechanics.
SUBSTRUCTURAL CONTROLLER SYNTHESIS
TZU-JENG SU and ROY R. CRAIG, JR. *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 621-635 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

A decentralized design procedure which combines substructural synthesis, model reduction, decentralized controller design, subcontroller synthesis, and controller reduction is proposed for the control design of flexible structures. The structure to be controlled is decomposed into several substructures, which are modeled by component mode synthesis methods. For each substructure, a subcontroller is designed by using the linear quadratic optimal control theory. Then, a controller synthesis scheme called Substructural Controller Synthesis (SCS) is used to assemble the subcontrollers into a system controller, which is to be used to control the whole structure. Author

N90-23059*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
ROBUST FIXED ORDER DYNAMIC COMPENSATION FOR LARGE SPACE STRUCTURE CONTROL
ANTHONY J. CALISE and EDWARD V. BYRNS, JR. *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 641-648 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 22/2

A simple formulation for designing fixed order dynamic compensators which are robust to both uncertainty at the plant input and structured uncertainty in the plant dynamics is presented. The emphasis is on designing low order compensators for systems of high order. The formulation is done in an output feedback setting which exploits an observer canonical form to represent the compensator dynamics. The formulation also precludes the use of direct feedback of the plant output. The main contribution lies in defining a method for penalizing the states of the plant and of the compensator, and for choosing the distribution on initial conditions so that the loop transfer matrix approximates that of a full state design. To improve robustness to parameter uncertainty, the formulation avoids the introduction of sensitivity states, which has led to complex formulations in earlier studies where only structured uncertainty has been considered. Author

N90-23064*# Michigan Univ., Ann Arbor. Dept. of Aerospace Engineering.
A NEW SECOND-ORDER INTEGRATION ALGORITHM FOR SIMULATING MECHANICAL DYNAMIC SYSTEMS
R. M. HOWE *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 700-712 15 Dec. 1989 Prepared in cooperation with Applied Dynamics International, Ann Arbor, MI
Avail: NTIS HC A20/MF A03 CSCL 09/2

A new integration algorithm which has the simplicity of Euler integration but exhibits second-order accuracy is described. In fixed-step numerical integration of differential equations for mechanical dynamic systems the method represents displacement and acceleration variables at integer step times and velocity variables at half-integer step times. Asymptotic accuracy of the algorithm is twice that of trapezoidal integration and ten times that of second-order Adams-Bashforth integration. The algorithm is also compatible with real-time inputs when used for a real-time simulation. It can be used to produce simulation outputs at double the integration frame rate, i.e., at both half-integer and integer frame times, even though it requires only one evaluation of state-variable derivatives per integration step. The new algorithm is shown to be especially effective in the simulation of lightly-damped structural modes. Both time-domain and frequency-domain accuracy comparisons with traditional integration methods are presented. Stability of the new algorithm is also examined. Author

N90-23070*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
JPL CONTROL/STRUCTURE INTERACTION TEST BED REAL-TIME CONTROL COMPUTER ARCHITECTURE
HUGH C. BRIGGS *In its* Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 739-755 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

The Control/Structure Interaction Program is a technology development program for spacecraft that exhibit interactions between the control system and structural dynamics. The program objectives include development and verification of new design concepts - such as active structure - and new tools - such as combined structure and control optimization algorithm - and their verification in ground and possibly flight test. A focus mission spacecraft was designed based upon a space interferometer and is the basis for design of the ground test article. The ground test bed objectives include verification of the spacecraft design concepts, the active structure elements and certain design tools such as the new combined structures and controls optimization tool. In anticipation of CSI technology flight experiments, the test bed control electronics must emulate the computation capacity and control architectures of space qualifiable systems as well as the command and control networks that will be used to connect investigators with the flight experiment hardware. The Test Bed facility electronics were functionally partitioned into three units: a laboratory data acquisition system for structural parameter identification and performance verification; an experiment supervisory computer to oversee the experiment, monitor the environmental parameters and perform data logging; and a multilevel real-time control computing system. The design of the Test Bed electronics is presented along with hardware and software component descriptions. The system should break new ground in experimental control electronics and is of interest to anyone working in the verification of control concepts for large structures. Author

N90-23072*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MULTIBODY DYNAMICS: MODELING COMPONENT FLEXIBILITY WITH FIXED, FREE, LOADED, CONSTRAINT, AND RESIDUAL MODES
JOHN T. SPANOS and WALTER S. TSUHA *In its* Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 761-777 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

The assumed-modes method in multibody dynamics allows the elastic deformation of each component in the system to be approximated by a sum of products of spatial and temporal functions commonly known as modes and modal coordinates respectively. The choice of component modes used to model articulating and non-articulating flexible multibody systems is examined. Attention is directed toward three classical Component Mode Synthesis (CMS) methods whereby component normal modes are generated by treating the component interface (I/F) as either fixed, free, or loaded with mass and stiffness contributions from the remaining components. The fixed and free I/F normal modes are augmented by static shape functions termed constraint and residual modes respectively. A mode selection procedure is outlined whereby component modes are selected from the Craig-Bampton (fixed I/F plus constraint), MacNeal-Rubin (free I/F plus residual), or Benfield-Hruda (loaded I/F) mode sets in accordance with a modal ordering scheme derived from balance realization theory. The success of the approach is judged by comparing the actuator-to-sensor frequency response of the reduced order system with that of the full order system over the frequency range of interest. A finite element model of the Galileo spacecraft serves as an example in demonstrating the effectiveness of the proposed mode selection method. Author

N90-23073*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
COMPONENT MODEL REDUCTION VIA THE PROJECTION AND ASSEMBLY METHOD
DOUGLAS E. BERNARD *In its* Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 778-791 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

The problem of acquiring a simple but sufficiently accurate model of a dynamic system is made more difficult when the dynamic system of interest is a multibody system comprised of several components. A low order system model may be created by reducing the order of the component models and making use of various available multibody dynamics programs to assemble them into a system model. The difficulty is in choosing the reduced order component models to meet system level requirements. The projection and assembly method, proposed originally by Eke, solves this difficulty by forming the full order system model, performing model reduction at the the system level using system level requirements, and then projecting the desired modes onto the components for component level model reduction. The projection and assembly method is analyzed to show the conditions under

which the desired modes are captured exactly; to the numerical precision of the algorithm. Author

N90-23074*# Iowa Univ., Iowa City. Dept. of Mechanical Engineering.
MODEL REDUCTION IN THE PHYSICAL COORDINATE SYSTEM
K. HAROLD YAE and K. Y. JOENG *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 792-804 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

In the dynamics modeling of a flexible structure, finite element analysis employs reduction techniques, such as Guyan's reduction, to remove some of the insignificant physical coordinates, thus producing a dynamics model that has smaller mass and stiffness matrices. But this reduction is limited in the sense that it removes certain degrees of freedom at a node points themselves in the model. From the standpoint of linear control design, the resultant model is still too large despite the reduction. Thus, some form of the model reduction is frequently used in control design by approximating a large dynamical system with a fewer number of state variables. However, a problem arises from the placement of sensors and actuators in the reduced model, because a model usually undergoes, before being reduced, some form of coordinate transformations that do not preserve the physical meanings of the states. To correct such a problem, a method is developed that expresses a reduced model in terms of a subset of the original states. The proposed method starts with a dynamic model that is originated and reduced in finite element analysis. Then the model is converted to the state space form, and reduced again by the internal balancing method. At this point, being in the balanced coordinate system, the states in the reduced model have no apparent resemblance to those of the original model. Through another coordinate transformation that is developed, however, this reduced model is expressed by a subset of the original states. Author

N90-23075*# Rockwell International Corp., Seal Beach, CA.
MODAL IDENTITIES FOR MULTIBODY ELASTIC SPACECRAFT: AN AID TO SELECTING MODES FOR SIMULATION
HARI B. HABLANI *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 805-817 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

The question: Which set of modes furnishes a higher fidelity math model of dynamics of a multibody, deformable spacecraft (hinges-free or hinges-locked vehicle modes) is answered. 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 a comparison of these equations, ten sets of modal identities are constructed which involve modal momenta coefficients and frequencies associated with both classes of modes. The sums of infinite series that appear in the identities are obtained in terms of mass, and first and second moments of inertia of the appendages, core body, and vehicle by using certain basic identities concerning appendage modes. 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; a characteristic proved and illustrated. Author

N90-23077*# Boeing Aerospace Co., Seattle, WA.
STRUCTURAL MODELING FOR CONTROL DESIGN (ARTICULATED MULTIBODY COMPONENT REPRESENTATION)
E. D. HAUGSE, R. E. JONES, and W. L. SALUS *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 819-830 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

High gain, high frequency flexible responses in gimbaled multibody systems are discussed. Their origin and physical significance are described in terms of detailed mass and stiffness modeling at actuator/sensor interfaces. Guyan Reduction, Generalized Dynamic Reduction, inadequate mass modeling detail, as well as system mode truncation, are shown to suppress the high gain high frequency response and thereby lose system flexibility important for stability and performance predictions. Model validation by modal survey testing is shown to risk similar loss of accuracy. Difficulties caused by high frequency responses in component mode simulations, such as DISCOS, and also linearized system mode simulations, are described, and approaches for handling these difficulties are discussed. Author

N90-23078*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SIGNIFICANCE OF NORMS AND COMPLETENESS IN VARIATIONAL BASED METHODS
JOEL A. STORCH *In its* Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 831-842 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

By means of a simple structural problem, an important requirement often overlooked in practice on the basis functions used in Rayleigh-Ritz-Galerkin type methods is brought into focus. The problem of the static deformation of a uniformly loaded beam is solved variationally by expanding the beam displacement in a Fourier Cosine series. The potential energy functional is rendered stationary subject to the geometric boundary conditions. It is demonstrated that the variational approach does not converge to the true solution. The object is to resolve this paradox, and in so doing, indicate the practical implications of norms and completeness in an appropriate inner product space. Author

N90-23080*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DYNAMIC ANALYSIS OF FLEXIBLE MECHANICAL SYSTEMS USING LATDYN
SHIH-CHIN WU, CHE-WEI CHANG (Comtek Co., Grafton, VA.), and JERROLD M. HOUSNER *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 844-859 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 22/2

A 3-D, finite element based simulation tool for flexible multibody systems is presented. Hinge degrees-of-freedom is built into equations of motion to reduce geometric constraints. The approach avoids the difficulty in selecting deformation modes for flexible components by using assumed mode method. The tool is applied to simulate a practical space structure deployment problem. Results of examples demonstrate the capability of the code and approach. Author

N90-23082*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MULTIBODY DYNAMICS MODEL BUILDING USING GRAPHICAL INTERFACES
GLENN A. MACALA *In its* Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 867-878 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

In recent years, the extremely laborious task of manually deriving equations of motion for the simulation of multibody spacecraft dynamics has largely been eliminated. Instead, the dynamicist now works with commonly available general purpose dynamics simulation programs which generate the equations of motion either explicitly or implicitly via computer codes. The user interface to these programs has predominantly been via input data files, each with its own required format and peculiarities, causing errors and frustrations during program setup. Recent progress in a more natural method of data input for dynamics programs: the graphical interface, is described. Author

N90-23083*# Buffalo Univ., NY. Dept. of Mechanical and Aerospace Engineering.
CONTROLLING FLEXIBLE STRUCTURES WITH SECOND ORDER ACTUATOR DYNAMICS
DANIEL J. INMAN, JEFFREY W. UMLAND, and JOHN BELLOS *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 879-890 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

The control of flexible structures for those systems with actuators that are modeled by second order dynamics is examined. Two modeling approaches are investigated. First a stability and performance analysis is performed using a low order finite dimensional model of the structure. Secondly, a continuum model of the flexible structure to be controlled, coupled with lumped parameter second order dynamic models of the actuators performing the control is used. This model is appropriate in the modeling of the control of a flexible panel by proof-mass actuators as well as other beam, plate and shell like structural numbers. The model is verified with experimental measurements. Author

N90-23086*# Ottawa Univ. (Ontario). Inst. of Electrical Engineering.
MODELING AND CONTROL OF FLEXIBLE SPACE STATIONS (SLEW MANEUVERS)
N. U. AHMED and S. S. LIM *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 900-914 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 22/2

Large orbiting space structures are expected to experience mechanical vibrations arising from several disturbing forces such as those induced by shuttle takeoff or docking and crew movements. The problem is considered of modeling and control of large space structures subject to these and other disturbing forces. The system consists of a (rigid) massive body, which may play the role of experimental modules located at the center of the space station and flexible configurations, consisting of several beams, forming the space structure. A complete dynamic model of the system was developed using Hamilton's principle. This model consists of radial equations describing the translational motion of the central body, rotational equations describing the attitude motions of the body and several beam equations governing the vibration of the flexible members (platform) including appropriate boundary conditions. In summary, the dynamics of the space structure is governed by a complex system of interconnected partial and ordinary differential equations. Using Lyapunov's approach the asymptotic stability of the space structure is investigated. For asymptotic stability of the rest state (nominal trajectory), feedback controls are suggested. In the investigation, stability of the slewing maneuvers is also considered. Several numerical results are presented for illustration of the impact of coupling and the effectiveness of the stabilizing controls. Some insight is provided into the complexity of modeling, analysis and stabilization of actual space structures. Author

N90-23089*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
A VERIFICATION LIBRARY FOR MULTIBODY SIMULATION SOFTWARE
SUNG-SOO KIM, EDWARD J. HAUG (Iowa Univ., Iowa City.), and HAROLD P. FRISCH *In* Jet Propulsion Lab., California Inst. of Tech., Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 2 p 917-928 15 Dec. 1989
Avail: NTIS HC A20/MF A03 CSCL 09/2

A multibody dynamics verification library, that maintains and manages test and validation data is proposed, based on RRC Robot arm and CASE backhoe validation and a comparitive study of DADS, DISCOS, and CONTOPS that are existing public domain and commercial multibody dynamic simulation programs. Using simple representative problems, simulation results from each program are cross checked, and the validation results are presented. Functionalities of the verification library are defined, in order to automate validation procedure. Author

N90-23138*# Institute for Computer Applications in Science and Engineering, Hampton, VA.
ANALYTIC SEMIGROUPS: APPLICATIONS TO INVERSE PROBLEMS FOR FLEXIBLE STRUCTURES Final Report
H. T. BANKS and D. A. REBNORD (Iowa State Univ. of Science and Technology, Ames.) May 1990 18 p Submitted for publication
(Contract NAS1-18605; NAG1-517; F49620-86-C-0111; NSF DMS-88-18530)
(NASA-CR-182047; NAS 1.26:182047; ICASE-90-36; AD-A223151) Avail: NTIS HC A03/MF A01 CSCL 12/1

Convergence and stability results for least squares inverse problems involving systems described by analytic semigroups are presented. The practical importance of these results is demonstrated by application to several examples from problems of estimation of material parameters in flexible structures using accelerometer data. Author

N90-23465# Stanford Univ., CA. Dept. of Aeronautics and Astronautics.
MODELING AND CONTROL OF FLEXIBLE VEHICLES IN SPACE Final Report, Oct. 1987 - Oct. 1989
A. E. BRYSON and F. A. WIESINGER 12 Feb. 1990 48 p
(Contract AF-AFOSR-0015-88; AF PROJ. 2302)
(AD-A219622; AFOSR-90-0299TR) Avail: NTIS HC A03/MF A01 CSCL 22/2

Several aspects of modeling and control of large space structures were investigated. A FORTRAN computer program is included which transforms modal data from commercially available finite element codes for personal computers to the forms needed for control system design. Design of a low order controller for a circular flat plate space structure is investigated by utilizing geometric symmetry of the structure and the control system actuators and sensor to decouple the system into smaller, single input-single output subsystems. GRA

N90-23468# California Univ., Los Angeles. Dept. of Electrical Engineering.
THEORY OF FILTERING AND CONTROL WITH APPLICATION TO CONTROL OF LARGE SPACE STRUCTURES Final Report, 1 Aug. 1988 - 31 Oct. 1989
A. V. BALAKRISHNAN 31 Oct. 1989 11 p
(Contract AF-AFOSR-0252-88; AF PROJ. 2304)
(AD-A219936; AFOSR-90-0345TR) Avail: NTIS HC A03/MF A01 CSCL 12/9

The problem of compensator design for co-located sensors using continuum models of flexible multibody systems was solved. Several nonlinear damping models for general distributed parameter systems for beam models of flexible multibody systems were developed. GRA

N90-23469# Texas Technological Univ., Lubbock. Dept. of Electrical Engineering.
A THEORY OF CONTROL FOR INFINITE DIMENSIONAL SYSTEMS WITH APPLICATION TO LARGE SCALE SPACE STRUCTURES Final Report, 15 Dec. 1987 - 14 Dec. 1989
EROL EMRE Feb. 1990 34 p
(Contract AF-AFOSR-0078-88; AF PROJ. 2304)
(AD-A219937; AFOSR-90-0332TR) Avail: NTIS HC A03/MF A01 CSCL 22/1

An extended and unifying system identification technique for a class of systems that include all main signal models that arise in the Harmonic Decomposition Problem has been obtained. This technique unifies and extends the previously developed system identification techniques which are improvements on the PISARENKO (MUSIC, dually) Harmonic Decomposition as they arise in arrays of sensors. The advantages of the technique and some of its specializations given here include having no assumptions of stationarity on the stochastic processes involved. Another contribution on this technique is to show that it can also

be used without any resort to probability theoretic concepts, thus bypassing the approximation of autocorrelations via time averages, yielding the system parameters exactly. This techniques can be utilized to determine the dominant modes of vibrations of flexible structures as well. An analogy is established between arrays of sensors for target signal returns and those that can be used for vibrations in flexible structures. GRA

N90-23588# Systems Engineering Labs., Inc., Greenbelt, MD.
NONLINEAR DYNAMICS AND CONTROL OF FLEXIBLE STRUCTURES Annual Report, 1 Sep. 1987 - 31 Aug. 1988
W. H. BENNETT, H. G. KWATNY, G. L. BLAKENSHIP, and O. AKHRIF 15 Nov. 1988 159 p
(Contract F49620-87-C-0103)
(AD-A218372; SEI-88-11-15-WB; AFOSR-90-0201TR) Avail: NTIS HC A08/MF A01 CSCL 13/2

The unprecedented requirements for rapid retargeting and precision pointing for spaced-based directed energy weapon platforms is the prime driver behind the reported modeling and control study. The combination of such requirements demand a comprehensive dynamic model of the nonlinear multibody dynamics of typical space platforms for such weapon including the interaction platform structural flexure effecting principal weapon system effective Line-Of-Sight. The first year effort of a three year project is described, which focuses on: the development of comprehensive; generic nonlinear dynamical models for typical space-based platforms; the development of high performance, nonlinear control laws for rapid slewing and precession pointing of primary weapon system payload apertures; and the design of a series of laboratory experiments to verify and test the control laws developed. The validation of the analytical models and the required control theory for the resulting class of nonlinear system is described. Simulation results are given for a simplified. Benchmark model of a space-based laser slewing control and consideration for compensation for structural flexure effecting optical LOS using optical steering mirrors is discussed. GRA

N90-23589# Techno-Sciences, Inc., Greenbelt, MD.
NONLINEAR DYNAMICS AND CONTROL OF FLEXIBLE STRUCTURES Annual Report, Sep. 1988 - Aug. 1989
W. H. BENNETT, H. G. KWATNY, G. L. BLAKENSHIP, O. AKHRIF, and C. LAVIGNA 12 Dec. 1989 128 p
(Contract F49620-87-C-0103; AF PROJ. D812)
(AD-A218476; TSI-89-1212-WB; AFOSR-90-0200TR) Avail: NTIS HC A07/MF A01 CSCL 15/6

Basic performance requirements for space-based directed energy weapons involve unprecedented requirements for integrated control of rapid retargeting and precision pointing of space structures. Multibody interactions excite nonlinear couplings which complicate the dynamic response. Attempts to reduce flexure response for such weapon platforms by passive techniques alone may be inadequate due to stringent pointing requirements. The principal objective of the research program is the validation and testing of high precision, nonlinear control of multibody systems with significant structural flexure where interactions arise due to rapid slewing. Dominant nonlinear couplings effecting LOS response have been identified based on a comprehensive model of the nonlinear multibody dynamics of a generic space weapon. The innovative approach to LOS slewing/pointing developed in this study is based on implementation of decoupling (by feedback control) of the principal nonlinear dynamics and structural flexure response. In this study we have focused on the implementation of partial feedback linearization and decoupling and have identified practical conditions for its implementation. A principal contribution of the study is the reconciliation of design of discontinuous control via sliding mode control with partial feedback linearization for rapid slewing of system effective LOS. GRA

N90-23745# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
STATISTICAL TECHNIQUES FOR DESIGNING A DECOUPLED CONTROLLER TO BE ROBUST TO MODEL AND SENSOR NOISE M.S. Thesis
JEB EWELL BREWER Mar. 1990 151 p
(AD-A220476; AFIT/GA/ENY/90M-1) Avail: NTIS HC A08/MF A01 CSCL 12/3

This thesis developed and tested statistical design methods for configuring a robust decoupled controller on a lightly damped structure. The test model used was a lumped mass finite element representation of the Charles Stark draper Laboratory Model I (CSDL-I). The decoupled control methods consisted of a system of three individual subcontrollers designed on the basis of a subset of plant dynamics with control authority enacted through the total system of structural actuators. Transforms were applied to the subcontrollers to insure that dynamic coupling, called observation spillover and control spillover, didn't destabilize the global system. The decoupled controller system was designed based on only the first eight of the twelve natural frequencies (modes) for the CSDL-I. The remaining four high frequency modes were modeled as residuals. This investigation used signal-to-noise ratios, orthogonal numerical experiments, and linear regression to efficiently probe the design space and to produce a robust control system. The measure of system performance was the structural alignment of a particular node referred to a line-of-sight (LOS). GRA

N90-23949# California Univ., Berkeley. Electronics Research Lab.
NUMERICAL OPTIMIZATION, SYSTEM THEORETIC AND SOFTWARE TOOLS FOR THE INTEGRATED DESIGN OF FLEXIBLE STRUCTURES AND THEIR CONTROL SYSTEMS Final Report, 30 Sep. 1986 - 29 Sep. 1989
ELIJAH POLAK 16 Feb. 1990 10 p
(Contract AF-AFOSR-0116-86; AF PROJ. 2304)
(AD-A219877; AFOSR-90-0339TR) Avail: NTIS HC A02/MF A01 CSCL 12/5

The research covered by this report was aimed at developing a broad, optimization-based methodology for use in computer-aided-design of engineering systems. To this end, research was carried out in the following areas: (1) the development of a theory which can be used as a general guide in the construction of semi-infinite optimization, shape optimization and optimal control algorithms; (2) the development of various new semi-infinite optimization and optimal control algorithms; (3) the development of techniques for formulating system stability and worst-case requirements as well-conditioned semi-infinite inequalities; (4) the exploration of the use of optimization in the design of control systems; and finally, (5) interactive software for optimization-based control system design. GRA

N90-24316# National Aerospace Lab., Amsterdam (Netherlands).
EQUIVALENT FLEXIBILITY MODELING: A NOVEL APPROACH TOWARDS RECURSIVE SIMULATION OF FLEXIBLE SPACECRAFT MANIPULATOR DYNAMICS
P. TH. L. M. VANWOERKOM *In* ESA, Second European In-Orbit Operations Technology Symposium p 289-295 Dec. 1989
(Contract NIVR-02506N)
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

For the simulation of rigid spacecraft manipulator dynamics there exists efficient recursive software. Extension of this software for the simulation of flexible spacecraft-manipulator dynamics would have important advantages. The method of Equivalent Flexibility Modelling (EFM) is outlined. Each flexible body is re-modeled as a concatenation of rigid bodies, acted upon by fictitious loads in addition to the real loads. To calculate the fictitious loads, some modifications of the software are required. A number of test cases were analyzed. The errors detected in these test cases are within the realm of computational inaccuracy. ESA

N90-24331# Centre d'Etudes et de Recherches, Toulouse (France). Dept. d'Etudes en Recherches Aerospatiales.
DYNAMIC MODELING AND CONTROL OF A FLEXIBLE ARM HOLDING A NON-RIGID PAYLOAD
P. CARTON, J. P. CHRETIEN, and M. MAURETTE (Centre National d'Etudes Spatiales, Toulouse, France) *In* ESA, Second European

In-Orbit Operations Technology Symposium p 405-411 Dec. 1989 Sponsored by CNES
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Payloads to be handled by space manipulators cannot always be considered as inert bodies represented by mass and inertias. They may feature flexible appendages, liquid sloshing in tanks or kinetic momentum wheels which will make their modeling and control more complex. Modeling is considered from the point of view of the connection of a dynamic model of a payload to a general purpose multi-body simulation package. Control issues are discussed in the frame of dynamic control, where the overall control loop is split up between an inner force control loop dependent only on the manipulator parameters, and on outer payload control loop which is designed for inert payloads and which performances for non-rigid ones are discussed. ESA

N90-24344# Groningen Rijksuniv. (Netherlands). Dept. of Agricultural Engineering and Physics.
DYNAMIC STABILIZATION OF LARGE FLEXIBLE SPACE STRUCTURES Ph.D. Thesis
JAN BONTSEMA 1989 239 p
(ETN-90-96926) Avail: NTIS HC A11/MF A02

Infinite dimensional models, and lower order finite dimensional models which are more used in practice are considered. The robustness theory is a valuable guide in deciding the right balance between the order of the stabilizing controller and the robustness margin desired to avoid spillover problems. Conclusions depend on the theory used. Insight into the problem of designing robust controllers for flexible systems under uncertainly is gained but the problem is far from solved. ESA

N90-24345# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
CONTROL OF LARGE SPACE STRUCTURES Final Report, 1 Feb. 1988 - 31 Jan. 1989
LEONARD MEIROVITCH 19 Feb. 1990 35 p
(Contract F49620-88-C-0044; AF PROJ. 2302)
(AD-A221216; AFOSR-90-0515TR) Avail: NTIS HC A03/MF A01 CSCL 22/1

Work during this period was concerned with: (1) development of a new method for the derivation of the state equations of motion for the control of flexible spacecraft in terms of quasi-coordinates; and (2) development of a method for the control of spacecraft in the form of articulated flexible multi-bodies. GRA

N90-24347# Lawrence Livermore National Lab., CA.
A HIERARCHICAL APPROACH TO LARGE SPACE STRUCTURE CONTROL
K. DAVID YOUNG 15 Jan. 1990 12 p Presented at the International Conference on Dynamics of Flexible Structures in Space, Cranfield, England, 15-18 May 1990
(Contract W-7405-ENG-48)
(DE90-010681; UCRL-102927; CONF-9005174-1) Avail: NTIS HC A03/MF A01

Controlled Component Synthesis (CCS) is a CSI approach to decentralized control of large structures which was developed by the author in 1987. In the CCS process, instead of following the conventional control system design path which begins with a model of the open loop plant, the controlled plant is assembled from controlled components for which the modeling phase and the control design phase are integrated at the component level. A hierarchical approach to large space structure control which utilizes the CCS process repeatedly in a multi-level setting is presented. DOE

N90-24636*# Polytechnic Univ., Farmingdale, NY. Research Inst.
REVIEW OF PROBABILISTIC ANALYSIS OF DYNAMIC RESPONSE OF SYSTEMS WITH RANDOM PARAMETERS Final Report
F. KOZIN and J. M. KLOSNER Dec. 1989 38 p
(Contract NAG1-986)
(NASA-CR-186171; NAS 1.26:186171; POLY-WRI-1569-89)
Avail: NTIS HC A03/MF A01 CSCL 20/11

The various methods that have been studied in the past to allow probabilistic analysis of dynamic response for systems with random parameters are reviewed. Dynamic response may have been obtained deterministically if the variations about the nominal values were small; however, for space structures which require precise pointing, the variations about the nominal values of the structural details and of the environmental conditions are too large to be considered as negligible. These uncertainties are accounted for in terms of probability distributions about their nominal values. The quantities of concern for describing the response of the structure includes displacements, velocities, and the distributions of natural frequencies. The exact statistical characterization of the response would yield joint probability distributions for the response variables. Since the random quantities will appear as coefficients, determining the exact distributions will be difficult at best. Thus, certain approximations will have to be made. A number of techniques that are available are discussed, even in the nonlinear case. The methods that are described were: (1) Liouville's equation; (2) perturbation methods; (3) mean square approximate systems; and (4) nonlinear systems with approximation by linear systems. M.G.

N90-24997*# Stevens Inst. of Tech., Hoboken, NJ. Dept. of Electrical Engineering and Computer Science.
OPTICAL RATE SENSOR ALGORITHMS Final Report
JO A. UHDE-LACOVARA *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 2 11 p Dec. 1989
Avail: NTIS HC A08/MF A01 CSCL 20/6

Optical sensors, in particular Charge Coupled Device (CCD) arrays, will be used on Space Station to track stars in order to provide inertial attitude reference. Algorithms are presented to derive attitude rate from the optical sensors. The first algorithm is a recursive differentiator. A variance reduction factor (VRF) of 0.0228 was achieved with a rise time of 10 samples. A VRF of 0.2522 gives a rise time of 4 samples. The second algorithm is based on the direct manipulation of the pixel intensity outputs of the sensor. In 1-dimensional simulations, the derived rate was with 0.07 percent of the actual rate in the presence of additive Gaussian noise with a signal to noise ratio of 60 dB. Author

N90-25362# Finnish Academy of Technology, Helsinki.
GENERATION OF AN AXISYMMETRIC CYLINDRICAL SHELL ELEMENT USING A SHOOTING METHOD
PENTTI TUOMINEN (Oulu Univ., Finland) 1989 54 p Sponsored by Tekniikan Edistaamissaeaetioe Foundation
(ACTA-POLYTEC-SCAND-CI-93; ISBN-951-666-287-0; ISSN-0355-2705; ETN-90-96567) Avail: NTIS HC A04/MF A01

A finite difference shooting method is considered. The method is used to generate axisymmetric shell finite elements. The method is first described generally in connection with axially symmetric thin surface elements. Secondly, a cylindrical shell element is formed. Properties of the method are considered using numerical examples. Results are compared with analytical ones. Some conclusions concerning the use of the method are drawn. A brief consideration of the differences in results obtained by approximate and complete Fluegge equations for a cylindrical shell is made. ESA

N90-25369*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST CONTROLLER DESIGNS FOR SECOND-ORDER DYNAMIC SYSTEM: A VIRTUAL PASSIVE APPROACH
JER-NAN JUANG and MINH PHAN (National Academy of Sciences - National Research Council, Washington, DC.) May 1990 22 p
(NASA-TM-102666; NAS 1.15:102666) Avail: NTIS HC A03/MF A01 CSCL 20/11

A robust controller design is presented for second-order dynamic systems. The controller is model-independent and itself

is a virtual second-order dynamic system. Conditions on actuator and sensor placements are identified for controller designs that guarantee overall closed-loop stability. The dynamic controller can be viewed as a virtual passive damping system that serves to stabilize the actual dynamic system. The control gains are interpreted as virtual mass, spring, and dashpot elements that play the same roles as actual physical elements in stability analysis. Position, velocity, and acceleration feedback are considered. Simple examples are provided to illustrate the physical meaning of this controller design. Author

N90-26046*# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
DESIGN AND IMPLEMENTATION OF ROBUST DECENTRALIZED CONTROL LAWS FOR THE ACES STRUCTURE AT MARSHALL SPACE FLIGHT CENTER Final Report, 30 Jan. 1989 - 40 Apr. 1990
EMMANUEL G. COLLINS, JR., DOUGLAS J. PHILLIPS, and DAVID C. HYLAND Washington Jul. 1990 76 p
(Contract NAS1-18872)
(NASA-CR-4310; NAS 1.26:4310) Avail: NTIS HC A05/MF A01 CSCL 22/2

Many large space system concepts will require active vibration control to satisfy critical performance requirements such as line-of-sight accuracy. In order for these concepts to become operational it is imperative that the benefits of active vibration control be practically demonstrated in ground based experiments. The results of the experiment successfully demonstrate active vibration control for a flexible structure. The testbed is the Active Control Technique Evaluation for Spacecraft (ACES) structure at NASA Marshall Space Flight Center. The ACES structure is dynamically traceable to future space systems and especially allows the study of line-of-sight control issues. Author

N90-26213*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Electrical Engineering.
FEASIBILITY STUDY OF A SYNTHESIS PROCEDURE FOR ARRAY FEEDS TO IMPROVE RADIATION PERFORMANCE OF LARGE DISTORTED REFLECTOR ANTENNAS Semiannual Status Report
W. L. STUTZMAN and W. T. SMITH Aug. 1990 251 p
(Contract NAG1-859)
(NASA-CR-186641; NAS 1.26:186641; EE-SATCOM-90-2) Avail: NTIS HC A12/MF A02 CSCL 20/14

Surface errors on parabolic reflector antennas degrade the overall performance of the antenna. Space antenna structures are difficult to build, deploy and control. They must maintain a nearly perfect parabolic shape in a harsh environment and must be lightweight. Electromagnetic compensation for surface errors in large space reflector antennas can be used to supplement mechanical compensation. Electromagnetic compensation for surface errors in large space reflector antennas has been the topic of several research studies. Most of these studies try to correct the focal plane fields of the reflector near the focal point and, hence, compensate for the distortions over the whole radiation pattern. An alternative approach to electromagnetic compensation is presented. The proposed technique uses pattern synthesis to compensate for the surface errors. The pattern synthesis approach uses a localized algorithm in which pattern corrections are directed specifically towards portions of the pattern requiring improvement. The pattern synthesis technique does not require knowledge of the reflector surface. It uses radiation pattern data to perform the compensation. Author

N90-26361*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STRUCTURAL MECHANICS DIVISION RESEARCH AND TECHNOLOGY PLANS FOR FY 1990 AND ACCOMPLISHMENTS FOR FY 1989
KAY S. BALES Apr. 1990 99 p
(NASA-TM-102654; NAS 1.15:102654) Avail: NTIS HC A05/MF A01 CSCL 20/11

The Objectives, FY 1990 Plans, Approach, and FY 1990 Milestones for the Structural Mechanics Division's research programs are presented. FY 1989 Accomplishments are presented where applicable. This information is useful in program coordination with other governmental organizations in areas of mutual interest. Author

N90-26862# Massachusetts Inst. of Tech., Cambridge. Space Systems Lab.
LOCAL DESIGN METHODOLOGIES FOR A HIERARCHIC CONTROL ARCHITECTURE Final Report, 9 Jan. 1988 - 30 Jun. 1989
JONATHAN P. HOW, STEVEN R. HALL, and EDWARD F. CRAWLEY 12 Apr. 1990 217 p
(Contract F49620-88-C-0015; AF PROJ. 2302)
(AD-A222006; MIT-SSL-14-89; AFOSR-90-0524TR) Avail: NTIS HC A10/MF A02 CSCL 22/2

The problems associated with the control of large intelligent space structures with many sensors and actuators has previously led to the development of a hierarchic control architecture. This control arrangement consists of a two level combination of a centralized global controller and a set of local controllers which are distributed to complement the dynamic behavior of the structure. Four decentralized control methodologies which are suitable for implementation at the lower level of the hierarchic architecture are developed and analyzed in this thesis. The first design only allows colocated feedback. The second design allows feedback from within a region of the structure. The third allows communication between adjacent local controllers so that information from neighboring regions can be used for the feedback. The last employs a distributed implementation of the full state feedback. The simulation results for the control of a long beam in bending show that employing the more complicated decentralized designs at the lower level of the hierarchic architecture will slightly improve the overall performance. However, the implementation costs for these more sophisticated designs are shown to increase dramatically. The most efficient hierarchic design for this beam example is one which combines a good global design with a simple colocated feedback. This conclusion may change for structures which require more performance at the local level. GRA

N90-26863# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
CONTROL OF ORBITING LARGE SPACE STRUCTURAL SYSTEMS WITH DISCRETE TIME OBSERVATIONAL DATA AND RANDOM MEASUREMENT NOISE Final Report, 29 Jul. 1988 - 28 Feb. 1989
PETER M. BAINUM, XING GUANGQIAN, and APRILLE J. ERICSSON Mar. 1990 75 p
(Contract F33615-88-C-3208; AF PROJ. 2401)
(AD-A222476; WRDC-TR-90-3012) Avail: NTIS HC A04/MF A01 CSCL 22/3

The objective of this research is to develop practical design procedures that can be used in conjunction with optimal digital controllers and estimators for future orbiting large space structural systems. In practice, observational data used to verify the orientation and shape of large flexible systems will, in general, be collected on a sampled basis (discrete time data system). Random noise is also included with such observational data. Systems which will be designed to control both the overall orientation as well as the shape of some of the subsystems (such as an antenna mesh form) must function in the discrete-time domain. The aim of this research is to develop methods that can be used to design linear quadratic Gaussian (LQG) controllers/ estimators for orbiting large flexible systems. The digital control of an orbiting shallow shell antenna-type system, as well as flexible platform-type systems are examined. GRA

N90-26864# Michigan Univ., Ann Arbor. Dept. of Electrical Engineering and Computer Science.
AIMING CONTROL: THEORY AND APPLICATIONS TO DYNAMIC CONTROL OF SPACE STRUCTURES Final Report, 1 Aug. 1987 - 31 Jul. 1989
SEMYON M. MEERKOV 25 Jul. 1989 90 p

(Contract F49620-87-C-0079; AF PROJ. 2304)
(AD-A221532; AFOSR-90-0520TR) Avail: NTIS HC A05/MF A01 CSCL 22/2

The goal is the investigation of fundamental bounds on the maximal achievable precision of aiming of dynamical systems with random perturbations and application of these bounds to control of space structures. To this end, the following results were obtained: it was shown that linear systems with small additive noise can be pointed with any desired accuracy by output feedback if and only if the system is invertable and minimum phase in an approximate sense; when the measurements noise is present, the maximal achievable precision of aiming is bounded, even if the conditions mentioned above are satisfied; thus, the measurement noise has a more severe effect on the pointability of dynamical system than the input noise. In addition, the problem of residence probability control was investigated and its relation to the problem of residence time control was analyzed. GRA

N90-26866# Optron Systems, Inc., Bedford, MA.
OPTICAL WAVEFRONT COMPUTER FOR STABILIZING LARGE SPACE STRUCTURES Final Technical Report, 1 Sep. 1989 - 28 Feb. 1990
IRA FARBER 1 Sep. 1989 26 p
(Contract N00014-89-C-0223)
(AD-A221707) Avail: NTIS HC A03/MF A01 CSCL 20/6

This final report investigates a new adaptive optics system architecture for wavefront correction based primarily on optical processing. The highlights are: (1) The design of a new adaptive optics system architecture incorporating optical rather than electronic processing for wavefront sampling and reconstruction. Unlike conventional adaptive systems incorporating electronic processors, the new optical system exhibits a framing rate that is independent of the sampling and reconstruction resolutions. (2) An analysis of requirements and specifications for all major components needed to implement the new optical architecture, including a lenslet array, an image intensifier tube, an optically addressed binary amplitude spatial light modulator, a transmission mask, a computer generated wavefront reconstruction hologram and an optically addressed phase modulator. (3) Design of the minimum mean square error phase reconstruction hologram. GRA

N90-26867# Virginia Univ., Charlottesville. Dept. of Applied Mathematics.
INCREASING THE MARGIN OF STABILITY OF ARBITRARILY FINITE MODES OF FLEXIBLE LARGE SPACE STRUCTURES WITH DAMPING Final Report, 1 Sep. 1987 - 30 Nov. 1989
R. TRIGGIANI and I. LASIECKA 22 Feb. 1990 18 p
(Contract AF-AFOSR-0321-87)
(AD-A221742; UVA/525701/AM90/101) Avail: NTIS HC A03/MF A01 CSCL 12/1

This final report summarizes the principal investigators' achievements on the research project during the period September 1, 1987 through November 30, 1989. These include new results for wave equations and plate equations, linear and nonlinear, on the following problems: exact controllability, strong and uniform stabilization, structural damping, quadratic optimal control problem, Riccati equations, robustness with respect to nonlinear uncertainties, and numerical aspects. GRA

N90-27459# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
INTEGRATED STRUCTURAL/CONTROL DESIGN VIA MULTIOBJECTIVE OPTIMIZATION Ph.D. Thesis
GARRET L. SCHNEIDER May 1990 88 p
(AD-A223088; AFIT/DS/ENY/90-02) Avail: NTIS HC A05/MF A01 CSCL 12/2

A minimum correction homotopy approach is used to obtain the simultaneous/integrated optimal design of a large flexible structure and its active control system. Instead of the usual method of weighting and summing all desired objectives to form a constrained scalar optimization problem, a vector of objective functions is dealt with directly. The Draper/RPL configuration (a central hub with four symmetric, identical arms) is the design structure. The design seeks to minimize the mass of the arms. Using simple feedback of arm displacements and velocities, the control system seeks to achieve specified closed-loop eigenvalues (frequencies and damping ratios) and control effort. Design variables are the arm dimensions, control system gains, and sensor and actuator locations. Not only can the structural design be accomplished while placing the closed-loop eigenvalues, but a simultaneous 50 percent reduction in mass and/or control effort can be obtained. Since reduced-order models were used for the structural/control design, the resultant configurations are easily driven unstable by spillover from higher-order unmodeled modes. A modal suppression technique is applied to eliminate observation spillover and provide a decade of deadband above the controller bandwidth. GRA

N90-27613# Universal Energy Systems, Inc., Dayton, OH.
UNITED STATES AIR FORCE RESEARCH INITIATION PROGRAM FOR 1988, VOLUME 1
RODNEY C. DARRAH and CLAUDE CAVENDER Apr. 1990 976 p
(Contract F49620-88-C-0053)
(AD-A223123; AFOSR-90-0707TR-VOL-1) Avail: NTIS HC A99/MF E09 CSCL 05/2

Papers from this program are presented. Some titles are: Synergistic effects of bomb cratering; Automated motion parameter determination from an image sequence; Modeling and simulation on microcomputers, 1989; Two dimensional MHD simulation of accelerating arc plasmas; Modeling reactive fragments; Target-aerosol discrimination for active optical proximity sensors; The dynamics of impact; Multigraph kernel for transputer based systems; MTF studies of IR focal plane arrays at low flux levels; Droplet size distributions and combustion modeling in a pintle injector spray; Multiple scattering in solid fuel rocket plumes; Influence of forced disturbances on the vortex core and the vortex burst; Large space structure parameter estimation; Calibration of the infrared spectropolarimeter; Computer code to include core polarization in effective potential basis set expansion studies; Fluorescence spectra of matrix-isolated lithium; Energy-and time-resolved photophysics and photochemistry of high energy cryogenic metal-containing rocket fuels; Experimental verification and development of structural identification techniques on a grid; Experimental investigation of the stability of jets near the critical point; HF network evaluation; High intensity compressive stress wave propagation through unsaturated sands. GRA

N90-27615# Universal Energy Systems, Inc., Dayton, OH.
UNITED STATES AIR FORCE RESEARCH INITIATION PROGRAM FOR 1988, VOLUME 3
RODNEY C. DARRAH and CLAUDE CAVENDER Apr. 1990 1050 p
(Contract F49620-88-C-0053)
(AD-A223125; AFOSR-90-0709TR-VOL-3) Avail: NTIS HC A99/MF E09 CSCL 05/2

Papers from this program are presented. Some titles are: Vaporization behavior of pure and multicomponent fuel droplets in a hot air stream; Vortical structures in a 2-D slot burner-cold flow; Calculations of interface-state occupation function and GaAs/Ge heterostructure solar cell efficiency; Computer simulation of adaptive resource management in real time; Proving equivalence of high and low level architectural descriptions in VHDL; Applications of evolutionary learning strategies to pattern recognition tasks; Effect of roughened surface on turbulent boundary layer separation at Mach 6.0; Stochastic model of fatigue crack growth due to random loading for application to aircraft wheels; Fatigue characteristics of F-16 composite transparency material determined by long term and accelerated methods; Convergence of upper-bound optimum design of large scale structures with specified frequency bands; Robustness with positive real controllers for large space structures; Robust eigenstructure assignment for flight control design; Comparative burning rates and duplex loads of solid propellants; Low velocity impact of composite materials; Aircraft availability model (Feasibility study

for POM forecasting); Tunable absorption in doping superlattices; Joining of carbon-carbon composites; Characterization of the phase separation behavior of poly(p-phenylene benzobisthiazole)/ Amorphous nylon molecular composites by small angle light scattering. GRA

N90-27757# Wright Research Development Center, Wright-Patterson AFB, OH.
FLEXIBLE STRUCTURE CONTROL AND RIGID BODY DYNAMICS
V. B. VENKAYYA *In* AGARD, Space Vehicle Flight Mechanics 6 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The main interest is to promote the objectives of Control-Structure Interaction (CSI) in vibration suppression and attitude control of large space structures. Integration of multibody dynamics, flexible structures and control system design is considered extremely important in CSI research. The concepts of decentralized controls and optimization of lightly damped systems are the promising approaches for realistic applications. Author

N90-28103*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST EIGENSYSTEM ASSIGNMENT FOR SECOND-ORDER ESTIMATORS
JER-NAN JUANG and PEIMAN G. MAGHAMI Jul. 1990 13 p Previously announced in IAA as A90-26778
(NASA-TM-102696; NAS 1.15:102696) Avail: NTIS HC A03/MF A01 CSCL 20/11

An approach for the robust eigensystem assignment of flexible structures using full state or output feedback is developed. Using the second-order dynamic equations, the approach can assign the eigenvalues of the system via velocity and displacement feedbacks, or acceleration and velocity feedbacks. The eigenvalues and eigenvectors of the system are assigned, via the second-order eigenvalue problem for the structural system, in two steps. First, an orthonormal basis spanning the attainable closed-loop eigenvector space corresponding to each desired closed-loop eigenvalue is generated using the Singular Value or QR decompositions. Second, a sequential procedure is used to choose a set of closed-loop eigenvectors that are as close as possible to the column space of a well-conditioned target matrix. Among the possible choices of the target matrix, the closest unitary matrix to the open-loop eigenvector matrix appears to be a suitable choice. A numerical example is given to illustrate the proposed algorithm. Author

N90-28575 Texas A&M Univ., College Station.
ACTIVE CONTROL OF FLEXIBLE STRUCTURES Ph.D. Thesis
SLIM CHOURA 1989 223 p
Avail: Univ. Microfilms Order No. DA9015472

The active control of vibratory motion in distributed parameter systems (DPS) caused by an initial disturbance is considered. Control strategies that eliminate such vibrations in a finite time using a single fixed actuator are proposed. Also explored is possible elimination of vibratory motions by moving actuators. An open loop control strategy based on minimum energy control elminates totally in finite time a predetermined set of vibratory modes using a single force actuator. The proposed minimum energy strategy compares well with the true minimum time achieved by a bang-bang control and does not have any intermediate discontinuities that are present in a bang-bang control. It can only have two discontinuities at most. A combination of feedforward and feedback provides robustness. The feedforward is based on the minimum energy solution. The novel control strategies developed yield results that are comparable if not better than those achievable by conventional control strategies. A simple experiment supports the viability of the proposed strategies. Also explored is a novel concept for actively controlling DPS by moving force actuators. The elimination of a predetermined set of vibratory modes, by one or more moving force actuators is possible. Two such control strategies are proposed. The first strategy uses a finite number of distinct actuators to control an equal number of critical modes. The second uses only a single actuator to control a finite number of critical modes and is based on energy functions. Dissert. Abstr.

N90-28591*# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES - 13 Final Report
PETER M. BAINUM, FEIYUE LI, and JIANKE XU Sep. 1990 82 p
(Contract NSG-1414)
(NASA-CR-186930; NAS 1.26:186930) Avail: NTIS HC A05/MF A01 CSCL 22/2

The optimal control of three-dimensional large angle maneuvers and vibrations of a Shuttle-mast-reflector system is considered. The nonlinear equations of motion are formulated by using Lagrange's formula, with the mast modeled as a continuous beam subject to three-dimensional deformations. Pontryagin's Maximum Principle is applied to the slewing problem, to derive the necessary conditions for the optimal controls, which are bounded by given saturation levels. The resulting two point boundary value problem is then solved by using the quasilinearization algorithm and the method of particular solutions. The study of the large angle maneuvering of the Shuttle-beam-reflector spacecraft in the plane of a circular earth orbit is extended to consider the effects of the structural offset connection, the axial shortening, and the gravitational torque on the slewing motion. Finally, the effect of additional design parameters (such as related to additional payload requirement) on the linear quadratic regulator based design of an orbiting control/structural system is examined. Author

N90-28754*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DEVELOPMENT AND APPROACH TO LOW-FREQUENCY MICROGRAVITY ISOLATION SYSTEMS
CARLOS M. GRODSINSKY Washington Aug. 1990 24 p
(NASA-TP-2984; E-5287; NAS 1.60:2984) Avail: NTIS HC A03/MF A01 CSCL 22/1

The low-gravity environment provided by space flight has afforded the science community a unique arena for the study of fundamental and technological sciences. However, the dynamic environment observed on space shuttle flights and predicted for Space Station Freedom has complicated the analysis of prior microgravity experiments and prompted concern for the viability of proposed space experiments requiring long-term, low-gravity environments. Thus, isolation systems capable of providing significant improvements to this random environment are being developed. The design constraints imposed by acceleration-sensitive, microgravity experiment payloads in the unique environment of space and a theoretical background for active isolation are discussed. A design is presented for a six-degree-of-freedom, active, inertial isolation system based on the baseline relative and inertial isolation techniques described. Author

N90-29425*# Houston Univ., Clear Lake, TX. Research Inst. for Computing and Information Systems.
A NEW MOMENTUM MANAGEMENT CONTROLLER FOR THE SPACE STATION
B. WIE, K. W. BYUN, and V. W. WARREN Jan. 1988 34 p Previously announced in IAA as A88-50233
(Contract NCC9-16)
(NASA-CR-187265; NAS 1.26:187265) Avail: NTIS HC A03/MF A01 CSCL 22/2

A new approach to CMG (control moment gyro) momentum management and attitude control of the Space Station is developed. The control algorithm utilizes both the gravity-gradient and gyroscopic torques to seek torque equilibrium attitude in the presence of secular and cyclic disturbances. Depending upon mission requirements, either pitch attitude or pitch-axis CMG momentum can be held constant: yaw attitude and roll-axis CMG

momentum can be held constant, while roll attitude and yaw-axis CMG momentum cannot be held constant. As a result, the overall attitude and CMG momentum oscillations caused by cyclic aero-dynamic disturbances are minimized. A state feedback controller with minimal computer storage requirement for gain scheduling is also developed. The overall closed-loop system is stable for + or - 30 percent inertia matrix variations and has more than + or - 10 dB and 45 deg stability margins in each loop. Author

N90-29643# Army Armament Research, Development and Engineering Center, Picatinny Arsenal, NJ. Fire Support Armament Center.
TIP-POSITION CONTROL OF A FLEXIBLE BEAM: MODELING APPROACHES AND EXPERIMENTAL VERIFICATION
Technical Report, Sep. 1988 - Sep. 1989
M. MATTICE, N. COLEMAN, and K. CRAIG (Rensselaer Polytechnic Inst., Troy, NY.) Jun. 1990 66 p
(AD-A224249; ARFSD-TR-90003) Avail: NTIS HC A04/MF A01 CSCL 20/11

The dynamic modeling part of an experimental/theoretical effort is presented to develop and test pointing and tracking control techniques for a mechanical system containing both rigid and flexible bodies. Recently much work has been done to model open loop chains of rigid and elastic bodies with application to kinematic linkages, spacecraft, and manipulators. GRA

N90-29661# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.
RESEARCH INTO TRAVELING WAVE CONTROL IN FLEXIBLE STRUCTURES Final Report, 1 Nov. 1988 - 28 Feb. 1990
ANDREAS H. VONFLOTOW 15 Jun. 1990 180 p
(Contract AF-AFOSR-0029-88; AF PROJ. 2302)
(AD-A224504; AFOSR-90-0837TR) Avail: NTIS HC A09/MF A01 CSCL 20/11

This report summarizes 16 months of research into active control of elastic wave propagation in flexible structures. The report format is that of a brief executive summary supported by an extensive appendix containing the research publications generated in the course of this research. The research performed can be broken into two major fields: broadband damping by impedance matching the control system to the underlying wave (or dereverberated) impedance of a flexible structure; and sensor development for purposes of wave observation and control. GRA

N90-29664# Wright Research Development Center, Wright-Patterson AFB, OH.
PROCEEDINGS OF DAMPING '89. VOLUME 1: PAGES AAB-1 THROUGH DCD-11 Final Report, Feb. 1986 - Feb. 1989
Nov. 1989 511 p Proceedings held in West Palm Beach, FL, 8-10 Feb. 1989
(Contract AF PROJ. 486U)
(AD-A223431; WRDC-TR-89-3116-VOL-1) Avail: NTIS HC A22/MF A03 CSCL 20/11

Session topics in this volume include: complex modules; aircraft applications; composite materials/structures; electro-rheological fluids; hydraulic dampers; damping identification and analysis; fractional derivatives; and space applications. GRA

N90-29665# Wright Research Development Center, Wright-Patterson AFB, OH.
PROCEEDINGS OF DAMPING '89. VOLUME 2: PAGES FAA-1 THROUGH IBD-15 Final Report, Feb. 1986 - Feb. 1989
Nov. 1989 694 p Proceedings held in West Palm Beach, FL, 8-10 Feb. 1989
(Contract AF PROJ. 486U)
(AD-A223432; WRDC-TR-89-3116-VOL-2) Avail: NTIS HC A99/MF A04 CSCL 20/11

Individual papers of Damping 89 are presented. The subjects include: mechanical properties of polymers, experimental methods, damping in metal matrix composites, friction damping, design of damping structure, modal damping values, and applications of damping. Session topics included in this volume are: complex modulus data; structural applications; control structure interactions; nonlinear systems; fluids/friction; struts; phenomena; large space structures; joints; viscous dampers; optimization; and aircraft experiments. GRA

N90-29666# Wright Research Development Center, Wright-Patterson AFB, OH.
PROCEEDINGS OF DAMPING '89. VOLUME 3: PAGES ICA-1 THROUGH KDC-15 Final Report, Feb. 1986 - Feb. 1989
Nov. 1989 608 p Proceedings held in West Palm Beach, FL, 8-10 Feb. 1989
(Contract AF PROJ. 486U)
(AD-A223433; WRDC-TR-89-3116-VOL-3) Avail: NTIS HC A99/MF A04 CSCL 20/11

Session topics in this volume include: vibration suppression; free layer damping; laminates; launching; model verification; metals; sandwich construction; impact damping; and space applications. GRA

N90-29871*# Massachusetts Inst. of Tech., Cambridge. Dept. of Mechanical Engineering.
THE CONTROL OF SPACE MANIPULATORS SUBJECT TO SPACECRAFT ATTITUDE CONTROL SATURATION LIMITS
S. DUBOWSKY, E. E. VANCE, and M. A. TORRES *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 409-418 31 Jan. 1989
Sponsored by NASA, Langley Research Center
Avail: NTIS HC A19/MF A03 CSCL 05/8

The motions of robotic manipulators mounted on spacecraft can disturb the spacecraft's positions and attitude. These disturbances can surpass the ability of the system's attitude control reaction jets to control them, for the disturbances increase as manipulator speeds increase. If the manipulator moves too quickly the resulting disturbances can exceed the saturation levels of the reaction jets, causing excessive spacecraft motions. A method for planning space manipulator's motions is presented, so that tasks can be performed as quickly as possible without saturating the system's attitude control jets. Author

08

ASSEMBLY, MAINTENANCE, and EXTRAVEHICULAR ACTIVITY

Description of on-orbit deployment or assembly including tools. Includes space suits and other EVA equipment or support.

A90-32344
NUMERICAL SIMULATION IN THE DEPLOYMENT OF SPACE STRUCTURES
M. GERADIN, A. CARDONA (CONICET, Buenos Aires, Argentina), and D. GRANVILLE (Liege, Universite de l'Etat, Belgium) IN: Computational experiments; Proceedings of the ASME/JSME Pressure Vessels and Piping Conference, Honolulu, HI, July 23-27, 1989. New York, American Society of Mechanical Engineers, 1989, p. 61-66. refs
Copyright

A finite-element methodology for modeling the dynamic behavior of flexible articulated structures is described. The key aspects of the simulation method - finite rotation description, finite-element modeling of beam-type elastic members, substructuring technique, and formulation of kinematic parts, are presented. Simulation of the deployment of large space structures is assessed, including the kinetostatic analysis of a foldable astromast cell, the deployment of the ERA platform for the MIR space station, and the deployment of a solar array whose dynamics are governed by the very nonlinear characteristics of actuating springs and shock interference in the joints. V.T.

A90-36199*# Ocean Systems Engineering, Inc., Falls Church, VA.
OPPORTUNITIES FOR SPACE STATION ASSEMBLY OPERATIONS DURING CREW ABSENCE
JOSEPH C. PARRISH (Ocean Systems Engineering, Inc., Falls Church, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, May-June 1990, p. 338-345. Previously cited in issue 09, p. 1296, Accession no. A89-25333. refs
(Contract NASW-4300)
Copyright

A90-38071* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PHOTOVOLTAIC MODULE ON-ORBIT ASSEMBLY FOR SPACE STATION FREEDOM
T. SOURS (NASA, Lewis Research Center, Cleveland, OH), R. LOVELY, and D. CLARK (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 251-256. Previously announced in STAR as N89-26887. refs
Copyright

One of the elements of the Space Station Freedom power system is the photovoltaic (PV) module. These modules will be assembled on-orbit during the assembly phase of the program. These modules will be assembled either from the Shuttle Orbiter or from the Mobile Servicing Center (MSC). The different types of assembly operations that will be used to assemble PV modules are described. Author

A90-43466* 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. (NASA, Langley Research Center, Hampton, VA) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 93-109. Previously announced in STAR as N89-13487. refs
(AAS PAPER 88-168) Copyright

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

A90-43467* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A TELEROBOTIC SYSTEM FOR AUTOMATED ASSEMBLY OF LARGE SPACE STRUCTURES
MARVIN D. RHODES, RALPH W. WILL (NASA, Langley Research Center, Hampton, VA), and MARION A. WISE (PRC Kentron, Inc., Hampton, VA) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 111-129. Previously announced in STAR as N89-21824.
(AAS PAPER 88-170) Copyright

Future space missions such as polar platforms and antennas are anticipated to require large truss structures as their primary support system. During the past several years considerable research has been conducted to develop hardware and construction techniques suitable for astronaut assembly of truss structures in space. A research program has recently been initiated to develop the technology and to demonstrate the potential for automated in-space assembly of large erectable structures. The initial effort will be focused on automated assembly of a tetrahedral truss composed of 2-meter members. The facility is designed as a ground based system to permit evaluation of assembly concepts and was not designed for space qualification. The system is intended to be used as a tool from which more sophisticated procedures and operations can be developed. The facility description includes a truss structure, motionbases and a robot arm equipped with an end effector. Other considerations and requirements of the structural assembly describe computer control systems to monitor and control the operations of the assembly facility. Author

A90-44553#
DEVELOPMENT OF LOCAL LIQUID COOLING GARMENT
GUOJIE DU, SHENRAN GE, and ZIYUAN LIN (Institute of Space Medico-Engineering, Beijing, People's Republic of China) Chinese Space Science and Technology (ISSN 1000-758X), vol. 9, Feb. 1989, p. 13-23. In Chinese, with abstract in English. refs

This paper systematically describes the design, pattern technology methodology characteristics, and functional features of a local liquid cooling garment. Experimental test results on the garment are reported. C.D.

A90-45210
A HELMET MOUNTED DISPLAY APPLICATION FOR THE SPACE STATION FREEDOM EXTRAVEHICULAR MOBILITY UNIT
CONSTANCE L. TRITSCH (Lockheed Engineering and Sciences Co., Houston, TX) IN: Helmet-mounted displays; Proceedings of the Meeting, Orlando, FL, Mar. 28, 29, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 76-79. refs
Copyright

Several designs evolved in the development of the helmet-mounted display for the Space Station EVA mobility unit involved in extravehicular activity are reviewed, including a binocular pupil-forming system with two CRT image sources, a binocular system utilizing LCD image sources, and two designs employing conventional and holographic optics. Key design parameters, such as image/illumination sources, field of view, exit-pupil versus nonpupil forming systems, and monocular versus binocular and biocular systems. The degree of image overlap and the use of holographic optical elements are also assessed. V.T.

A90-48524
SOVIETS PLAN INTENSIVE EVA PROGRAM TO RECONFIGURE, REPAIR MIR STATION
Aviation Week and Space Technology (ISSN 0005-2175), vol. 133, Aug. 27, 1990, p. 65, 68, 69.
Copyright

A major reconfiguration of the Mir space station's electrical power system and repair of a balky hatch is being planned. Crewmembers will perform a series of extravehicular activities to remove two solar panels presently installed on Mir's Kristall building block module and reposition them on the Kvant 1 module. Change in Mir's electrical system calls for the installation of new cabling inside the station. Power from solar panels on the core station and the Kvant 2/Kristall modules is to be redistributed via the cables to meet varying power needs that depend upon equipment-system operating cycles in the various parts of the station. Mission planning into 1992 calls for cosmonaut flights lasting about six months. R.E.P.

A90-48543
ORIGINS OF SOVIET SPACE PRESSURE SUITS, 1930-1963
DAVID J. SHAYLER (Astro Info Services, Halesowen, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Sept. 1990, p. 417-423. refs
Copyright

The origins of the Soviet space pressure suits and their development are discussed. A detailed account is given of the first Soviet pressure suit which was tested in 1937 in a

low-temperature and low-pressure chamber to 90 mm Hg chamber pressure, -50 C, and an altitude of 9.02 km, and subsequent testing and developments through 1949. Aviation pressure garments and initial space-suit designs are reviewed including fur leggings and full space pressure suits for dogs. The first true space-suit, the Vostok space-suit, worn by Yuri Gagarin is shown and its features described, and the subsequent test program is assessed. L.K.S.

A90-48994
FREE-FLYERS FOR SPACE STATION EXTRAVEHICULAR ACTIVITY
Aerospace Engineering (ISSN 0736-2536), vol. 10, Sept. 1990, p. 21-24.
Copyright

Free-flyer designs that may reduce EVA operational time requirements are being examined. They are expected to be employed for a great variety of tasks, including transportation, inspection, positioning of large structures, and retrieval operations. Advantages of free-flyers, manned or unmanned, include improved accessibility to certain worksites, remote servicing, crew and equipment retrieval, and equipment and crew translation. Among the free-flyers currently under development are the Beam Assembly Teleoperator, the Multimode Proximity Operations Device, the Extravehicular Activity Retriever (EVAR), and the Crew and Equipment Retrieval Free-Flyer. The EVAR, sponsored by NASA, is an autonomous free-flyer that would assist EVA activities in a variety of ways. By using an object recognition capability, it can retrieve a dropped object, then seize the object, and return it while avoiding any collision. The EVAR will react to voice commands from both EVA crewmembers and extravehicular activity. R.E.P.

A90-49314
DEVELOPMENT OF THE SUIT ENCLOSURE OF THE EUROPEAN EVA SPACE SUIT
Y. OLLIVIER (AMDBA, Saint-Cloud, France) and M. DIENER (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. Research supported by ESA.
(SAE PAPER 901244) Copyright

The effort carried out in Europe for the design and development of an EVA suit enclosure module (ESEM) operating at 500 hPa within the framework of the development studies of the Hermes EVA system is presented. The ESEM design is supported by technology studies focused on a breadboard manufacturing and testing program. A glove breadboard is tested in a dedicated glove box and a material screening is performed leading to an arm thermal protection and an elbow soft joint respectively thermally and mechanically tested. These technology programs and a general definition study of the ESEM flight model are described. R.E.P.

A90-49315
EVA LIFE SUPPORT DESIGN ADVANCEMENTS
ROLAND VAETH and A. INGEMAR SKOOG (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 19 p.
(SAE PAPER 901245) Copyright

The European Space Agency has initiated the development of a system for Extra Vehicular Activities (EVA), which will allow European astronauts to work in space. The key element in this development is a space suit. This paper provides the development status of critical technologies started in this predevelopment phase with respect to the EVA life support functions. The results of these technology investigations on breadboard model level will be used as starting point for the Phase C/D to reduce the development risk. This European EVA Space Suit System shall be operational for the first manned Hermes flight in 1999. Author

A90-49316
EMULATION OF THE EVA SOVIET SUIT FOR NEUTRAL BUOYANCY SIMULATIONS
D. HORNET (AMDBA, Vaucresson, France), L. DECRAMER, M. TOGNINI (CNES, Paris, France), and C. GORTAN (Compagnie Maritime d'Expertises, Marseille, France) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p.
(SAE PAPER 901246) Copyright

DASSAULT and COMEX have developed a 'wet' suit prototype, under a one year CNES contract, for the simulation of the Soviet EVA flight suit during underwater trainings. This concept, full of water and requiring a breathing system, allows to perfectly balance the astronaut in a neutrally buoyant suit like in O-g environment. The modeling of real pressurized joints has been overcome by means of adjustable mechanical articulations the principle of which is fully described. The prototype performances and representativity have been evaluated and validated through underwater donning/doffing and the replay of an actual EVA already performed in space by Soviet-French astronauts. This suit prototype is available today, for the European space system designers to evaluate the future EVA operations to refine the procedures and hardware requirements. The suit concept capabilities, linked to its high modularity and low development duration, are finally discussed. Author

A90-49332
LSOPP II - A PROGRAM FOR ADVANCED EVA SYSTEM MODELING AND TRADE STUDIES
BRIAN E. AMES and JOHN V. IOVINE (Lockheed Engineering and Sciences Co., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p. refs
(SAE PAPER 901264) Copyright

A computer analysis program designed to predict and evaluate the steady state performance and size of integrated extravehicular mobility unit life support systems has been developed for advanced missions. Trade study evaluations for various extravehicular activity technologies can be accomplished using the Life Support Options Performance Program, version 2.0 (LSOPP II). LSOPP II is an interactive menu-driven program based upon a dual loop structure (vent loop - water loop). It solves for the outlet flow conditions of each component in a loop, given the associated heat loads and inlet flow conditions. System and component results of LSOPP II include heat load, flow rate, pressure, temperature, power, weight, and volume. Author

A90-49335* Lockheed Engineering and Sciences Co., Houston, TX.
INTEGRATED MODEL OF G189A AND ASPEN-PLUS FOR THE TRANSIENT MODELING OF EXTRAVEHICULAR ACTIVITY ATMOSPHERIC CONTROL SYSTEMS
MATTHEW KOLODNEY and BRUCE C. CONGER (Lockheed Engineering and Sciences Co., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 13 p. Research supported by NASA.
(SAE PAPER 901268) Copyright

A computerized modeling tool, under development for the transient modeling of an extravehicular activity atmospheric control subsystem is described. This subsystem includes the astronaut, temperature control, moisture control, CO2 removal, and oxygen make-up components. Trade studies evaluating competing components and subsystems to guide the selection and development of hardware for lunar and Martian missions will use this modeling tool. The integrated modeling tool uses the Advanced System for Process Engineering (ASPEN) to accomplish pseudosteady-state simulations, and the general environmental thermal control and life support program (G189A) to manage overall control of the run and transient input output, as well as transient modeling computations and database functions. Flow charts and flow diagrams are included. R.E.P.

A90-49394* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AX-5 SPACE SUIT RELIABILITY MODEL
AL REINHARDT (NASA, Ames Research Center, Moffett Field,

CA; USAF, Office of Scientific Research, Washington, DC) and JOHN MAGISTAD (San Jose State University, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. Research supported by USAF and San Jose State University. refs
(SAE PAPER 901361) Copyright

The AX-5 is an all metal Extra-vehicular (EVA) space suit currently under consideration for use on Space Station Freedom. A reliability model was developed based on the suit's unique design and on projected joint cycle requirements. Three AX-5 space suit component joints were cycled under simulated load conditions in accordance with NASA's advanced space suit evaluation plan. This paper will describe the reliability model developed, the results of the cycle testing, and an interpretation of the model and test results in terms of projected Mean Time Between Failure for the AX-5. A discussion of the maintenance implications and life cycle for the AX-5 based on this projection is also included. Author

A90-49431* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT OF A REGENERABLE METAL OXIDE CO REMOVAL SYSTEM
ROBERT J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 21 p.
(Contract NAS9-17822)
(SAE PAPER 901430) Copyright

A regenerable metal oxide carbon dioxide (CO2) removal system was developed to replace the current means of a nonreusable chemical, lithium hydroxide, for removing the metabolic CO2 of an astronaut in a space suit. Testing indicates that a viable low-volume metal oxide concept can be used in the portable life support system for CO2 removal during Space Station extravehicular activity (EVA). A canister of nearly the same volume as that used for the Space Shuttle, containing 0.10 cu ft of silver-oxide-based pellets, was tested; test data analysis indicates that 0.18 cu ft of the metal oxide will result in an 8-hour EVA capability. The testing suggests that the metal oxide technology offers a low-volume approach for a reusable CO2 removal concept applicable for at least 40 EVA missions. The development and testing of the breadboard regeneration package is also described. Author

A90-49432* Allied-Signal Aerospace Co., Torrance, CA.
CHARACTERIZATION OF METAL OXIDE ABSORBENTS FOR REGENERATIVE CARBON DIOXIDE AND WATER VAPOR REMOVAL FOR ADVANCED PORTABLE LIFE SUPPORT SYSTEMS
TIMOTHY P. KAST, MAURENA S. NACHEFF-BENEDICT (Allied-Signal Aerospace Co., Torrance, CA), CRAIG H. CHANG (Allied-Signal Research and Technology, Des Plaines, IL), and ROBERT J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 9 p. refs
(Contract NAS9-17836; NAS9-17900)
(SAE PAPER 901431) Copyright

Characterization of the performance of a silver-oxide-based absorbent in terms of its ability to remove both gaseous CO2 and water vapor in an astronaut portable life support systems (PLSS) is discussed. Attention is focused on regeneration of the absorbent from the carbonite state of the oxide state, preconditioning of the absorbent using a humidified gas stream, and absorption breakthrough testing. Based on the results of bench-scale experiments, a test plan is carried out to further characterize the silver-oxide-based absorbent on a larger scale; it calls for examination of the absorbent in both an adiabatic packed bed and a near-isothermal cooled bed configuration. It is demonstrated that the tested absorbent can be utilized in a way that removes substantial amounts of CO2 and water vapor during an 8-hour extravehicular activity mission, and that applying the absorbent to PLSS applications can simplify the ventilation loop. V.T.

A90-49433* Allied-Signal Aerospace Co., Torrance, CA.
AN AIR BEARING FAN FOR EVA SUIT VENTILATION
ROGER P. MURRY (Allied-Signal Aerospace Co., Torrance, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 8 p. Research supported by NASA.
(SAE PAPER 901432) Copyright

The portable life-support system (PLSS) ventilation requirements are outlined, along with the application of a high-speed axial fan technology for extravehicular-activity (EVA) space-suit ventilation. Focus is placed on a mechanical design employing high-speed gas bearings, permanent magnet rotor, and current-fed chopper/inverter electronics. The operational characteristics of the fan unit and its applicability for use in a pure-oxygen environment are discussed. It delivers a nominal 0.17 cu m/min at 1.24 kPa pressure rise using 13.8 w of input power. It is shown that the overall selection of materials for all major component meets the NASA requirements. V.T.

A90-49434* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A DIRECT-INTERFACE FUSIBLE HEAT SINK FOR ASTRONAUT COOLING
CURTIS LOMAX and B. W. WEBBON (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 14 p. Previously announced in STAR as N90-25292. refs
(SAE PAPER 901433) Copyright

Astronaut cooling during extravehicular activity is a critical design issue in developing a portable life support system that meets the requirements of a space station mission. Some the requirements are that the cooling device can be easily regenerable and nonventing during operation. In response to this, a direct-interface, fusible heat sink prototpye with freezable quick-disconnects was developed. A proof-of-concept prototype was constructed and tested that consists of an elastic container filled with normal tap water and having two quick-disconnects embedded in a wall. These quick-disconnects are designed so that they may be frozen with the ice and yet still be joined to the cooling system, allowing an immediate flow path. The inherent difficulties in a direct-interface heat sink have been overcome, i.e., (1) establishing an initial flow path; (2) avoiding low-flow freeze-up; and (3) achieving adequate heat-transfer rates at the end of the melting process. The requirements, design, fabrication, and testing are discussed. Author

A90-50639#
THE USE OF SPIDER IN CONJUNCTION WITH TSS
SIMONETTA DI PIPPO (ASI, Rome, Italy), MARIO D. GROSSI, and ENRICO C. LORENZINI (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) AIAA, International Conference on Tethers in Space, 3rd, San Francisco, CA, May 17-19, 1989. 7 p. refs
(AIAA PAPER 89-1612)

The SPIDER (Space Inspection Device for Extravehicular Repairs) is an autonomous integrated space robot, designed by the Italian Space Agency primarily to perform visual inspection and precision repairing of space structures. SPIDER's candidacy as a free-flyer for TSS is discussed since SPIDER and TSS are expected to be on the same Shuttle flight. By using instrumentation carried by a two-meter-long expandable arm, SPIDER can conduct measurements in the bands from ULF (less than 1 Hz to 30 Hz) to HF (3 to 30 MHz) of the Ey and Ez components of the electric vector of the electromagnetic waves generated by the tether, as well as of the Bx, By, and Bz wave components. It can also conduct experiments on thermal, superthermal, and high-energy particles. Thus, SPIDER will be capable of exhaustively monitoring the interaction between the tether and the magnetoionic medium of the ionosphere. B.P.

N90-20121*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPONENT COUNT AND PRELIMINARY ASSEMBLY CONSIDERATIONS FOR LARGE SPACE TRUSS STRUCTURES
W. SCOTT KENNER, MARVIN D. RHODES, and W. B. FICHTER Feb. 1990 25 p
(NASA-TM-102604; NAS 1.15:102604) Avail: NTIS HC A03/MF A01 CSCL 22/2

Expressions for the number of truss components per truss division are presented along with expressions for the area and dimensions of mosaic hexagonal panel arrangements. The expressions were developed by substituting the number of truss components in specific truss divisions into associated polynomial equations and solving for the coefficients of the polynomials. To assist in automated or astronaut truss/panel assembly operations, a concept for assembling a tetrahedral truss with hexagonal panels is presented. The assembly concept minimizes the exchange of truss assembly devices and panel attachment devices, assuming that the number of exchanges is a driving assembly concern.
Author

N90-22080*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CYCLE LIFE MACHINE FOR AX-5 SPACE SUIT
DEBORAH S. SCHENBERGER *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 1-8 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 20/11

In order to accurately test the AX-5 space suit, a complex series of motions needed to be performed which provided a unique opportunity for mechanism design. The cycle life machine design showed how 3-D computer images can enhance mechanical design as well as help in visualizing mechanisms before manufacturing them. In the early stages of the design, potential problems in the motion of the joint and in the four bar linkage system were resolved using CAD. Since these problems would have been very difficult and tedious to solve on a drawing board, they would probably not have been addressed prior to fabrication, thus limiting the final design or requiring design modification after fabrication. Author

N90-22105*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEVELOPMENT OF CABLE DRIVE SYSTEMS FOR AN AUTOMATED ASSEMBLY PROJECT
CHARLES A. MONROE, JR. *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 353-367 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 13/9

In a robotic assembly project, a method was needed to accurately position a robot and a structure which the robot was to assemble. The requirements for high precision and relatively long travel distances dictated the use of cable drive systems. The design of the mechanisms used in translating the robot and in rotating the assembly under construction is discussed. The design criteria are discussed, and the effect of particular requirements on the design is noted. Finally, the measured performance of the completed mechanism is compared with design requirements.
Author

N90-23463# Naval Postgraduate School, Monterey, CA.
OMV (ORBITAL MANEUVERING VEHICLE) PAYLOAD SUPPORT CONCEPT FOR PEGASUS BOOSTED PAYLOADS M.S. Thesis
RONALD C. REPPER Sep. 1989 85 p
(AD-A218371) Avail: NTIS HC A05/MF A01 CSCL 22/2

A new concept of orbiting and maintaining payloads in low earth orbit is examined. Two existing technologies, namely the Pegasus Air-Launched Space Booster and the Orbital Maneuvering Vehicle (OMV), are merged to create an operational space system. The boosted payload need be an autonomous satellite, as the OMV will provide all required support to the payload. This allows new satellite design, as the weight and volume of non-productive satellite subsystems can be replaced with more payload. A superior system could then be orbited while maintaining a fixed weight and volume budget. Background on the proposed concept and the OMV and Pegasus vehicles is provided. The docking and activation of the Pegasus payload to the OMV are described. A comparison of a current NOAA satellite system to the OMV/Pegasus concept is offered to determine the merits of this strategy. Conclusions and recommendations are then offered concerning the economic and operational advantages over current space systems with the implementation of this new concept.
GRA

N90-24283*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ON-ORBIT OPERATIONS OF THE SPACE STATION FREEDOM ATTACHED PAYLOADS ACCOMMODATIONS EQUIPMENT
JEAN FOLSE LANE and JOSEPH STIVALETTI (Swales and Associates, Beltsville, MD.) *In* ESA, Second In-Orbit Operations Technology Symposium p 3-6 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 22/2

The Space Station Freedom which will serve as a base of operations for instruments performing space science is discussed. The Attached Payload Accommodation Equipment (APAE) will be a set of equipment designed to provide standard structural, power, data and thermal interfaces between payloads and the space station. The APAE is designed to minimize and simplify the on-orbit operations required for payload installation, replacement, and servicing. In addition, the APAE supplies launch support for small payloads and attitude control for payloads that required it. ESA

N90-24284*# Booz-Allen and Hamilton, Inc., Bethesda, MD.
OPERATIONS CONSIDERATIONS IN SPACE STATION FREEDOM ASSEMBLY
STEPHEN C. DOERING and WILLIAM G. BASTEDO, JR. *In* ESA, Second European In-Orbit Operations Technology Symposium p 7-11 Dec. 1989
(Contract NASW-4300)
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 22/2

The importance of planning the on-orbit operations inherent in the Space Station Freedom assembly sequence is discussed. Any solution to the assembly puzzle requires the simultaneous satisfaction of many diverse constraints, including: on-orbit assembly operations, NSTS (National Space Transportation System) payload bay constraints, NSTS performance capabilities, and provision of the requisite functionality for each on-orbit configuration. Because operations are in the critical path SSFP (Space Station Freedom Program) has chosen to carefully assess assembly operations as each launch manifest is developed and evaluated. ESA

N90-24295*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
EVOLUTION OF EVA CAPABILITIES FOR SPACE STATION CONSTRUCTION AND MAINTENANCE: SOVIET AND AMERICAN EXPERIENCE
CATHY D. KRAMER *In* ESA, Second European In-Orbit Operations Technology Symposium p 85-92 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 22/2

The evolution of both Soviet and American Extravehicular Activity (EVA) is discussed. A qualitative review evaluates each EVA with respect to risk, criticality, complexity, and duration. Graphics summarizing increase and rate of increase in productivity emphasize related advancements in the space suits, EVA tools, and equipment technology. Specifics that demonstrated ingenuity in accomplishing unplanned activities which required man's direct manipulation of large payloads and structures are presented. Accumulated EVA successes allow an effective, flexible, recommended approach for construction and maintenance of Space Station to be given in conclusion. ESA

N90-24296# Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).
THE EUROPEAN EVA SUIT: AN OPTIMIZED TOOL FOR HERMES/MTFF IN-ORBIT OPERATIONS
L. SIOMIONESCO, J. R. CHEVALLIER, A. I. SKOOG, and N. HERBER (Dornier System G.m.b.H., Friedrichshafen, Germany, F.R.) *In* ESA, Second European In-Orbit Operations Technology Symposium p 93-98 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

An historical review of the different concepts of EVA suits, both in U.S. and USSR; is given and the coherence of today's concepts in both countries is shown. The complexity of the U.S. Orbiter, and the type of missions for which it is designed lead to a ground serviced EVA suit system optimized for in-orbit autonomy and mobility. The MIR Salyut and EVA suits are fundamentally housekeeping tools for these stations. They are optimized for on-orbit adjustment and maintenance. An analysis of the technical requirements of crew protection, mobility, life support and crew productivity depending on the type of activities to be performed in-orbit is given. It shows different concepts and associated constraints. Technology developments which are required to make the European EVA space suit system a productivity optimized tool, are discussed. ESA

N90-24298# McDonnell-Douglas Space Systems Co., Huntington Beach, CA. Space Station Div.
TELEROBOTIC APPLICATION TO EVA
DAVIS E. ANDERSON *In* ESA, Second European In-Orbit Operations Technology Symposium p 115-121 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

An investigation of EVA/telerobotic cooperation dynamics through development of a data base that incorporates neutral buoyancy testing, verification, and demonstration is presented. A division between human and telerobotic Extravehicular Activity (EVA) tasks is defined. A propellant tank farm neutral buoyancy experiment is discussed as a combination of telerobot preferred, human preferred, and interchangeable elements. The capabilities of humans and telerobots to interact during such EVA operations are applied to the EVA requirements for the operation to determine the best mix of man and machine. The resulting cooperative scenarios are verified by neutral buoyancy simulation. ESA

N90-24299# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
HERA AND EVA CO-OPERATION SCENARIOS
F. DIDOT and W. LUETTGEN *In its* Second European In-Orbit Operations Technology Symposium p 123-128 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Co-operation of EVA astronauts and the Hermes Robot Arm (HERA) for in-orbit servicing operations is addressed. The Columbus Free Flying Laboratory (Free Flyer) has a system life of thirty years. In order to fulfil this specification, concept of a serviceable Resource Module (RM) was issued. Every six months, the Hermes spacecraft will perform servicing tasks on the Free Flyer. The external servicing tasks consist mainly of spacecraft inspection and Orbital Replaceable Unit (ORU) exchange. These servicing tasks can be done either by EVA servicing, or by HERA. Some strategies for EVA mission preparation and scenarios for EVA-HERA combined servicing mission are proposed. The benefit the servicing mission will gain in EVA-HERA co-operations is stated. ESA

N90-24314# Norwegian Marine Technology Research Inst., Trondheim.
GROUNDBASED SIMULATIONS OF IN-ORBIT OPERATIONS
T. E. BERG and M. VILLABOE *In* ESA, Second European In-Orbit Operations Technology Symposium p 273-279 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The need for groundbased facilities for studies of manned and unmanned in-orbit operations is documented in numerous U.S., Soviet and European studies. The cost of simulating such operations are high. During development of numerical and physical simulators care should be taken to obtain a consistent set of simulators without undue overlapp between each of them. To obtain this result simulator requirements have to be specified by designers, hardware suppliers and operational specialists at an early stage in the project. Numerical and physical simulators emphasizing the neutral buoyancy facility as a tool for design, hardware and operational procedure testing, are described. ESA

N90-24320*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ORBITAL REPLACEMENT UNITS (ORUS) DESIGN CONSIDERATIONS
EDWARD FALKENHAYN *In* ESA, Second European In-Orbit Operations Technology Symposium p 325-328 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 22/2

The packaging of avionics and mechanisms in containers, called orbital replacement units, which permits in-orbit repair and replacement is the key to man's expanded ventures into space with increasingly costly assets. In designing ORUs, the designer must accommodate the environments of launch and space. The subjects of ORU attachment, thermal, electrical connectors, and size and configuration, are addressed. ESA

N90-24321# Space Technology Labs., Inc., El Segundo, CA.
TECHNOLOGY REQUIREMENTS FOR ON-ORBIT SERVICING OF SPACECRAFT
OTTO C. LEDFORD and NEAL ELY (Air Force Space Div., El Segundo, CA.) *In* ESA, Second European In-Orbit Operations Technology Symposium p 329-333 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

A study undertaken to identify the technology required to implement an on-orbit servicing capability is described. These technology requirements were derived by a top-down, requirements driven analysis. Typical satellite subsystems were examined on a generic basis, failure modes within each subsystem identified, and possible response addressed. The technology required to provide an on-orbit servicing response to each issue was identified. It was found that a system to provide servicing support to orbital assets is technically feasible, even in the near term. In most cases the technology requirements are met by modest extrapolation or demonstration of current capabilities. It appears that the deployment of a support system which offers the advantages of servicing satellites in orbit will be paced less by the requirements of overcoming technology shortfalls than by issues of spacecraft architecture and standardization. ESA

N90-24326# Fabrica Italiana Apparecchiature Radioelettriche S.p.A., Milan.
COLLISION DETECTION USING LINEAR PROGRAMMING
R. GALLERINI and A. SCIOMACHEN (Milan Univ., Italy) *In* ESA, Second European In-Orbit Operations Technology Symposium p 367-372 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Two linear programming based algorithms for the detection of a collision between a manipulator arm and its surounding obstacles are considered on the basis of a real study case. In particular, the first algorithm uses a simplex-like method in order to find the intersections between two convex polyhedra, while the second one consists in finding the intersections between a suitable model of involved objects. A comparison between the two algorithms is presented on the basis of experimental data. ESA

N90-24333# Tecnomare S.p.A. (Italy).
SUPERVISORY CONTROLLED TELEMANIPULATION AND VISION SYSTEMS FOR INSPECTION AND MAINTENANCE OPERATIONS

WALTER PRENDIN, DANILO MADDALENA, ANTONIO TERRIBILE, and GIOVANNI SYLOS LABINI (Italian Space Agency, Rome.) *In* ESA, Second European In-Orbit Operations Technology Symposium p 429-435 Dec. 1989 Sponsored by Commission of the European Communities; Istituto Mobiliare Italiano; AGIP; ANSALDO; European Nuclear Energy Agency; SAIPEM; and Tecnomare S.p.A.
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Characteristics and test results of an innovative telemanipulation system for underwater applications, based on a supervisory control scheme, are described. The system makes use of a new stereoscopic vision system to measure the workspace geometry before manipulation. The characteristics of the telemanipulation system are: computer assisted control of manipulator motion, sophisticated MMI, capability of performing a wide range of complex tasks. The telemanipulation and vision system were extensively tested and their effectiveness demonstrated through full scale trials. The applicability of these systems to space environment was analyzed in the framework of two contracts on behalf of the Italian Space Agency. ESA

N90-24480# Aerospatiale, Cannes (France).
MECHANISMS TO ASSEMBLE SPACE STRUCTURES IN EXTRAVEHICULAR ENVIRONMENT
FREDDY GEYER *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 125-128 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Development of space operated mechanisms requiring only low precision, low amplitude, low energy human motions to install, position and fasten into place different structural members is described. The technical and time-dependent difficulties involved in developing such mechanisms are described. The significant forces involved, the high stiffness specified and the prohibition of any play or backlash in the assembled structures has to be matched with the weakness of the cosmonaut's physical output. Development of the system over a six month period for use in the French-Soviet ARAGAZ mission is described. ESA

N90-24481# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Life Support and Habitability Section.
THE EUROPEAN EVA SPACESUIT MECHANISMS
GUIDO ALBERTINI *In its* Fourth European Space Mechanisms and Tribology Symposium p 129-133 Mar. 1990
(Contract ESTEC-7790/88/NL/PB(SC))
Copyright Avail: NTIS HC A14/MF A02

The Extravehicular Activities (EVA) spacesuit developed by ESA and ESTEC is described. Protection, mobility, dexterity, visibility, pressurization, atmosphere regulation and thermal control functions are discussed. The shoulder joint, bearings and other joints in the suit are described and shown in diagrammatic form. The gloves and spacesuit rear entry door mechanisms are described and shown in diagrammatic form. The fan/water separator is described and shown in diagrammatic form. The designs represented constitute the technical baseline of the European EVA spacesuit. ESA

N90-24482# Tecnospazio S.p.A., Milan (Italy).
EVA POWER TOOL PROTOTYPE
MAURIZIO ARTESANI *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 135-140 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The design, features and performance of a servicing aid tool developed by Technospazio is described. The tool, developed as part of the ESA Extravehicular Activity (EVA) and robotic servicing aids' program, is destined for use on both manned and man tended permanent orbiting structures. The main features of the tool are tested in a neutral buoyancy facility. The results are satisfactory both from the point of view of functional performance and ergonomics. Ways in which to further improve the tool are presented. ESA

N90-24484# Cambridge Univ. (England). Dept. of Engineering.
A CABLE-RIGIDIZED 3D PANTOGRAPH
A. S. K. KWAN and S. PELLEGRINO *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 149-154 Mar. 1990 Sponsored by Cambridge Commonwealth Trust, England
Copyright Avail: NTIS HC A14/MF A02

A deployable mast consisting of a three dimentional pantograph formed by a set of rods hinged together is described. Two active cables control the deployment and prestressing of the pantograph. Several passive cables remain slack until the pantograph folds out into its fully deployed configuration. A technique for analyzing both the deployment of the mast and the response to external loads of the fully deployed mast is outlined. The transition from a bending-dominated pantograph to a braced truss is shown to be an effective way of achieving large increases in stiffness when the fully-deployed configuration is reached. ESA

N90-24497# Sener S.A., Las Arenas (Spain).
DETACHABLE INTERFACE MECHANISM
M. SIERRA and C. PASCUAL *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 235-240 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

A detachable interface mechanism able to be incorporated in the large deployable/retractable solar arrays of the Columbus space station is described. The mechanism is designed to allow for easy removal and deplacement in orbit of solar arrays or parts of solar arrays which have become damaged or defective. The mechanism is designed to be actuated by a robot or by an astronaut. Photographs and diagrams of the detachable mechanism are presented. Static load and thermal test results are presented. The need to carry out further study in order to reduce the mass and improve the thermal requirements and constraints of the mechanism is stressed. ESA

N90-24508# British Aerospace Public Ltd. Co., Stevenage (England).
INMARSAT OMNI-ANTENNA DEPLOYMENT MECHANISM
P. MCMAHON *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 311-315 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The Inmarsat omni-antenna deployment mechanism is described. Deployment of the antenna occurs in two stages. Stage one, which occurs while the spacecraft is spinning in transfer orbit, deploys the antenna parallel to the spacecraft Z axis. Stage 2, which occurs on station, moves the antenna radially outward from the spacecraft center line. Both stages are initiated by pyrotechnic release nuts. Novel features, such as the use of roller bearings in the stage one deployment mechanism and the use of a passive low force device to retain the coax cable in position during the launch vibration environment, are discussed. ESA

N90-24995*# Texas Lutheran Coll., Seguin. Dept. of Biology.
THE USE OF UNDERWATER DYNAMOMETRY TO EVALUATE TWO SPACE SUITS Final Report
W. G. SQUIRES *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 2 6 p Dec. 1989
Avail: NTIS HC A08/MF A01 CSCL 06/11

Four Astronauts were instrumented and donned one of three extravehicular activity (EVA) suits: the currently in use shuttle suit (STS), the Mark III (MK3), and the AX5. The STS was used as the comparison suit because of approved status. Each subject performed ten different exercises in each suit in three different manners (static, dynamic and fatigue) in two different environments, WETF and KC-135 (KC-135 not completed as of this report). Data were recorded from a flight qualified underwater dynamometer (Cybex power head) with a TEAC multichannel recorder/tape and downloaded into the VAX computer system for analysis. Also direct hard copy strip chart recordings were made for backup comparisons. Data were analyzed using the ANOVA procedure and results were graphed and reported without interpretation to the NASA/JSC ABL manager. Author

N90-25292*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A DIRECT-INTERFACE, FUSIBLE HEAT SINK FOR ASTRONAUT COOLING
CURTIS LOMAX and B. W. WEBBON May 1990 15 p Presented at the SAE/ICES 20th International Conference on Environmental Systems, Williamsburg, VA, 9 Jul. 1990
(NASA-TM-102835; A-90189; NAS 1.15:102835) Avail: NTIS HC A03/MF A01 CSCL 20/4

Astronaut cooling during extravehicular activity is a critical design issue in developing a portable life support system that meets the requirements of a space station mission. Some of the requirements are that the cooling device can be easily regenerable and nonventing during operation. In response to this, a direct-interface, fusible heat sink prototype with freezable quick-disconnects was developed. A proof-of-concept prototype was constructed and tested that consists of an elastic container filled with normal tap water and having two quick-disconnects embedded in a wall. These quick-disconnects are designed so that they may be frozen with the ice and yet still be joined to the cooling system, allowing an immediate flow path. The inherent difficulties in a direct-interface heat sink have been overcome, i.e., (1) establishing an initial flow path; (2) avoiding low-flow freeze-up; and (3) achieving adequate heat-transfer rates at the end of the melting process. The requirements, design, fabrication, and testing are discussed. Author

N90-25498* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
HAZARDS PROTECTION FOR SPACE SUITS AND SPACECRAFT Patent
JOSEPH J. KOSMO, inventor (to NASA) and FREDERIC S. DAWN, inventor (to NASA) 8 May 1990 9 p Filed 30 Jun. 1988 Supersedes N89-12206 (27 - 3, p 367)
(NASA-CASE-MSC-21366-1; US-PATENT-4,923,741; US-PATENT-APPL-SN-213880; US-PATENT-CLASS-428-252; US-PATENT-CLASS-428-290; US-PATENT-CLASS-428-328; US-PATENT-CLASS-428-422; US-PATENT-CLASS-428-447; US-PATENT-CLASS-428-458; US-PATENT-CLASS-428-474.4)
Avail: US Patent and Trademark Office CSCL 06/11

A flexible multi-layered covering article for protection against the hazards of exposure to the environment of outer space is disclosed. The covering includes an outer layer section comprising an outermost lamina of woven expanded tetrafluoroethylene yarns (Gore Tex) for protecting against abrasion and tearing, an underlying weave of meta-aramid yarns (Nomex) and para-aramid yarns (Kevlar) for particle impart protection, and electrostatic charge dissipation and control system incorporated 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 infra-red emissivity and low solar radiation absorption characteristics and separated from adjacent insulating layers by a low thermal conductance material. The covering further 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 the polyester-material for added micrometeroid protection. Securing means of low heat conductance material secures the multi-layers together as a laminar composite.
Official Gazette of the U.S. Patent and Trademark Office

N90-25505*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MOBILE TRANSPORTER PATH PLANNING
PAUL BAFFES and LUI WANG *In its* Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 51-59 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 09/2

The use of a genetic algorithm (GA) for solving the mobile transporter path planning problem is investigated. The mobile transporter is a traveling robotic vehicle proposed for the space station which must be able to reach any point of the structure autonomously. Elements of the genetic algorithm are explored in both a theoretical and experimental sense. Specifically, double crossover, greedy crossover, and tournament selection techniques are examined. Additionally, the use of local optimization techniques working in concert with the GA are also explored. Recent developments in genetic algorithm theory are shown to be particularly effective in a path planning problem domain, though problem areas can be cited which require more research. Author

N90-25506*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SOAR 89: SPACE STATION. SPACE SUIT TEST PROGRAM
JOSEPH J. KOSMO, PHILIP WEST, and MICHAEL ROUEN *In its* Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 61-90 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 22/2

The elements of the test program for the space suit to be used on Space Station Freedom are noted in viewgraph form. Information is given on evaluation objectives, zero gravity evaluation, mobility evaluation, extravehicular activity task evaluation, and shoulder joint evaluation. Author

N90-25517*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE USE OF PLAID IN THE SPACE STATION FREEDOM VIEWING ANALYSIS
FRANCES E. MOUNT and SANDRA D. MCKEE (Lockheed Engineering and Sciences Co., Houston, TX.) *In its* Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 149-153 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 09/2

The focus early in the Space Station Freedom Program was on identifying viewing requirements for both direct viewing (windows) and indirect viewing (closed-circuit television). Currently, an analysis is being conducted to address the feasibility of viewing for Space Station Freedom. The goal of this analysis is to determine the optimum location for the windows and closed-circuit television cameras in order to meet the established requirements. Additionally all viewing provisions must adequately support Space Station assembly and on-board operations once the Station is operable. PLAID, a three-dimensional graphics system developed at NASA/Johnson Space Center, was selected for use as the primary tool in this analysis. PLAID provides the capability to simulate the assembly of the Space Station Freedom, as well as to examine operations on the Station as it evolves. In addition, it is used as a tool to analyze general out-the-window viewing conditions for all Space Station components, and provides the ability to integrate an anthropometric scale-modeled person (representing a crewmember) with the Station's interior architecture. Author

N90-25518*# Lockheed Engineering and Sciences Co., Houston, TX.
QUANTITATIVE ASSESSMENT OF HUMAN MOTION USING VIDEO MOTION ANALYSIS
JOHN D. PROBE *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 155-157 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 05/8

In the study of the dynamics and kinematics of the human body, a wide variety of technologies was developed. Photogrammetric techniques are well documented and are known to provide reliable positional data from recorded images. Often these techniques are used in conjunction with cinematography and videography for analysis of planar motion, and to a lesser degree three-dimensional motion. Cinematography has been the most widely used medium for movement analysis. Excessive operating costs and the lag time required for film development coupled with recent advances in video technology have allowed video based motion analysis systems to emerge as a cost effective method of collecting and analyzing human movement. The Anthropometric and Biomechanics Lab at Johnson Space Center utilizes the video based Ariel Performance Analysis System to

develop data on shirt-sleeved and space-suited human performance in order to plan efficient on orbit intravehicular and extravehicular activities. The system is described. Author

N90-25564*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
TECHNOLOGY FOR AN INTELLIGENT, FREE-FLYING ROBOT FOR CREW AND EQUIPMENT RETRIEVAL IN SPACE
J. D. ERICKSON, G. J. REUTER, KATHLEEN J. HEALEY, and D. E. PHINNEY (Lockheed Engineering and Sciences Co., Houston, TX.) *In its* Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 559-565 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 22/2

Crew rescue and equipment retrieval is a Space Station Freedom requirement. During Freedom's lifetime, there is a high probability that a number of objects will accidently become separated. Members of the crew, replacement units, and key tools are examples. Retrieval of these objects within a short time is essential. Systems engineering studies were conducted to identify system requirements and candidate approaches. One such approach, based on a voice-supervised, intelligent, free-flying robot was selected for further analysis. A ground-based technology demonstration, now in its second phase, was designed to provide an integrated robotic hardware and software testbed supporting design of a space-borne system. The ground system, known as the EVA Retriever, is examining the problem of autonomously planning and executing a target rendezvous, grapple, and return to base while avoiding stationary and moving obstacles. The current prototype is an anthropomorphic manipulator unit with dexterous arms and hands attached to a robot body and latched in a manned maneuvering unit. A precision air-bearing floor is used to simulate space. Sensor data include two vision systems and force/proximity/tactile sensors on the hands and arms. Planning for a shuttle file experiment is underway. A set of scenarios and strawman requirements were defined to support conceptual development. Initial design activities are expected to begin in late 1989 with the flight occurring in 1994. The flight hardware and software will be based on lessons learned from both the ground prototype and computer simulations. Author

N90-27763*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE CHALLENGE OF ASSEMBLING A SPACE STATION IN ORBIT
VANCE D. BRAND *In* AGARD, Space Vehicle Flight Mechanics 8 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 22/2

Assembly of a space station in orbit is a challenging and complicated task. If mankind is to exploit the knowledge already gained from space flight and continue to advance the frontiers of space exploration, then space stations in orbit must be part of the overall space infrastructure. Space stations, like the Freedom, having relatively large mass which greatly exceeds the lifting capability of their transportation system, are candidates for on-orbit assembly. However, when a large wide-body booster is available, there are significant advantages to having a deployable space station assembled on Earth and transported into orbit intact or in a few large pieces. The United States will build the Space Station Freedom by the assembly method. Freedom's assembly is feasible, but a significant challenge, and it will absorb much of NASA's effort in the next 8 years. The Space Station Freedom is an international program which will be the centerpiece of the free world's space activities in the late 1990's. Scientific information and products from the Space Station Freedom and its use as a transportation depot will advance technology and facilitate the anticipated manned space exploration surge to the Moon and Mars early in the 21st century. Author

N90-27764*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
IN-SPACE CONSTRUCTION AND DYNAMICS OF LARGE SPACE STRUCTURES
MARTIN M. MIKULAS, JR. *In* AGARD, Space Vehicle Flight Mechanics 10 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 22/2

The types of equipment and structures that will be required to construct very large spacecraft in space are discussed. One of the basic issues that must be resolved is the appropriate mix of humans and machines in the construction process. While the use of robots offers the potential for reducing the number of extra-vehicular activity (EVA) hours required for particular construction operations, the availability of humans greatly increases the reliability of complex construction tasks. A hybrid system is described which makes the best use of man and machine to provide a highly reliable and versatile construction approach. Such a system will provide an efficient method for constructing large spacecraft until fully automated, robotic devices can be perfected. Details are given on an extensive ground test program which was designed to evaluate and demonstrate large spacecraft construction. A discussion is presented on the use of the Space Station Freedom, or an appropriate derivative, as a construction facility. Finally, a construction scenario and assembly timelines are presented for constructing a 20-meter-diameter high precision reflector. Author

N90-27765# Aeritalia S.p.A., Turin (Italy).
A NEW METHOD FOR A TETHERED SYSTEM AIDED SPACE STATION ASSEMBLY
SALVATORE CIARDO and SILVIO BERGAMASCHI (Padua Univ., Italy) *In* AGARD, Space Vehicle Flight Mechanics 15 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

During the Space Station Freedom building phase the major assembled item will be the main truss. Due to the gravity gradient torques, the stable equilibrium configuration is that with the minimum inertia aligned with the local vertical (yaw). Nevertheless, due to some user requirements, the planned building sequence imposes the same axis be pointed toward the pole of the orbit plane (pitch), in a configuration unstable at least in roll-yaw. Therefore, the Attitude Control System (ACS) has to be designed in such a way as to counteract the gravity gradient effects as well as the relatively small environment perturbing torques. The dynamic behavior of a system whose moments of inertia are substantially altered by means of the displacement of a certain amount of additional mass connected to the S.S. Freedom by means of one or two tethers is investigated. The expected benefits and the potential disadvantages of the methods will be discussed. The configuration selection rationales will be analyzed, especially taking into account the operational aspects. A description of the relevant assumptions of the adopted dynamic model and an analytic deduction of the stability criteria is given. The results of an ad-hoc developed computer program will be shown. The dynamic response of the system during non-nominal operative conditions were analyzed in order to provide a complete assessment. The additional disturbance to the station attitude both due to the presence of the tethered system and to the probability that the tether is severed by micrometeoroids or man-made debris will be computed. During the building phase numerous substantial changes in the moments of inertia of the S.S. Freedom are planned. In these cases, the approach discussed permits a very versatile intervention strategy. Author

N90-27766# Liege Univ. (Belgium). Dynamique des Constructions Mecaniques.
DEPLOYMENT OF LARGE FLEXIBLE SPACE STRUCTURES
M. GERADIN, A. CARDONA (Consejo Nacional de Investigaciones Cientificas y Tecnicas, Mar del Plata, Argentina), and D.

GRANVILLE *In* AGARD, Space Vehicle Flight Mechanics 11 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A fairly general methodology developed to simulate the deployment of large flexible space structures using the finite element concept is described. Three simulations of structural deployment are presented to demonstrate the effectiveness of the method: an elementary cell of astromast, an elementary cell of the ERA structure and a 3-D antenna. Author

N90-29017*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
FORMULATION OF DESIGN GUIDELINES FOR AUTOMATED ROBOTIC ASSEMBLY IN OUTERSPACE
SUREN N. DWIVEDI, GARY JONES, S. BANERJEE, and S. SRIVASTAVA (Bowie State Univ., MD.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 197-206 31 Jan. 1989
Avail: NTIS HC A21/MF A03 CSCL 05/8

The approach for arriving at design guidelines for assembly by robots in outerspace is illustrated. The use of robots in a zero gravity environment necessitates that extra factors over and above normal design guidelines be taken into account. Besides, many of the guidelines for assembly by robots on earth do not apply in space. However, considering the axioms for normal design and assembly as one set, guidelines for design and robotic assembly as another, and guidelines for design and assembly in space as the third set, unions and intersections of these sets can generate guidelines for two or more of these conditions taken together - say design and manual assembly in space. Therein lies the potential to develop expert systems in the future, which would use an exhaustive database and similar guidelines to arrive at those required by a superposition of these conditions. Author

N90-29897*# Advanced Decision Systems, Mountain View, CA.
THE ASTRONAUT AND THE BANANA PEEL: AN EVA RETRIEVER SCENARIO
DANIEL G. SHAPIRO *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 225-234 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 05/8

To prepare for the problem of accidents in Space Station activities, the Extravehicular Activity Retriever (EVAR) robot is being constructed, whose purpose is to retrieve astronauts and tools that float free of the Space Station. Advanced Decision Systems is at the beginning of a project to develop research software capable of guiding EVAR through the retrieval process. This involves addressing problems in machine vision, dexterous manipulation, real time construction of programs via speech input, and reactive execution of plans despite the mishaps and unexpected conditions that arise in uncontrolled domains. The problem analysis phase of this work is presented. An EVAR scenario is used to elucidate major domain and technical problems. An overview of the technical approach to prototyping an EVAR system is also presented. Author

N90-29918# Bertin et Cie., Plaisir (France). Dept. Surete de Fonctionnement.
PRELIMINARY HAZARD ANALYSIS IN DESIGN APPLICATION TO EVA SPACE SUIT
T. BOUCON and R. CHASE (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) 1990 3 p In FRENCH; ENGLISH summary Presented at the 7th International Conference on Reliability and Maintainability, Brest, France, 18-23 Jun. 1990
(ETN-90-97585) Avail: NTIS HC A01/MF A01

The method developed for the analysis of hazards during the design steps of a system is described. The method takes into account material and human risks. An application example concerning the Extra Vehicular Activity (EVA) suit is presented. The results of the analysis, the hazard scenarios and recommendations are included. ESA

09

ROBOTICS & REMOTE OPERATIONS

Simulations, models, analytical techniques, and requirements for remote, automated or robotic mechanical systems. Includes remote control of experiments.

A90-33301* Catholic Univ. of America, Washington, DC.
JOINT-SPACE ADAPTIVE CONTROL OF A REDUNDANT TELEROBOT MANIPULATOR
CHARLES C. NGUYEN, ZHEN-LEI ZHOU (Catholic University of America, Washington, DC), and GARY E. MOSIER (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: IEEE International Symposium on Intelligent Control, Albany, NY, Sept. 25, 26, 1989, Proceedings. Washington, DC, IEEE Computer Society Press, 1989, p. 59-65. refs
(Contract NAG5-1124)
Copyright

The design of a joint-space adaptive control scheme for controlling the slave arm motion of a dual-arm telerobot system is presented. Each slave arm of the dual-arm system is a kinematically redundant manipulator with 7 DOF. The implementation of the derived control scheme does not require the computation of manipulator dynamics, which makes the control scheme sufficiently fast for real-time applications. Author

A90-33630* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
CANADA'S MOBILE SERVICING SYSTEM
R. BRYAN ERB (NASA, Johnson Space Center; Canadian Space Agency, Houston, TX) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 19-25.
Copyright

An overview of Canada's part in the Space Station Freedom program, as a provider and operator of station flight elements and as a user, is given. The Mobile Servicing System (MSS) which will provide the Station with its manipulative capability, systems functions, station assembly, and maintenance of station elements, is described. Organizational activities and schedule requirements are examined, and the performance characteristics of the system are presented. N.B.

A90-33639
AUTOMATION AND ROBOTICS (A&R) ON-BOARD
MARC TOUSSAINT (ESA, Space Station and Platforms Directorate, Paris, France) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 105-108.
Copyright

The A&R development and implementation issues in the framework of the Columbus program are summarized. Automation areas in the attached laboratory and in the free flyer are described. The rationale behind the A&R and its advantages, such as an increase in mission productivity and probability of success, are discussed. The A&R preparatory activities in the Columbus program, review of user requirements for A&R, the Columbus A&R ground testbed (CAT), and the A&R in-orbit demonstration (AID) mission, are discussed. N.B.

A90-34005* Catholic Univ. of America, Washington, DC.
DYNAMIC ANALYSIS OF A 6 DOF CKCM ROBOT END-EFFECTOR FOR DUAL-ARM TELEROBOT SYSTEMS
CHARLES C. NGUYEN and FARHAD J. POORAN (Catholic University of America, Washington, DC) Robotics and Autonomous Systems (ISSN 0921-8830), vol. 5, 1989, p. 377-394. refs
(Contract NAG5-780)
Copyright

A dynamical analysis is performed for a six DOF robot end-effector built to study telerobotic service and maintenance of NASA hardwares in space. The design of the end-effector is based on the concept of closed-kinematic chain mechanism capable of performing precise motion in a small workspace. After presenting a closed-form solution for the inverse kinematic problem, the Lagrangian approach is used to derive a set of equations of motion for the end-effector where the generalized coordinates are selected to be the Cartesian coordinates. A computer simulation study shows that the centrifugal and Coriolis terms can be neglected for slow motion. Author

A90-38852
STEREO TV IMPROVES MANIPULATOR PERFORMANCE
ROBERT E. COLE and DONNA L. PARKER (Hawaii, University, Honolulu) IN: Three-dimensional visualization and display technologies; Proceedings of the Meeting, Los Angeles, CA, Jan. 18-20, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 18-27. Research sponsored by Martin Marietta Corp. refs
Copyright

Six observers, experienced in telerobotic operations, were used across four replicated studies of remote performance of a simulated Space Station assembly task. An alignment/insertion task was performed with a remotely operated manipulator arm viewed either directly or through stereoscopic or monoscopic TV viewing systems. Target position, space light, and learning effects were also assessed by measures of task time and manipulator collisions. Results clearly show the superiority of stereo TV over mono viewing systems. They suggest that learning can also improve performance under mono view when accompanied by direct view and stereo view experience, but such learning is specific to the perceptual and motor conditions that were present in practice. Author

A90-41198* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
A PROTOTYPE AUTONOMOUS AGENT FOR CREW AND EQUIPMENT RETRIEVAL IN SPACE
J. D. ERICKSON (NASA, Johnson Space Center, Houston, TX), D. E. PHINNEY, R. S. NORSWORTHY, M. ZACKSENHOUSE, K. T. HARTNESS (Lockheed Engineering and Sciences Co., Houston, TX) et al. IN: IEA/AIE-89; Proceedings of the Second International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, Tullahoma, TN, June 6-9, 1989. Volume 2. Tullahoma, TN, University of Tennessee, 1989, p. 1052-1058. refs
Copyright

The ground-based demonstration of Extra Vehicular Activity (EVA) Retriever, a voice-supervised, intelligent, free-flying robot, is designed to evaluate the capability to retrieve objects (astronauts, equipment, and tools) which have accidentally separated from the Space Station. The EVA Retriever software is required to autonomously plan and execute a target rendezvous, grapple, and return to base while avoiding stationary and moving obstacles. The software architecture incorporates a hierarchical decomposition of the control system that is horizontally partitioned into five major functional subsystems: perception, world model, reasoning, sensing, and acting. The design provides for supervised autonomy as the primary mode of operation with teleoperation as the backup mode. It is intended to be an evolutionary system improving in capability over time and as it earns crew trust through reliable operation. Author

A90-43155
PUSHING THE ENVELOPE - SPACE TELEROBOTICS AT CARNEGIE MELLON UNIVERSITY
CHRISTOPHER LOCKE (Carnegie-Mellon University, Pittsburgh, PA) IEEE Expert (ISSN 0885-9000), vol. 5, June 1990, p. 2-6.
Copyright

Three space-oriented projects at the CMU Robotics Institute are described: the Ambler Planetary Rover, the self-mobile space manipulator, and the Hubble Space Telescope scheduling system. The Ambler Planetary Rover Project is a comprehensive research program to design and build an intelligent machine that will explore and sample extraterrestrial planetary surfaces. The self-mobile space manipulator robot is part of an effort to develop technologies that will enable mobile robots to be used on the Space Station and other space structures. The Hubble Space Telescope scheduling project is developing a software architecture to formulate and solve complex planning and scheduling problems. I.E.

A90-43156* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PLANNING FOR SPACE TELEROBOTICS - THE REMOTE MISSION SPECIALIST
MARK ROKEY and SVEN GRENANDER (JPL, Pasadena, CA) IEEE Expert (ISSN 0885-9000), vol. 5, June 1990, p. 8-15. refs
Copyright

A brief history of planning research done by the group that produced the RMS (Remote Mission Specialist) planner is presented. Space telerobotics under study at JPL is then discussed, and RMS is described in detail. How RMS functions in an example execution is examined. The planner's capabilities are summarized, and possible future applications are suggested. I.E.

A90-43468* National Aeronautics and Space Administration, Washington, DC.
A&R CHALLENGES FOR IN-SPACE OPERATIONS
JAMES UNDERWOOD (NASA, Office of Exploration, Washington, DC) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 151-156. Abridged.
(AAS PAPER 88-182) Copyright

Automation and robotics (A&R) challenges for in-space operations are examined, with emphasis on the interaction between developing requirements, developing solutions, design concepts, and the nature of the applicability of automation in robotic technologies. Attention is first given to the use of A&R in establishing outposts on the moon and Mars. Then emphasis is placed on the requirements for the assembly of transportation systems in low earth orbit. Concepts of the Space Station which show how the assembly, processing, and checkout of systems in LEO might be accommodated are examined. B.J.

A90-43469
THE 21ST CENTURY IN SPACE: FUTURE ROBOTIC TECHNOLOGIES - AN INDUSTRIAL RESEARCHER'S VIEW
STEPHEN J. BARTHOLET (Odetics, Inc., Anaheim, CA) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 157-163.
(AAS PAPER 88-183) Copyright

A narrow segment of robotic technologies that is crucial to many space applications is considered, namely machine vision derived from direct three-dimensional imaging sensors. Consideration is given to the machine interpretation of imaging sensor data and the impact of this interpretation on the distribution of information and control. The particular focus is on laser range imagers, which play a significant role because the data produced by them is inherently machine-friendly and their hardware technology is space-qualifiable in the near term. Particular attention is given to the use of the Odetics Laser Imaging Radar in the NASA EVA Retriever Project. B.J.

A90-43470
AN ASSESSMENT OF THE DEVELOPMENT AND APPLICATION POTENTIAL FOR ROBOTS TO SUPPORT SPACE STATION OPERATIONS
DELBERT TESAR (Texas, University, Austin) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 165-208. refs
(AAS PAPER 88-184) Copyright

It is suggested that the top seven long-term robotics component priorities for the Space Station are: man-machine interface, end effectors, actuator modules, sensor technology, computer architecture, graphics, CAD, and intelligent control. It is further suggested that the progress of a major national robotics program must be measured in terms of a finite number of system criteria for the operation of robotics in the Space Station. The top seven long-term criteria are: multiple task capability, level of machine intelligence, precision, portability and mobility, reliability, obstacle avoidance, and force sensing. A matrix analysis for these priorities indicates that no one component technology or system criterion can solve the mission needs of Space Station robotics. Instead, what is critically needed is a balanced development of all component technologies and system criteria in proportion to the demonstrated needs derived from a careful functional analysis.
B.J.

A90-46399* General Electric Co., Schenectady, NY.
THE KINEMATICS AND DYNAMICS OF SPACE MANIPULATORS - THE VIRTUAL MANIPULATOR APPROACH
Z. VAFA (General Electric Co., Schenectady, NY) and S. DUBOWSKY (MIT, Cambridge, MA) International Journal of Robotics Research (ISSN 0278-3649), vol. 9, Aug. 1990, p. 3-21. refs
(Contract NAG1-801)
Copyright

Future robotic manipulator systems will be required to perform complex tasks in space such as satellite repair. These robotic manipulators will encounter a number of kinematic, dynamic, and control problems caused by the dynamic coupling between the manipulators and its spacecraft. This dynamic coupling also makes it difficult to analyze these systems. This paper introduces a new analytical modeling method for space manipulators called the Virtual Manipulator (VM), which has a fixed based in inertial space at a point called a Virtual Ground. The kinematics and dynamics of the manipulator, spacecraft, and payload can be described relatively easily in terms of the VM. With its fixed base, the Virtual Manipulator is shown to have the potential to be an effective aid for the analysis, design, and development of future space manipulator systems.
Author

A90-46827
TRAJECTORY PLANNING FOR A SPACE MANIPULATOR
KATSUHIKO YAMADA and KAZUO TSUCHIYA (Mitsubishi Electric Corp., Mechanics and Technology Dept., Amagasaki, Japan) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 1265-1281. refs
(AAS PAPER 89-440) Copyright

Trajectory planning of a manipulator mounted on a satellite is considered. The trajectory is designed in order to suppress the attitude variation of the satellite caused by the manipulator motion. A simple time trajectory of the manipulator hand in the work space is obtained from a simplified satellite model. This trajectory is applied to a satellite model with a 6-DOF manipulator, and compared with the trajectory obtained by the numerical calculation to minimize a cost function. The result shows that the proposed trajectory is similar to the optimal trajectory and can suppress the attitude variation of the satellite.
Author

A90-47651*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON DYNAMICS AND CONTROL OF MULTI-LINK FLEXIBLE SPACE MANIPULATORS
W. GAWRONSKI, C.-H. C. IH, and S. J. WANG (JPL, Pasadena, CA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 725-734. refs
(AIAA PAPER 90-3396) Copyright

In this paper dynamics, inverse dynamics, and control problems for multi-link flexible space manipulators are presented. In deriving the flexible manipulator dynamics the following are assumed: flexible deformations are relatively small; angular rates of the links are much smaller than their fundamental frequencies; nonlinear terms (centrifugal and Coriolis forces) in the flexible manipulator model are the same as those in the rigid body model. These assumptions are reasonable for large space manipulators, such as the space crane. Flexible displacements are measured with respect to the rigid body configuration, for which a linear time-varying system is obtained. The inverse dynamics problem consists of determination of joint torques, given tip trajectory, such that joint angles in flexible configuration are equal to the angles in the rigid body configuration. The manipulator control system consists of the feedforward compensation and feedback control loops. Simulation results of a two-link space crane with large payload show that the performance of this linearized dynamics and control approach is reasonable and robust subject to parameter variations during slew operations.
Author

A90-47652#
DYNAMICS AND POSITIONING CONTROL OF SPACE ROBOT WITH FLEXIBLE MANIPULATORS
YOSHISADA MUROTSU, SHOZO TSUJIO, KEI SENDA (Osaka Prefecture, University, Sakai, Japan), and MASATO HAYASHI IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 735-742. refs
(AIAA PAPER 90-3397) Copyright

Advanced space robots consist of a satellite base to fly freely and manipulators with structural flexibility caused by requirement of a light weight system. Motions of manipulators influence positions and orientations of the satellite base because the system has no fixed supports. Motions of space robots also induce vibrational motions of structurally flexible manipulators. To control such complicated systems, a mathematical model of a space robot with structurally flexible manipulators is developed in this paper by using a Finite Element Method. An extended local PD-control scheme to control the flexible manipulators on a satellite base is proposed. The presented scheme is very simple and the stability of the closed loop system is proved by Liapunov's direct method. The effectiveness of the control scheme is also verified by numerical simulation.
Author

A90-47653#
MODEL-BASED ITERATIVE LEARNING CONTROL OF SPACE-SHUTTLE MANIPULATOR
B. PORTER and S. S. MOHAMED (Salford, University, England) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 743-746. refs
(AIAA PAPER 90-3398) Copyright

It is shown that robotic manipulators give rise to completely irregular linear time-invariant plants under the action of computed-torque control, and therefore that previous results for the iterative learning control of regular plants are inapplicable in such cases. However, it is also shown that new results for the iterative learning control of irregular plants are directly applicable to the design of iterative learning controllers for robotic manipulators. The practical relevance of these theoretical results to the design of model-based iterative learning controllers for robotic manipulators is illustrated by the presentation of numerical results for the iterative learning control of the manipulator in the Space Shuttle.
Author

A90-47654#
A PRELIMINARY STUDY ON EXPERIMENTAL SIMULATION OF DYNAMICS OF SPACE MANIPULATOR SYSTEM
HIRONORI FUJII, KOHJI SUGAHARA (Tokyo Metropolitan Institute of Technology, Japan), TAKASHI UCHIYAMA (Fujitsu Laboratories, Ltd., Kawasaki, Japan), and KENJI UCHIYAMA IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 747-752. refs
(AIAA PAPER 90-3399) Copyright

A basic study is reported in this paper concerning a method to simulate on the ground the dynamics of a space manipulator. The space manipulator model is suspended from tethers at the joints of the links to cancel effects of the earth gravity in order to simulate its dynamics in space. Two cases of the system model of the manipulator arm are treated for the simulation: the first case assumes a simple model consisting of a rigid link, and the second case model consists of a link with structural flexibility in its structure. The results of the numerical simulation and on-ground experiment demomstrate the capability of the on-ground simulation. Author

A90-47684#
THE INTRINSIC APPROACH TO SPACE ROBOTIC MANIPULATORS
M. SHEFER (Rafael Armament Development Authority, Haifa, Israel) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1050-1055. refs
(AIAA PAPER 90-3431) Copyright

A novel approach to the robot rendezvous problem is presented, where the process' equations of motion are formulated in a coordinate frame that is attached to an intrinsic line of sight between the manipulator and the target. This enables one to cast the rendezvous problem into a form of a standard, yet nonlinear, regulation task about a universal zero set point, independent of the mission geometry. Optimal state feedback solution is subsequently obtained by solving the associated Dynamic Programming Equation off-line, ahead of time. The present algorithms are shown to admit a very simple and low cost implementation. Author

A90-47685#
CAPTURE CONTROL FOR MANIPULATOR ARM OF FREE-FLYING SPACE ROBOT
HIRONORI FUJII, TSUTOMU MURAYAMA, KAZUNARI NAKAJIMA, and SEI-ICHI ANAZAWA (Tokyo Metropolitan Institute of Technology, Hino, Japan) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1056-1060. refs
(AIAA PAPER 90-3432) Copyright

A control problem is studied in this paper: to capture an object by a manipulator arm of a free-flying space robot. The space robot consists of a rigid main body and a two-link manipulator. The robot is a type of the free-flying space robots and the position and attitude of the main body changes as the manipulator arm moves and changes its configuration. The changes in position and attitude of the main body cause significant complexity in the control of the manipulator arm in comparison with those robots operating on the ground with the fixed points or plane in inertial space. The control problem treated in this paper is for the manipulator arm of the space robot to capture any object which may be drifting in space and must be handled with the manipulator arm of the robot. Only planar motion is treated in the course of this analysis for simplicity. The control algorithm employed is the 'Mission-Function Control' algorithm presented by the first author and is a type of the Liapunov method for nonlinear dynamical systems. Results of numerical simulation affirm excellent performance of the control algorithm applied to the control problem of the capture of an object by a manipulator arm of a free-flying space robot. Author

A90-47687#
SMART END EFFECTOR FOR DEXTEROUS MANIPULATION IN SPACE
KAZUO MACHIDA, YOSHITSUGU TODA, TOSHIAKI IWATA (Electrotechnical Laboratory, Tsukuba, Japan), SHOUICHI IIKURA, TADASHI KOMATSU (Toshiba Corp., Tokyo, Japan) et al. IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1072-1078. refs
(AIAA PAPER 90-3434) Copyright

A smart end effector has been developed to add dexterous and flexible capability to coarse space work systems. It provides fine adjustment for precise error compensation by using a relative proximity sensor, and delicate force control by using a force-torque sensor. It also automatically tracks the marked target and capture it with specified impedance. The new mechanism of parallel link has been devised for the end effector, and the visual proximity sensor has been developed for six-dimensional position-attitude measurement of a flying target. The experiments are carried out using a two-dimensional air-bearing test bed, and sufficient performance has been achieved. Author

A90-50242
POSSIBILITIES OF APPLYING THE PRODUCTION-TECHNICAL PRINCIPLES OF AUTOMATION AND ROBOTICS IN OUTER SPACE [MOEGLICHKEITEN DER UEBERTRAGBARKEIT PRODUKTIONSTECHNISCHER PRINZIPIEN DES EINSATZES VON AUTOMATION UND ROBOTIK AUF WELTRAUMANWENDUNGEN]
G. DUELEN and U. KIRCHHOFF (Fraunhofer-Institut fuer Produktionsanlagen und Konstruktionstechnik, Berlin, Federal Republic of Germany) IN: Yearbook 1988 II; DGLR, Annual Meeting, Darmstadt, Federal Republic of Germany, Sept. 20-23, 1988, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1988, p. 915-923. In German. refs
(DGLR PAPER 88-102) Copyright

Existing and alternative ways of automating space systems to maximize their use of robotics and automation are discussed. The design principles of such systems are examined, presenting flow diagrams. The role of ground-based technologies in such systems is addressed. C.D.

A90-52863#
MAPPING PROCESSES TO PROCESSORS FOR SPACE BASED ROBOT SYSTEMS
THOMAS E. WHEATLEY (NIST, Gaithersburg, MD) IN: IEEE International Conference on Systems Engineering, Dayton, OH, Aug. 24-26, 1989, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 65-68. refs

A stepwise process is shown that maps a logical description of a system architecture onto a functional computer architecture based on a description of the application at hand and the response times required for that application. The response times are broken into execution and communication times to partially separate the application-dependent issues from the technology-dependent issues. An example utilizing the knowledge of the dominant response time required to aid in the selection process is given. Coupled with knowledge of the interfaces required and times of key operations taken from actual code on the target hardware, the system architect is provided with a powerful set of tools in the iterative procedure of assigning processes to processors. The use of algorithms or the addition of redundancy to the system can be examined before any of the system is actually built. This technique can be expanded to characterize an entire system for examining such issues as processor utilization, bus bandwidth, and dynamic process allocation. I.E.

A90-52946* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
REMOTE MISSION SPECIALIST - A STUDY IN REAL-TIME, ADAPTIVE PLANNING
MARK J. ROKEY (JPL, Pasadena, CA) IEEE Transactions on

Robotics and Automation (ISSN 1042-296X), vol. 6, Aug. 1990, p. 455-461. refs
Copyright

A high-level planning architecture for robotic operations is presented. The remote mission specialist integrates high-level directives with low-level primitives executable by a run-time controller for command of autonomous servicing activities. The planner has been designed to address such issues as adaptive plan generation, real-time performance, and operator intervention. I.E.

A90-52997#
NEAR-MINIMUM-TIME CONTROL OF A FLEXIBLE MANIPULATOR
J. L. JUNKINS (Texas A &.M University, College Station) and N. K. HECHT IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 426-430. Research supported by the Texas Advanced Technology Program. refs
(Contract F49620-87-C-0078)
(AIAA PAPER 90-2916) Copyright

Near-minimum-time control of flexible manipulators can be accomplished by designing a controller that tracks a reference maneuver. The control method presented here uses a near-minimum-time rigid link reference maneuver to generate reference control torques, and a Liapunov controller to make the flexible manipulator track the reference maneuver while reducing and eventually eliminating flexible motions. The near-minimum-time reference maneuver uses a smoothed bang-bang control plus a term to cancel the nonlinear dynamics of the rigid manipulator. The Liapunov function is a weighted sum of the energies of the elements of the flexible manipulator, and the control law is chosen to make the rate of change of the Liapunov function negative. The Liapunov function if bounded during a maneuver, and decays asymptotically after the maneuver ends. Author

N90-20670*# Lockheed Engineering and Sciences Co., Houston, TX.
THE USE OF GRAPHICS IN THE DESIGN OF THE HUMAN-TELEROBOT INTERFACE
MARK A. STUART and RANDY L. SMITH *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 135-142 Aug. 1989
(Contract NAS9-17900)
Avail: NTIS HC A11/MF A02 CSCL 09/2

The Man-Systems Telerobotics Laboratory (MSTL) of NASA's Johnson Space Center employs computer graphics tools in their design and evaluation of the Flight Telerobotic Servicer (FTS) human/telerobot interface on the Shuttle and on the Space Station. It has been determined by the MSTL that the use of computer graphics can promote more expedient and less costly design endeavors. Several specific examples of computer graphics applied to the FTS user interface by the MSTL are described. Author

N90-20674*# Mitre Corp., Houston, TX.
GRAPHICAL PROGRAMMING AND THE USE OF SIMULATION FOR SPACE-BASED MANIPULATORS
DEBRA S. MCGRATH and JAMES C. REYNOLDS *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 165-170 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 09/2

Robotic manipulators are difficult to program even without the special requirements of a zero-gravity environment. While attention should be paid to investigating the usefulness of industrial application programming methods to space manipulators, new methods with potential application to both environments need to be invented. These methods should allow various levels of autonomy and human-in-the-loop interaction and simple, rapid switching among them. For all methods simulation must be integrated to provide reliability and safety. Graphical programming of manipulators is a candidate for an effective robot programming method despite current limitations in input devices and displays. A research project in task-level robot programming has built an innovative interface to a state-of-the-art commercial simulation and robot programming platform. The prototype demonstrates simple augmented methods for graphical programming and simulation which may be of particular interest to those concerned with Space Station applications; its development has also raised important issues for the development of more sophisticated robot programming tools. Both aspects of the project are discussed. Author

N90-20676*# CAE Electronics Ltd., Montreal (Quebec).
THE DEVELOPMENT OF THE CANADIAN MOBILE SERVICING SYSTEM KINEMATIC SIMULATION FACILITY
G. BEYER, B. DIEBOLD, W. BRIMLEY, and H. KLEINBERG (Spar Aerospace Ltd., Weston, Ontario) *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 177-186 Aug. 1989 Sponsored by National Research Council of Canada
Avail: NTIS HC A11/MF A02 CSCL 09/2

Canada will develop a Mobile Servicing System (MSS) as its contribution to the U.S./International Space Station Freedom. Components of the MSS will include a remote manipulator (SSRMS), a Special Purpose Dexterous Manipulator (SPDM), and a mobile base (MRS). In order to support requirements analysis and the evaluation of operational concepts related to the use of the MSS, a graphics based kinematic simulation/human-computer interface facility has been created. The facility consists of the following elements: (1) A two-dimensional graphics editor allowing the rapid development of virtual control stations; (2) Kinematic simulations of the space station remote manipulators (SSRMS and SPDM), and mobile base; and (3) A three-dimensional graphics model of the space station, MSS, orbiter, and payloads. These software elements combined with state of the art computer graphics hardware provide the capability to prototype MSS workstations, evaluate MSS operational capabilities, and investigate the human-computer interface in an interactive simulation environment. The graphics technology involved in the development and use of this facility is described. Author

N90-22088*# Fairchild Space Co., Germantown, MD.
A ROBOT END EFFECTOR EXCHANGE MECHANISM FOR SPACE APPLICATIONS
BARNEY F. GORIN *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 121-126 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 13/9

Efficient robot operation requires the use of specialized end effectors or tools for tasks. In spacecraft applications, the microgravity environment precludes the use of gravitational forces to retain the tools in holding fixture. As a result of this, a retention mechanism which forms a part of the tool storage container is required. A unique approach to this problem has resulted in the development of an end effector exchange mechanism that meets the requirements for spaceflight applications while avoiding the complexity usually involved. This mechanism uses multiple latching cams both on the manipulator and in the tool storage container, combined with a system of catch rings to provide retention in both locations and the required failure tolerance. Because of the cam configuration the mechanism operates passively, requiring no electrical commands except those needed to move the manipulator into position. Similarly, it inherently provides interlocks to prevent the release of one cam before its opposite number is engaged. Author

N90-22089*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A NEW SIX-DEGREE-OF-FREEDOM FORCE-REFLECTING HAND CONTROLLER FOR SPACE TELEROBOTICS
DOUGLAS MCAFFEE, EDWARD SNOW, WILLIAM TOWNSEND, LEE ROBINSON, and JOE HANSON *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 127-141 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 13/9

A new 6 degree of freedom universal Force Reflecting Hand Controller (FRHC) was designed for use as the man-machine interface in teleoperated and telerobotic flight systems. The features of this new design include highly intuitive operation, excellent kinesthetic feedback, high fidelity force/torque feedback, a kinematically simple structure, mechanically decoupled motion in all 6 DOF, good back-drivability, and zero backlash. In addition, the new design has a much larger work envelope, smaller stowage volume, greater stiffness and responsiveness, and better overlap of the human operator's range of motion than do previous designs. The utility and basic operation of a new, flight prototype FRHC called the Model X is briefly discussed. The design heritage, general design goals, and design implementation of this advanced new generation of FRHCs are presented, followed by a discussion of basic features and the results of initial testing. Author

N90-22312*# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
THE JPL/KSC TELEROBOTIC INSPECTION DEMONSTRATION
DAVID MITTMAN, BRUCE BON, CAROL COLLINS, GERRY FLEISCHER, TODD LITWIN, JACK MORRISON, JACQUIE OMEARA, STEPHEN PETERS (Jet Propulsion Lab., California Inst. of Tech., Pasadena.), JOHN BROGDON, BOB HUMENIUK et al. *In* NASA, Goddard Space Flight Center, The 1990 Goddard Conference on Space Applications of Artificial Intelligence p 213-222 May 1990
Avail: NTIS HC A15/MF A02 CSCL 09/2

An ASEA IRB90 robotic manipulator with attached inspection cameras was moved through a Space Shuttle Payload Assist Module (PAM) Cradle under computer control. The Operator and Operator Control Station, including graphics simulation, gross-motion spatial planning, and machine vision processing, were located at JPL. The Safety and Support personnel, PAM Cradle, IRB90, and image acquisition system, were stationed at the Kennedy Space Center (KSC). Images captured at KSC were used both for processing by a machine vision system at JPL, and for inspection by the JPL Operator. The system found collision-free paths through the PAM Cradle, demonstrated accurate knowledge of the location of both objects of interest and obstacles, and operated with a communication delay of two seconds. Safe operation of the IRB90 near Shuttle flight hardware was obtained both through the use of a gross-motion spatial planner developed at JPL using artificial intelligence techniques, and infrared beams and pressure sensitive strips mounted to the critical surfaces of the flight hardward at KSC. The Demonstration showed that telerobotics is effective for real tasks, safe for personnel and hardware, and highly productive and reliable for Shuttle payload operations and Space Station external operations. Author

N90-22317*# Naval Research Lab., Washington, DC.
ADAPTIVE PATTERN RECOGNITION BY MINI-MAX NEURAL NETWORKS AS A PART OF AN INTELLIGENT PROCESSOR
HAROLD H. SZU *In* NASA, Goddard Space Flight Center, The 1990 Goddard Conference on Space Applications of Artificial Intelligence p 287-306 May 1990
Avail: NTIS HC A15/MF A02 CSCL 09/2

In this decade and progressing into 21st Century, NASA will have missions including Space Station and the Earth related Planet Sciences. To support these missions, a high degree of sophistication in machine automation and an increasing amount of data processing throughput rate are necessary. Meeting these challenges requires intelligent machines, designed to support the necessary automations in a remote space and hazardous environment. There are two approaches to designing these intelligent machines. One of these is the knowledge-based expert system approach, namely AI. The other is a non-rule approach based on parallel and distributed computing for adaptive fault-tolerances, namely Neural or Natural Intelligence (NI). The union of AI and NI is the solution to the problem stated above. The NI segment of this unit extracts features automatically by applying Cauchy simulated annealing to a mini-max cost energy function. The feature discovered by NI can then be passed to the AI system for future processing, and vice versa. This passing increases reliability, for AI can follow the NI formulated algorithm exactly, and can provide the context knowledge base as the constraints of neurocomputing. The mini-max cost function that solves the unknown feature can furthermore give us a top-down architectural design of neural networks by means of Taylor series expansion of the cost function. A typical mini-max cost function consists of the sample variance of each class in the numerator, and separation of the center of each class in the denominator. Thus, when the total cost energy is minimized, the conflicting goals of intraclass clustering and interclass segregation are achieved simultaneously. Author

N90-23899*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCING AUTOMATION AND ROBOTICS TECHNOLOGY FOR THE SPACE STATION FREEDOM AND FOR THE US ECONOMY Progress Report No. 10, 13 Jul. 1989 - 14 Feb. 1990
Jun. 1990 37 p
(NASA-TM-102668; NAS 1.15:102668) Avail: NTIS HC A03/MF A01 CSCL 12/1

In April 1985, the NASA Advanced Technology Advisory Committee (ATAC) reported to Congress the results of its studies on advanced automation and robotics technology for use on Space Station Freedom. This material was documented in the initial report (NASA Technical Memorandum 87566). The progress made by Levels 1, 2, and 3 of the Office of Space Station in developing and applying advanced automation and robotics technology are described. Emphasis was placed upon the Space Station Freedom Program responses to specific recommendations made in ATAC Progress Report 9, the Flight Telerobotic Servicer, the Advanced Development Program, and the Data Management System. Assessments are presented for these and other areas as they apply to the advancement of automation and robotics technology for the Space Station Freedom. Author

N90-24280# European Space Agency, Paris (France).
SECOND EUROPEAN IN-ORBIT OPERATIONS TECHNOLOGY SYMPOSIUM
E. J. ROLFE, ed. Dec. 1989 430 p Symposium held in Toulouse, France, 12-14 Sep. 1989; sponsored in cooperation by ESA and CNES
(ESA-SP-297; ISBN-92-9092-030-0; ISSN-0379-6566; ETN-90-96976) Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Robotics for use in space, with particular relation to orbital servicing of spacecraft and extravehicular activity is investigated. Space stations, man tended free flyers and the Hermes manned spaceplane are particularly focused on. Operations, interfaces, tools, teleoperation, rendezvous and docking, simulation, orbital replacement units, robot components and dynamic controls are covered.

N90-24281# *Tokyo Inst. of Tech. (Japan). Dept. of Mechanical* Engineering Science.
TOWARD THE DEVELOPMENT OF COSMO-LAB
YOJI UMETANI *In* ESA, Second European In-Orbit Operations Technology Symposuim p xxi-xxvi Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

A brief summary of the annual report of Space Robotics Forum in 1988 is presented. The purpose of this Forum was to discuss technological problems related to robotics and automation in space, and it proposed a new concept on the unmanned space experiment facility called COSMO-LAB. The outline of this concept is described, emphasizing two kinds of robots, the one for EVA and IVA of the COSMO-LAB experimental module and the other for constructing the facility bus structure. ESA

N90-24285*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ROBOTICS PROGRAM AT THE NASA GODDARD SPACE FLIGHT CENTER
STANFORD OLLENDORF *In* ESA, Second European In-Orbit Operations Technology Symposium p 13-21 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 13/9

The NASA Goddard telerobotic program is structured to increase the scope and efficiency of what man can accomplish in space through the use of robotics. The main focus is to service Space Station Freedom and its payloads, but robotic assembly of Space Station Freedom and platforms is also anticipated. The approach being taken to achieve this by telerobotics, where manipulators can be controlled by human operators or computer programs. The Goddard Space Flight Center (GSFC) has the responsability to develop the Flight Telerobotic Servicer (FTS) for Space Station Freedom. The current plan at GSFC in support of telerobotics for Space Station Freedom and the in-orbit servicing of platforms are reviewed. Plans for ground demonstrations involving the use of an engineering test bed and an operational facility are discussed. ESA

N90-24287# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.).
SERVICING TEST FACILITY: A HARDWARE SIMULATOR FOR TELEROBOTIC IN-ORBIT SERVICING
BERND E. SCHAEFER *In* ESA, Second European In-Orbit Operations Technology Symposium p 31-38 Dec. 1989
(Contract DLR-5-575-4359)
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Automatically operating devices and manipulator systems being operated by ground-based teleoperators will be necessary during unmanned phases of the Columbus Free Flying Laboratory for both internal and external robotic manipulations. The Servicing Test Facility is to provide a facility capable of hosting the simulation of the various manipulator configurations to support concept studies, and to perform complete system verification, teleoperator training, parallel operations simultaneously to actual in-orbit manipulations, and ground operations segment verification for robotic tasks. Both the necessities for the ground operational support and the present status of definition for the facility functional and operational concept are focussed upon. ESA

N90-24289# National Space Development Agency, Ibaraki (Japan). Tsukuba Space Center.
ADVANCED ROBOTICS FOR THE ON-ORBIT SERVICING
MITSUSHIGE ODA *In* ESA, Second European In-Orbit Operations Technology Symposium p 47-50 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The National Space Development Agency of Japan (NASDA), which is supporting a wide range of research and development activities on space automation and robotics, is discussed. The remote manipulator system of the international space station Japanese Experiment Module (JEM), now under development, is addressed. Research effort is now concentrated on the advanced space robotics. The second generation space robotics, which will be used for an orbital servicing vehicle and other unmanned vehicles, is now the main research. The characteristics of the second generation space robotics is teleoperation and shared autonomy. The role sharing between human operator and robot will be the key issue of this advanced space robotics. ESA

N90-24291# Italian Space Agency, Rome.
THE SPIDER ROBOTIC SYSTEM
SIMONETTA DIPIPPO, P. G. MAGNANI, WALTER PRENDIN, and ANTONIO TERRIBILE (Tecnomare S.p.A., Italy) *In* ESA, Second European In-Orbit Operations Technology Symposium p 57-62 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The Italian Space Agency (ASI) started a strategic long term program in the field of automation and robotics, named SPIDER (SPace Inspection Device for Extravehicular Repairs). The SPIDER system is an autonomous integrated space robot, designed primarily to perform visual inspection and precision repairing in the space stations environment. A preliminary description of the robotic system and, in particular, the manipulation subsystem, is given. ESA

N90-24300# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
ROBOT-BASED EQUIPMENT MANIPULATION AND TRANSPORTATION FOR THE COLUMBUS FREE FLYING LABORATORY
W. DEPEUTER, P. PUTZ, and G. COLOMBINA (Tecnospazio S.p.A., Milan, Italy) *In its* Second European In-Orbit Operations Technology Symposium p 129-134 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The concept for a robot-based Equipment Manipulation and Transportation System (EMATS) for the Columbus Free Flying Laboratory is described. EMATS could not only automatically provide the greater part of the payload facility handling and logistics functions during the unmanned microgravity periods, but also perform unmanned servicing operations in conjunction with various logistics vehicles concepts and assist the crew during manned servicing from the Space Station Freedom and from Hermes. To that end, a variety of telerobotics features are foreseen such as teleoperation and supervised automatic operation from ground or from a small control station aboard the Free Flyer, Hermes, or the Space Station Freedom. The overall EMATS architecture is summarized and the flexibility of the concept is illustrated by results from computer graphics simulations. ESA

N90-24302*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
TELEROBOTIC ARCHITECTURE FOR AN ON-ORBIT SERVICER
NEVILLE I. MARZWELL *In* ESA, Second European In-Orbit Operations Technology Symposium p 151-157 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 05/8

An on-orbit servicer system has unique functional and human factors requirements. The servicing, whether it be teleoperation task, a supervised control task or an autonomous robotic task, the man-machine interface function is likely to be a bottleneck to the operation of the whole system. The man-machine interface system for a space servicer, namely the operator control station, includes several subsystems with a hierarchical architecture. Those subsystems include a reasoning and planning subsystem (also known as the artificial intelligence planner), a run-time control subsystem, a manipulator control and mechanization subsystem, and a sensing and perception subsystem. Indicative of these potentials, certain generic tasks, suggestive of space assembly, maintenance and repair, were performed in a testbed environment. Through performance in several modes: direct teleoperation, shared control, traded control, and robotic operation, the benefits of the individual technology contributions to the operation were quantized and recommendations for use in telerobotic systems were established. ESA

N90-24303# Centre National d'Etudes Spatiales, Toulouse (France).
HERA TELEOPERATION TEST FACILITY
V. BOURDON-HENRY *In* ESA, Second European In-Orbit Operations Technology Symposium p 161-165 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The activities of the French Space Agency robotics laboratory are strongly related to the Hermes Robot Arm (HERA) project. With the purpose of providing the HERA team with an experimental support, a testbed was built to simulate some specific HERA tasks

such as satellite grasping and berthing of Hermes with the Man Tended Free Flyer (MTFF) of Columbus. This set-up gives the possibility to analyze the operator performances as far as teleoperation ergonomy is concerned. The objectives of the tests performed are reviewed and an in-depth description of the test facility is given. Strong emphasis is put on test results. ESA

N90-24304# British Aerospace Dynamics Group, Bristol (England). Dept. of Human Factors.
A FLEXIBLE TELEOPERATION TEST BED FOR HUMAN FACTORS EXPERIMENTATION
J. L. EVANS and I. G. D. STRACHAN (United Kingdom Atomic Energy Authority, Culham, England) *In* ESA, Second European In-Orbit Operations Technology Symposium p 167-171 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Research conducted for the European Space Agency in the field of teleoperation is described. The overall aim was to design and build a telerobotic test bed which could be used for experimental investigations of the remote control of robotic manipulator in space from a ground control station. The development of the test bed, and in particular, the development of a General Purpose Robot Controller (GPRC) is described. This permitted the simultaneous control of all 6 degrees of freedom of the experimental robot. The human factors experiments which were conducted using the test bed are described. A brief summary of the principal results and conclusions is provided. ESA

N90-24305# Tohoku Univ., Sendai (Japan). Dept. of Precision Engineering.
TELEOPERATION OF A FORCE CONTROLLED ROBOT MANIPULATOR WITHOUT FORCE FEEDBACK TO A HUMAN OPERATOR
MASARU UCHIYAMA and KOSEI KITAGAKI *In* ESA, Second European In-Orbit Operations Technology Symposium p 173-179 Dec. 1989 Sponsored in part by Ministry of Education, Science and Culture, Japan
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

A teleoperation scheme of a manipulator in orbit is presented. The schemes uses no force reflection to a human operator on the ground. Instead, the manipulator is hybrid controlled: forces or velocities of the end-effector are selectively controlled. The force or velocity control modes are automatically selected by monitoring forces measured by a force/torque sensor at the wrist of the manipulator. The human operator uses only a joy stick consisting of a force/toque sensor to send commands to the manipulator. The commands are interpreted as force commands or velocity commands by the manipulator. A coefficient to convert the commands into the velocity commands is calculated theoretically based on an index to evaluate the control of collision. The scheme is implemented by a robot system on the ground. Experimental results to show its feasability are obtained. ESA

N90-24307# MATRA Espace, Paris-Velizy (France).
THE BI-ARM SERVICER: A MULTIMISSION CONCEPT AND A TECHNOLOGICAL MODEL FOR SPACE ROBOTICS
G. ANDRE, G. BERGER, and A. ELFVING (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Second European In-Orbit Operations Technology Symposium p 191-204 Dec. 1989
(Contract ESTEC-7946/87)
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The Bi-Arm Servicer (BIAS) concept: its potential application, its conceptual design and associated system and feasability analyses, is presented. An application review where four different mission configurations, depending on the carrier type, were investigated, is given. A model mission including a reference environment and reference tasks is established and an overview of the major requirements for the BIAS system is given. The conceptual design of the BIAS is presented. The system architecture is based on two main entities: the servicer equipped with two dexterous manipulators and the teleoperation and control station. The key analyses in several disciplines are outlined and geometry, kinematics, dynamics characteristics are investigated. The sensory subsystem, coordination algorithms, and the teleoperation and control architectures are described. Three test beds and on-going demonstration experiments which support the BIAS main study are presented. ESA

N90-24315# Singer-Link-Miles Ltd., Lancing (England).
ROBOTIC SIMULATION SUPPORT TO SYSTEMS DEVELOPMENT
R. M. DAINTREE and G. K. SPEED *In* ESA, Second European In-Orbit Operations Technology Symposium p 281-287 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

Robotics and telemanipulation will be key features of future space missions and the systems upon which these missions depend for their success will require extensive design and development effort. An intrinsic and important feature of this preparatory activity will be simulations to support the development of systems from their conceptual design through to their use in operational missions. The role of simulation in the development of space robotic systems in general is outlined and by means of two recent examples of activity, some of the considerations arising from the application of these techniques to particular aspects of evolving an in-orbit infrastructure, are discussed. ESA

N90-24317# Technische Hochschule, Darmstadt (Germany, F.R.). Control Systems Theory and Robotics Section.
SIMULATION AND GROUND-BASED TESTING OF ORU-HANDLING WITH A BI-ARM ROBOT
H. BRUHM *In* ESA, Second European In-Orbit Operations Technology Symposium p 299-308 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

With the Bi-Arm Servicer (BIAS) and the Flight Telerobotic Servicer (FTS), ESA and NASA are studying concepts of robotic systems with cooperating arms which promise increased versatility and superior performance over comparable single-arm systems for the in-orbit operations envisaged in connection with construction, operation and maintenance of the International Space Station and its accompanying unmanned elements. The importance of early validation of key technologies relied upon by such projects is discussed and the role of simulation and ground-based testing in this context is illustrated with, as example, a study on the validation of a coordination strategy for robots with cooperating arms. Following its introduction in mathematical notation, the implementation of the coordination strategy on a laboratory demonstration system in the form of a distributed algorithm is described. A design method for the coordination controller is presented and validated by simulation of ORU handling with two cooperating SMS arms. A summary of experiences from the study and recommendations concerning a possible continuation of the project are given. ESA

N90-24325# National Inst. of Standards and Technology, Gaithersburg, MD. Intelligent Controls Group.
NASREM: A FUNCTIONAL ARCHITECTURE FOR CONTROL OF THE FLIGHT TELEROBOTIC SERVICER
RONALD LUMIA *In* ESA, Second European In-Orbit Operations Technology Symposium p 361-365 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The NASA/NBS (National Bureau of Standards) Standard Reference Model for Telerobot Control System Architecture (NASREM), adopted by NASA for use in the Flight Telerobotic Servicer (FTS), a two armed telerobotic manipulator which will build and maintain the Space Station is addressed. NASREM is technology independent; the same functions must be performed by all controllers. NASREM provides the paradigm which allows

the FTS to evolve with technology because standard interfaces can be defined so that functionally equivalent software and hardware modules may be interchanged. After a brief tutorial on the NASREM functional architecture, the approach to its implementation is shown. Interfaces must be defined which are capable of supporting the known algorithms. This is illustrated by considering the interfaces required for the servolevel of the NASREM functional architecture. After interface definition, the specific computer architecture for the implementation must be determined. This choice is obviously technology dependent. An example illustrating one possible mapping of the NASREM functional architecture to a particular set of computers which implements it is shown. The result of choosing the NASERM functional architecture is that it provides a technology independent paradigm which can be mapped into a technology dependent implementation capable of evolving with technology in the laboratory as well as in space. ESA

N90-24328*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
NASA/GSFC SPLIT-RAIL PARALLEL GRIPPER
JOHN M. VRANISH and MOHAMMED SHARIFI *In* ESA, Second European In-Orbit Operations Technology Symposium p 383-387 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 13/9

The current state of development of the NASA/GSFC (Goddard Space Flight Center) Split-Rail Parallel Gripper (SRPG) is described. The SPRG has been shown to be a high performance gripper for industrial robots. It has a precise wide throw and at the same time, it is light, simple, compact, rugged, and jam-proof against side loads. Originated at the National Bureau of Standards (NBS), this gripper is undergoing further development at NASA/GSFC in pursuit of two goals: as a potential gripper for robots in space and as the basis for sensory-interactive industrial gripper as part of NASA's technology utilization program. The gripper design features, its principles of operation and how it is constructed are described. Test results are included. ESA

N90-24329# Technische Hochschule, Darmstadt (Germany, F.R.). Control Systems Theory and Robotics Section.
A THREE FINGERED MULTIJOINTED GRIPPER AS A WORKING TOOL FOR EXPERIMENTAL USE
W. PAETSCH and M. KANEKO (Ministry of International Trade and Industry, Tsukuba, Japan) *In* ESA, Second European In-Orbit Operations Technology Symposium p 389-392 Dec. 1989 Sponsored by BMFT
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

A three fingered, multijointed robot gripper for experimental use is presented. The mechanics as well as the control architecture are designed for this special purpose. The gripper system provides the basic means in terms of position and force control to perform experiments about grasping and object motion in a useful way. The gripper will be used to develop and evaluate different approaches of stable grasping and object manipulation for space application. ESA

N90-24330# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
HIGH PERFORMANCE PROCESSING SYSTEM FOR EMBEDDED CONTROL APPLICATIONS IN SPACE
A. ELFVING and A. T. SUND *In its* Second European In-Orbit Operations Technology Symposium p 393-401 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The limitations of current space qualified microprocessor systems, and the need for improving the characteristics of such systems significantly, are addressed. This is considered mandatory to implement future automation and robotics concepts. The relevant requirements for such systems are discussed. RISC (Reduced Instruction Set Computer) microprocessor technology is now breaking the performance bottleneck, and is being designed into an increasing number of systems, including military embedded systems. A brief introduction to RISC technology is given. A complete breadboard designed of an embedded system based on a RISC microprocessor is presented. This system intensionally resembles a spacecraft control computer. It is shown that such a computer can not only satisfy future performance requirements of space systems, but also power consumption, reliability, multisourcing, and software requirements. Additional benefits are flexibility of system design, easier microprocessor validation, and standardization. The current and planned activities around this RISC computer at ESA/ESTEC are presented. ESA

N90-24332# Tecnomare S.p.A. (Italy).
DYNAMICS AND CONTROL OF FREE-FLYING INSPECTION AND MAINTENANCE VEHICLE WITH MANIPULATORS
J. MARCZYK and A. BELLAZZI (Politecnico di Milano, Italy) *In* ESA, Second European In-Orbit Operations Technology Symposium p 413-427 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The intention of this research effort is to investigate the salient dynamic characteristics and related control problems of a free-flying robotic device devoted to Extra-Vehicular Activity (EVA) in the vicinity of International Space Station. The system, comprising a rigid main-body and two independent three-link manipulators, is analyzed with the ESA multi-body code DCAP. Typical tasks and missions, such as station-keeping and attitude control with manipulator activity and payload transfer, is extensively simulated via time-domain numerical simulations. In particular, the impact of link and payload flexibility is examined from a control and performance evaluation point of view. ESA

N90-24334# Pisa Univ. (Italy). Centro Spazio.
FLEXIBLE TEST BED FOR SPACE TELEPRESENCE AND TELEMANIPULATION RESEARCH
M. ANDRENUCCI, M. BERGAMASCO, P. DARIO, and G. SANDINI (Genoa Univ., Italy) *In* ESA, Second European In-Orbit Operations Technology Symposium p 439-443 Dec. 1989 Sponsored in part by Axis S.p.A. and IBM Italia
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The overall objective of this study is the setting up of a flexible teleoperation test bed, based around a commercially available industrial robot which will permit the experimental investigation of a variety of approaches to sensor-based control and supervision of robotic fine manipulation. The main components of the bed under development are a PUMA 562 manipulator equipped with a multifingered hand, a multicamera visual system, an interactive workstation with a force-controlled joystick, and a set of visual, force and tactile-based advanced interfaces wearable by the master operator. A conceptual analysis of overall test bed architecture and a discussion of the subsystems implemented so far, which include two different end-effectors incorporating force and tactile sensors, a remote stereo system to acquire the three dimensional structure of the operation environment, a joystick-life interface with force feedback for controlling the robot arm, a workstation for manipulating stereo representations of objects, and an instrument glove for investigating the isomorphic control of end-effector based on force feedback, are presented. ESA

N90-24466# Ruhr Univ., Bochum (Germany, F.R.). Inst. fuer Werkstoffe.
SHAPE MEMORY ALLOYS FOR ROBOT GRIPPERS AND MECHANICAL HANDS
K. ESCHER and E. HORNBOGEN *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 27-32 Mar. 1990 Sponsored by DFVLR
Copyright Avail: NTIS HC A14/MF A02

The use of shape memory alloys for grippers and actuators is proposed. These alloys, able to carry out complicated and versatile motions due to heating or cooling without application of external stress require no lubrification. The martensitic phase

transformations which provide the alloy with its shape memory are discussed. Three different characteristics of shape memory behavior such as training procedure, composite principle or application of an external recovering force are described. The problems to be solved before an engineering use of shape memory can be made are identified. These include low efficiency, thermal and mechanical fatigue of the alloy and very sluggish reverse motion during the cooling process. ESA

N90-25255*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
ROTATING-UNBALANCED-MASS DEVICES FOR SCANNING BALLOON-BORNE EXPERIMENTS, FREE-FLYING SPACECRAFT, AND SPACE SHUTTLE/SPACE STATION EXPERIMENTS
MICHAEL E. POLITES Jun. 1990 17 p
(NASA-TP-3030; NAS 1.60:3030) Avail: NTIS HC A03/MF A01 CSCL 14/2

A new method is presented for scanning balloon-borne experiments, free-flying spacecraft, and gimballed experiments mounted to the space shuttle or the space station. It uses rotating-unbalanced-mass (RUM) devices for generating circular, line, or raster scan patterns and an auxiliary control system for target acquisition, keeping the scan centered on the target, and producing complementary motion for raster scanning. It is ideal for applications where the only possible way to accomplish the required scan is to physically scan the entire experiment or spacecraft as in x ray and gamma ray experiments. In such cases, this new method should have advantages over prior methods in terms of either power, weight, cost, performance, stability, or a combination of these. Author

N90-25503*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THIRD ANNUAL WORKSHOP ON SPACE OPERATIONS AUTOMATION AND ROBOTICS (SOAR 1989)
SANDY GRIFFIN, ed. Washington Mar. 1990 651 p Workshop held in Houston, TX, 25-27 Jul. 1989; sponsored by NASA, Washington, the AF, and Houston-Clear Lake Univ.
(NASA-CP-3059; S-599; NAS 1.55:3059) Avail: NTIS HC A99/MF A04 CSCL 12/1

Papers presented at the Third Annual Workshop on Space Operations Automation and Robotics (SOAR '89), hosted by the NASA Lyndon B. Johnson Space Center at Houston, Texas, on July 25 to 27, 1989, are given. Approximately 100 technical papers were presented by experts from NASA, the USAF, universities, and technical companies. Also held were panel discussions on Air Force/NASA Artificial Intelligence Overview and Expert System Verification and Validation.

N90-25514*# Air Force Systems Command, Wright-Patterson AFB, OH.
SDIO ROBOTICS IN SPACE APPLICATIONS
RICHARD ILIFF *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 133-136 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 05/8

Robotics in space supporting the Strategic Defense System (SDS) program is discussed. Ongoing initiatives which are intended to establish an initial Robotics in Space capability are addressed. This is specifically being referred to as the Satellite Servicing System (SSS). This system is based on the NASA Orbital Maneuvering Vehicle (OMV) with a Robotic Manipulator(s) based on the NASA Flight Telerobotic Servicer (FTS) and other SSS equipment required to do the satellite servicing work attached to the OMV. Specific Robotics in Space Requirements which have resulted from the completion of the Robotics Requirements Study Contract are addressed. Author

N90-25527*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
TELEPRESENCE AND SPACE STATION FREEDOM WORKSTATION OPERATIONS
DEAN G. JENSEN, SUSAN C. ADAM, JAMES H. STRAMLER, and ROBERT P. WILMINGTON (Lockheed Engineering and Sciences Co., Houston, TX.) *In its* Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 229-234 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 05/8

The Space Station Freedom workstation system is a distributed network of computer based workstations that provides the man-machine interfaces for controlling space station systems. This includes control of external manipulator, robotic and free flyer devices by crewmembers in the space station's pressurized shirt-sleeve environment. These remotely controlled devices help minimize the requirement for costly crew extravehicular activity (EVA) time for such tasks as station assembly and payload support. Direct window views may be used for controlling some of the systems, but many activities will be remote or require levels of detail not possible by direct observation. Since controlling remote devices becomes more difficult when direct views are inadequate or unavailable, many performance enhancing techniques have been considered for representing information about remote activities to the operator. Described here are the telepresence techniques under consideration to support operations and training. This includes video enhancements (e.g., graphic and text overlays and stereo viewing), machine vision systems, remote activity animation, and force reflection representation. Author

N90-25537*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE FLIGHT TELEROBOTIC SERVICER (FTS) NASA'S FIRST OPERATIONAL ROBOTIC SYSTEM
J. ANDARY, K. HALTERMAN, D. HEWITT, and P. SABELHAUS *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 311-318 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 05/8

NASA has completed the preliminary definition phase of the Flight Telerobotic Servicer (FTS) and is now preparing to begin the detailed design and fabrication phase. The FTS will be designed and built by Martin Marietta Astronautics Group in Denver, CO, for the Goddard Space Flight Center, in support of the Space Station Freedom Program. The design concepts for the FTS are discussed, as well as operational scenarios for the assembly, maintenance, servicing and inspection tasks which are being considered for the FTS. The upcoming Development Test Flight (DTF-1) is the first of two shuttle test flights to test FTS operations in the environment of space and to demonstrate the FTS capabilities in performing tasks for Space Station Freedom. Operational planning for DTF-1 is discussed as well as development plans for the operational support of the FTS on the space station. Author

N90-25550*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SMART HANDS FOR THE EVA RETRIEVER
CLIFFORD W. HESS and LARRY C. LI *In its* Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 441-446 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 13/9

Dexterous, robotic hands are required for the extravehicular activity retriever (EVAR) system being developed by the NASA Johnson Space Center (JSC). These hands, as part of the EVAR system, must be able to grasp objects autonomously and securely which inadvertently separate from the Space Station. Development of the required hands was initiated in 1987. Outlined here are the hand development activities, including design considerations, progress to date, and future plans. Several types of dexterous hands that were evaluated, along with a proximity-sensing capability that was developed to initiate a reflexive, adaptive grasp, are described. The evaluations resulted in the design and fabrication of a 6-degree-of-freedom (DOF) hand that has two fingers and a thumb arranged in an anthropomorphic configuration. Finger joint force and position sensors are included in the design, as well as

infrared proximity sensors which allow initiation of the grasp sequence when an object is detected within the grasp envelope. Author

N90-25556*# Carlow Associates, Inc., Fairfax, VA.
HUMAN FACTORS ISSUES IN TELEROBOTIC SYSTEMS FOR SPACE STATION FREEDOM SERVICING
THOMAS B. MALONE and KATHRYN E. PERMENTER *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 485-492 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 05/8

Requirements for Space Station Freedom servicing are described and the state-of-the-art for telerobotic system on-orbit servicing of spacecraft is defined. The projected requirements for the Space Station Flight Telerobotic Servicer (FTS) are identified. Finally, the human factors issues in telerobotic servicing are discussed. The human factors issues are basically three: the definition of the role of the human versus automation in system control; the identification of operator-device interface design requirements; and the requirements for development of an operator-machine interface simulation capability. Author

N90-26304*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
ROTATING-UNBALANCED-MASS DEVICES AND METHODS FOR SCANNING BALLOON-BORNE-EXPERIMENTS, FREE-FLYING SPACECRAFT, AND SPACE SHUTTLE/SPACE STATION ATTACHED EXPERIMENTS Patent Application
MICHAEL E. POLITES, inventor (to NASA) 23 May 1990 40 p (NASA-CASE-MFS-28425-1; NAS 1.71:MFS-28425-1; US-PATENT-APPL-SN-527462) Avail: NTIS HC A03/MF A01 CSCL 14/2

A method and apparatus for scanning balloon-borne experiments, free-flying spacecraft, or gimballed experiments mounted on a space shuttle or space station, makes use of one or more rotating unbalanced mass devices for selectively generating circular, line, or raster scan patterns for the experiment line of sight. An auxiliary control system may also be used in combination with the rotating unbalanced mass device, for target acquisition, keeping the scan centered on the target, or for producing complementary motion for raster scanning. The rotating unbalanced mass makes use of a mass associated with a drive shaft, such mass having a center of gravity which is displaced from the drive shaft rotation axis. The drive shaft is driven with a substantially constant angular velocity, thereby resulting in relatively low power requirements since no acceleration or deceleration of the mass is generally involved during steady state operations. The resulting centrifugal force of the rotating unbalanced mass is used to generate desired reaction forces on the experiment or spacecraft to create a desired scan pattern for the experiment line of sight. NASA

N90-26577*# Martin Marietta Space Systems, Inc., Denver, CO. Astronautics Group.
SPACE STATION DEFINITIONS, DESIGN, AND DEVELOPMENT. TASK 5: MULTIPLE ARM TELEROBOT COORDINATION AND CONTROL: MANIPULATOR DESIGN METHODOLOGY Final Report
R. M. STOUGHTON Jul. 1990 109 p
(Contract NAS1-18230)
(NASA-CR-182043; NAS 1.26:182043; MCR-88-612) Avail: NTIS HC A06/MF A01 CSCL 09/2

A proposed methodology applicable to the design of manipulator systems is described. The current design process is especially weak in the preliminary design phase, since there is no accepted measure to be used in trading off different options available for the various subsystems. The design process described uses Cartesian End-Effector Impedance as a measure of performance for the system. Having this measure of performance, it is shown how it may be used to determine the trade-offs necessary to the preliminary design phase. The design process involves three main parts: (1) determination of desired system performance in terms of End-Effector Impedance; (2) trade-off design options to achieve this desired performance; and (3) verification of system performance through laboratory testing. The design process is developed using numerous examples and experiments to demonstrate the feasability of this approach to manipulator design. Author

N90-27298*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SIMULATION-BASED INTELLIGENT ROBOTIC AGENT FOR SPACE STATION FREEDOM
CSABA A. BIEGL, JAMES F. SPRINGFIELD, GEORGE E. COOK, and KENNETH R. FERNANDEZ (Vanderbilt Univ., Nashville, TN.) *In its* Fifth Conference on Artificial Intelligence for Space Applications p 203-210 May 1990
Avail: NTIS HC A25/MF A04 CSCL 05/8

A robot control package is described which utilizes on-line structural simulation of robot manipulators and objects in their workspace. The model-based controller is interfaced with a high level agent-independent planner, which is responsible for the task-level planning of the robot's actions. Commands received from the agent-independent planner are refined and executed in the simulated workspace, and upon successful completion, they are transferred to the real manipulators. Author

N90-27300*# McDonnell-Douglas Space Systems Co., Houston, TX.
SPACE STATION ADVANCED AUTOMATION
DONALD WOODS *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 221-230 May 1990
(Contract NAS9-18200)
Avail: NTIS HC A25/MF A04 CSCL 22/2

In the development of a safe, productive and maintainable space station, Automation and Robotics (A and R) has been identified as an enabling technology which will allow efficient operation at a reasonable cost. The Space Station Freedom's (SSF) systems are very complex, and interdependent. The usage of Advanced Automation (AA) will help restructure, and integrate system status so that station and ground personnel can operate more efficiently. To use AA technology for the augmentation of system management functions requires a development model which consists of well defined phases of: evaluation, development, integration, and maintenance. The evaluation phase will consider system management functions against traditional solutions, implementation techniques and requirements; the end result of this phase should be a well developed concept along with a feasibility analysis. In the development phase the AA system will be developed in accordance with a traditional Life Cycle Model (LCM) modified for Knowledge Based System (KBS) applications. A way by which both knowledge bases and reasoning techniques can be reused to control costs is explained. During the integration phase the KBS software must be integrated with conventional software, and verified and validated. The Verification and Validation (V and V) techniques applicable to these KBS are based on the ideas of consistency, minimal competency, and graph theory. The maintenance phase will be aided by having well designed and documented KBS software. Author

N90-27312*# Scientific Research Associates, Inc., Glastonbury, CT.
THE REAL-TIME LEARNING MECHANISM OF THE SCIENTIFIC RESEARCH ASSOCIATES ADVANCED ROBOTIC SYSTEM (SRAARS)
ALEXANDER Y. CHEN *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 331-340 May 1990
(Contract NAS7-1012)
Avail: NTIS HC A25/MF A04 CSCL 09/2

Scientific research associates advanced robotic system (SRAARS) is an intelligent robotic system which has autonomous learning capability in geometric reasoning. The system is equipped with one global intelligence center (GIC) and eight local intelligence

centers (LICs). It controls mainly sixteen links with fourteen active joints, which constitute two articulated arms, an extensible lower body, a vision system with two CCD cameras and a mobile base. The on-board knowledge-based system supports the learning controller with model representations of both the robot and the working environment. By consecutive verifying and planning procedures, hypothesis-and-test routines and learning-by-analogy paradigm, the system would autonomously build up its own understanding of the relationship between itself (i.e., the robot) and the focused environment for the purposes of collision avoidance, motion analysis and object manipulation. The intelligence of SRAARS presents a valuable technical advantage to implement robotic systems for space exploration and space station operations. Author

N90-28062*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
REACTION-COMPENSATION TECHNOLOGY FOR MICROGRAVITY LABORATORY ROBOTS
DOUGLAS A. ROHN, CHARLES LAWRENCE, and JEFFREY H. MILLER (Sverdrup Technology, Inc., Brook Park, OH.) 1990 5 p Proposed for presentation at the i-SAIRAS 1990 International Symposium on Artificial Intelligence, Robotics and Automation in Space, Kobe, Japan, 18-20 Nov. 1990
(NASA-TM-103271; E-5713; NAS 1.15:103271) Avail: NTIS HC A01/MF A01 CSCL 13/9

Robots operating in the microgravity environment of an orbiting laboratory should be capable of manipulating payloads such that the motion of the robot does not disturb adjacent experiments. The current results of a NASA Lewis Research Center technology program to develop smooth, reaction-compensated manipulation based on both mechanism technology and trajectory planning strategies are present. Experimental validation of methods to reduce robot base reactions through the use of redundant degrees of freedom is discussed. Merits of smooth operation roller-driven robot joints for microgravity manipulators are also reviewed. Author

N90-29000*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 1
GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 481 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989
(Contract NAS7-918)
(NASA-CR-186856; JPL-PUBL-89-7-VOL-1; NAS 1.26:186856)
Avail: NTIS HC A21/MF A03 CSCL 05/8

The theme of the Conference was man-machine collaboration in space. Topics addressed include: redundant manipulators; man-machine systems; telerobot architecture; remote sensing and planning; navigation; neural networks; fundamental AI research; and reasoning under uncertainty.

N90-29013*# Dortmund Univ. (Germany, F.R.). Inst. of Robotics Research.
CONTROL OF INTELLIGENT ROBOTS IN SPACE
E. FREUND and CH. BUEHLER *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 141-150 31 Jan. 1989 Sponsored in part by Bundeminister fuer Forschung und Technologie, Federal Republic of Germany
Avail: NTIS HC A21/MF A03 CSCL 05/8

In view of space activities like International Space Station, Man-Tended-Free-Flyer (MTFF) and free flying platforms, the development of intelligent robotic systems is gaining increasing importance. The range of applications that have to be performed by robotic systems in space includes e.g., the execution of experiments in space laboratories, the service and maintenance of satellites and flying platforms, the support of automatic production processes or the assembly of large network structures. Some of these tasks will require the development of bi-armed or of multiple robotic systems including functional redundancy. For the development of robotic systems which are able to perform this variety of tasks a hierarchically structured modular concept of automation is required. This concept is characterized by high flexibility as well as by automatic specialization to the particular sequence of tasks that have to be performed. On the other hand it has to be designed such that the human operator can influence or guide the system on different levels of control supervision, and decision. This leads to requirements for the hardware and software concept which permit a range of application of the robotic systems from telemanipulation to autonomous operation. The realization of this goal requires strong efforts in the development of new methods, software and hardware concepts, and the integration into an automation concept. Author

N90-29016*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE NASA/OAST TELEROBOT TESTBED ARCHITECTURE
J. R. MATIJEVIC, W. F. ZIMMERMAN, and S. DOLINSKY *In its* Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 185-195 31 Jan. 1989
Avail: NTIS HC A21/MF A03 CSCL 05/8

Through a phased development such as a laboratory-based research testbed, the NASA/OAST Telerobot Testbed provides an environment for system test and demonstration of the technology which will usefully complement, significantly enhance, or even replace manned space activities. By integrating advanced sensing, robotic manipulation and intelligent control under human-interactive supervision, the Testbed will ultimately demonstrate execution of a variety of generic tasks suggestive of space assembly, maintenance, repair, and telescience. The Testbed system features a hierarchical layered control structure compatible with the incorporation of evolving technologies as they become available. The Testbed system is physically implemented in a computing architecture which allows for ease of integration of these technologies while preserving the flexibility for test of a variety of man-machine modes. The development currently in progress on the functional and implementation architectures of the NASA/OAST Testbed and capabilities planned for the coming years are presented. Author

N90-29044*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 2
GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 393 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989
(Contract NAS7-918)
(NASA-CR-186857; JPL-PUBL-89-7-VOL-2; NAS 1.26:186857)
Avail: NTIS HC A17/MF A03 CSCL 05/8

These proceedings contain papers presented at the NASA Conference on Space Telerobotics held in Pasadena, January 31 to February 2, 1989. The theme of the Conference was man-machine collaboration in space. The Conference provided a forum for researchers and engineers to exchange ideas on the research and development required for application of telerobotics technology to the space systems planned for the 1990s and beyond. The Conference: (1) provided a view of current NASA telerobotic research and development; (2) stimulated technical exchange on man-machine systems, manipulator control, machine sensing, machine intelligence, concurrent computation, and system architectures; and (3) identified important unsolved problems of current interest which can be dealt with by future research.

N90-29051*# Teledyne Brown Engineering, Huntsville, AL.
DESIGN OF A MONITOR AND SIMULATION TERMINAL (MASTER) FOR SPACE STATION TELEROBOTICS AND TELESCIENCE
L. LOPEZ, C. KONKEL, P. HARMON (System Dynamics, Inc., Huntsville, AL.), and S. KING *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 75-86 31 Jan. 1989
Avail: NTIS HC A17/MF A03 CSCL 05/8

Based on Space Station and planetary spacecraft communication time delays and bandwidth limitations, it will be necessary to develop an intelligent, general purpose ground monitor terminal capable of sophisticated data display and control of on-orbit facilities and remote spacecraft. The basic elements that make up a Monitor and Simulation Terminal (MASTER) include computer overlay video, data compression, forward simulation, mission resource optimization and high level robotic control. Hardware and software elements of a MASTER are being assembled for testbed use. Applications of Neural Networks (NNs) to some key functions of a MASTER are also discussed. These functions are overlay graphics adjustment, object correlation and kinematic-dynamic characterization of the manipulator. Author

N90-29057*# Ford Aerospace Corp., Palo Alto, CA. Space Systems Div.
PRELIMINARY RESULTS ON NONCOLLOCATED TORQUE CONTROL OF SPACE ROBOT ACTUATORS
SCOTT W. TILLEY, COLIN M. FRANCIS, KEN EMERICK, and MICHAEL G. HOLLARS *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 143-152 31 Jan. 1989
Avail: NTIS HC A17/MF A03 CSCL 05/8

In the Space Station era, more operations will be performed robotically in space in the areas of servicing, assembly, and experiment tending among others. These robots may have various sets of requirements for accuracy, speed, and force generation, but there will be design constraints such as size, mass, and power dissipation limits. For actuation, a leading motor candidate is a dc brushless type, and there are numerous potential drive trains each with its own advantages and disadvantages. This experiment uses a harmonic drive and addresses some inherent limitations, namely its backdriveability and low frequency structural resonances. These effects are controlled and diminished by instrumenting the actuator system with a torque transducer on the output shaft. This noncollocated loop is closed to ensure that the commanded torque is accurately delivered to the manipulator link. The actuator system is modelled and its essential parameters identified. The nonlinear model for simulations will include inertias, gearing, stiction, flexibility, and the effects of output load variations. A linear model is extracted and used for designing the noncollocated torque and position feedback loops. These loops are simulated with the structural frequency encountered in the testbed system. Simulation results are given for various commands in position. The use of torque feedback is demonstrated to yield superior performance in settling time and positioning accuracy. An experimental setup being finished consists of a bench mounted motor and harmonic drive actuator system. A torque transducer and two position encoders, each with sufficient resolution and bandwidth, will provide sensory information. Parameters of the physical system are being identified and matched to analytical predictions. Initial feedback control laws will be incorporated in the bench test equipment and various experiments run to validate the designs. The status of these experiments is given. Author

N90-29059*# Jet Propulsion Lab., California Inst. of Tech., Pasadena. Tele-Autonomous Systems Group.
EXPERIENCES WITH THE JPL TELEROBOT TESTBED: ISSUES AND INSIGHTS
HENRY W. STONE, BOB BALARAM, and JOHN BEAHAN *In its* Proceedings of the NASA Conference on Space Telerobotics, Volume 2 p 163-172 31 Jan. 1989
Avail: NTIS HC A17/MF A03 CSCL 05/8

The Jet Propulsion Laboratory's (JPL) Telerobot Testbed is an integrated robotic testbed used to develop, implement, and evaluate the performance of advanced concepts in autonomous, tele-autonomous, and tele-operated control of robotic manipulators. Using the Telerobot Testbed, researchers demonstrated several of the capabilities and technological advances in the control and integration of robotic systems which have been under development at JPL for several years. In particular, the Telerobot Testbed was recently employed to perform a near completely automated, end-to-end, satellite grapple and repair sequence. The task of integrating existing as well as new concepts in robot control into the Telerobot Testbed has been a very difficult and timely one. Now that researchers have completed the first major milestone (i.e., the end-to-end demonstration) it is important to reflect back upon experiences and to collect the knowledge that has been gained so that improvements can be made to the existing system. It is also believed that the experiences are of value to the others in the robotics community. Therefore, the primary objective here will be to use the Telerobot Testbed as a case study to identify real problems and technological gaps which exist in the areas of robotics and in particular systems integration. Such problems have surely hindered the development of what could be reasonably called an intelligent robot. In addition to identifying such problems, researchers briefly discuss what approaches have been taken to resolve them or, in several cases, to circumvent them until better approaches can be developed. Author

N90-29781*# National Aeronautics and Space Administration. *Goddard Space Flight Center, Greenbelt, MD.*
THE FLIGHT TELEROBOTIC SERVICER: NASA'S FIRST OPERATIONAL SPACE ROBOT
CHARLES F. FUECHSEL *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 3-7 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

Alternatives to the exploration of Mars by direct human presence are under consideration by both the United States and the Soviet Union. In these concepts, autonomous surface vehicles would navigate the planet performing a variety of detailed exploratory functions such as mapping, seismic measurements, sample collection and analysis. Both of these approaches to the exploration of Mars depend to a high degree on the ability of robotic machinery to perform complex functions without real time human direction. Closer to home and in time, robotics will begin to play a role in space operations in the construction and maintenance of Space Station Freedom. The Flight Telerobotic Servicer Project is introduced as an element of the Space Station Freedom, and its objectives and some special challenges it faces are discussed. Author

N90-29784*# Toshiba Corp., Kawasaki (Japan).
CAPTURE OF FREE-FLYING PAYLOADS WITH FLEXIBLE SPACE MANIPULATORS
T. KOMATSU, M. UENOHARA, S. IIKURA, H. MIURA, and I. SHIMOYAMA (Tokyo Univ., Japan) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 35-44 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

A recently developed control system for capturing free-flying payloads with flexible manipulators is discussed. Three essential points in this control system are, calculating optimal path, using a vision sensor for an external sensor, and controlling active vibration. Experimental results are shown using a planar flexible manipulator. Author

N90-29790*# Oak Ridge National Lab., TN.
TRACTION-DRIVE FORCE TRANSMISSION FOR TELEROBOTIC JOINTS
D. P. KUBAN and D. M. WILLIAMS *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 103-115 31 Jan. 1989 Previously announced as N89-25461
(Contract MMES-40-1553-85)
Avail: NTIS HC A23/MF A04 CSCL 05/8

The U.S. Space Station Program is providing many technological developments to meet the increasing demands of designing such a facility. One of the key areas of research is that of telerobotics for space station assembly and maintenance. Initial implementation will be teleoperated, but long-term plans call for autonomous robotics. One of the essential components for making this transition successful is the manipulator joints mechanism. Historically, teleoperated manipulators and industrial robotics have had very different mechanisms for force transmission. This is

because the design objectives are almost mutually exclusive. A teleoperator must have very low friction and inertia to minimize operator fatigue; backlash and stiffness are of secondary concern. A robot, however, must have minimum backlash, and high stiffness for accurate and rapid positioning. A joint mechanism has yet to be developed that can optimize these divergent performance objectives. A joint mechanism that approaches this optimal performance was developed for NASA Langley, Automation Technology Branch. It is a traction-drive differential that uses variable preload mechanisms. The differential provides compact, dexterous motion range with a torque density similar to geared systems. The traction drive offers high stiffness and zero backlash, for good robotic performance, and the variable loading mechanism (VLM) minimizes the drive-train friction, for improved teleoperation. Author

N90-29798*# Boeing Aerospace Co., Seattle, WA.
GUIDANCE ALGORITHMS FOR A FREE-FLYING SPACE ROBOT
A. F. BRINDLE, H. E. M. VIGGH, and J. H. ALBERT *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 191-200 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

Robotics is a promising technology for assembly, servicing, and maintenance of platforms in space. Several aspects of planning and guidance for telesupervised and fully autonomous robotic servicers are investigated. Guidance algorithms for proximity operation of a free flyer are described. Numeric trajectory optimization is combined with artificial intelligence based obstacle avoidance. An initial algorithm and the results of its simulating platform servicing scenario are discussed. A second algorithm experiment is then proposed. Author

N90-29800*# California Univ., Berkeley. Telerobotics Unit.
THE 3D MODEL CONTROL OF IMAGE PROCESSING
AN H. NGUYEN and LAWRENCE STARK *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 213-222 31 Jan. 1989 Sponsored by NASA, Ames Research Center
Avail: NTIS HC A23/MF A04 CSCL 05/8

Telerobotics studies remote control of distant robots by a human operator using supervisory or direct control. Even if the robot manipulators has vision or other senses, problems arise involving control, communications, and delay. The communication delays that may be expected with telerobots working in space stations while being controlled from an Earth lab have led to a number of experiments attempting to circumvent the problem. This delay in communication is a main motivating factor in moving from well understood instantaneous hands-on manual control to less well understood supervisory control; the ultimate step would be the realization of a fully autonomous robot. The 3-D model control plays a crucial role in resolving many conflicting image processing problems that are inherent in resolving in the bottom-up approach of most current machine vision processes. The 3-D model control approach is also capable of providing the necessary visual feedback information for both the control algorithms and for the human operator. E.R.

N90-29801*# Purdue Univ., West Lafayette, IN. School of Electrical Engineering.
WEIGHTED FEATURE SELECTION CRITERIA FOR VISUAL SERVOING OF A TELEROBOT
JOHN T. FEDDEMA, C. S. G. LEE, and O. R. MITCHELL *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 223-233 31 Jan. 1989 Sponsored in part by IBM
(Contract NSF CDR-88-03017)
Avail: NTIS HC A23/MF A04 CSCL 05/8

Because of the continually changing environment of a space station, visual feedback is a vital element of a telerobotic system. A real time visual servoing system would allow a telerobot to track and manipulate randomly moving objects. Methodologies for the automatic selection of image features to be used to visually control the relative position between an eye-in-hand telerobot and a known object are devised. A weighted criteria function with both image recognition and control components is used to select the combination of image features which provides the best control. Simulation and experimental results of a PUMA robot arm visually tracking a randomly moving carburetor gasket with a visual update time of 70 milliseconds are discussed. Author

N90-29805*# Bolt, Beranek, and Newman, Inc., Cambridge, MA.
TELEROBOTIC WORKSTATION DESIGN AID
K. CORKER, E. HUDLICKA, D. YOUNG, and N. CRAMER *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 265-275 31 Jan. 1989 Sponsored in part by JPL and NASA; Ames Research Center
Avail: NTIS HC A23/MF A04 CSCL 05/8

Telerobot systems are being developed to support a number of space mission applications. In low earth orbit, telerobots and teleoperated manipulators will be used in shuttle operations and space station construction/maintenance. Free flying telerobotic service vehicles will be used at low and geosynchronous orbital operations. Rovers and autonomous vehicles will be equipped with telerobotic devices in planetary exploration. In all of these systems, human operators will interact with the robot system at varied levels during the scheduled operations. The human operators may be in either orbital or ground-based control systems. To assure integrated system development and maximum utility across these systems, designers must be sensitive to the constraints and capabilities that the human brings to system operation and must be assisted in applying these human factors to system development. The simulation and analysis system is intended to serve the needs of system analysis/designers as an integrated workstation in support of telerobotic design. Author

N90-29806*# Tecnospazio S.p.A., Milan (Italy).
SPACE ROBOTIC SYSTEM FOR PROXIMITY OPERATIONS
P. G. MAGNANI and M. COLOMBA *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 277-285 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

Key to an efficient accomplishment of space station servicing operations is the development of a scenario where the presence of man in space is well integrated with the capability of teleoperated and automatic robot system outside the stations. Results focusing on mission requirements, trajectory sequences, propulsion subsystem features, and manipulative kit characteristics relevant to proximity servicing during a Man Tended Free Flyers Robotic Mission (MTFF-RM) are illustrated. E.R.

N90-29821*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE FLIGHT TELEROBOTIC SERVICER PROJECT: A TECHNICAL OVERVIEW
HARRY G. MCCAIN *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 437-445 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

The Flight Telerobotic Servicer (FTS) technical challenge is the development and integration of a spaceflight quality system with both teleoperative and autonomous capabilities. The system must be safe and reliable in the space environment. Background and rationale leading to the desired FTS telerobotic capabilities are provided. Some of the specific technical requirements to which the FTS must be designed in order to meet the projects goals and operate effectively in the space environment are described. E.R.

N90-29822*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE FLIGHT TELEROBOTIC SERVICER TINMAN CONCEPT: SYSTEM DESIGN DRIVERS AND TASK ANALYSIS
J. F. ANDARY, D. R. HEWITT, and S. W. HINKAL *In* JPL,

California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 447-471 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

A study was conducted to develop a preliminary definition of the Flight Telerobotic Servicer (FTS) that could be used to understand the operational concepts and scenarios for the FTS. Called the Tinman, this design concept was also used to begin the process of establishing resources and interfaces for the FTS on Space Station Freedom, the National Space Transportation System shuttle orbiter, and the Orbital Maneuvering vehicle. Starting with an analysis of the requirements and task capabilities as stated in the Phase B study requirements document, the study identified eight major design drivers for the FTS. Each of these design drivers and their impacts on the Tinman design concept are described. Next, the planning that is currently underway for providing resources for the FTS on Space Station Freedom is discussed, including up to 2000 W of peak power, up to four color video channels, and command and data rates up to 500 kbps between the telerobot and the control station. Finally, an example is presented to show how the Tinman design concept was used to analyze task scenarios and explore the operational capabilities of the FTS. A structured methodology using a standard terminology consistent with the NASA/National Bureau of Standards Standard Reference Model for Telerobot Control System Architecture (NASREM) was developed for this analysis. Author

N90-29823*# National Inst. of Standards and Technology, Gaithersburg, MD. Robot Systems Div.
THE FLIGHT TELEROBOTIC SERVICER: FROM FUNCTIONAL ARCHITECTURE TO COMPUTER ARCHITECTURE
RONALD LUMIA and JOHN FIALA *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 473-482 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

After a brief tutorial on the NASA/National Bureau of Standards Standard Reference Model for Telerobot Control System Architecture (NASREM) functional architecture, the approach to its implementation is shown. First, interfaces must be defined which are capable of supporting the known algorithms. This is illustrated by considering the interfaces required for the SERVO level of the NASREM functional architecture. After interface definition, the specific computer architecture for the implementation must be determined. This choice is obviously technology dependent. An example illustrating one possible mapping of the NASREM functional architecture to a particular set of computers which implements it is shown. The result of choosing the NASREM functional architecture is that it provides a technology independent paradigm which can be mapped into a technology dependent implementation capable of evolving with technology in the laboratory and in space. E.R.

N90-29824*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
RESEARCH AND DEVELOPMENT ACTIVITIES AT THE GODDARD SPACE FLIGHT CENTER FOR THE FLIGHT TELEROBOTIC SERVICER PROJECT
STANFORD OLLENDORF *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 483-489 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

The Flight Telerobotic Servicer (FTS) is being developed by the Goddard Space Flight Center (GSFC) for performing a variety of assembly, servicing, inspection and maintenance tasks on the Space Station. The Project Office at GSFC has tasked the Engineering Directorate to assemble a robotics research and development program which will support the FTS project. The activities center around support for the Development Test Flight (DTF) on the Space Shuttle and investigations of operational problems associated with the FTS on Space Station Freedom. For the DTF, areas such as control algorithms, safety systems, and end-effectors will be developed. For FTS operations, the emphasis will be to develop a dual-arm bi-lateral force-reflecting teleoperator and use it as an FTS Operational Simulator (FTSOS). The simulator will be used to investigate operational techniques, camera configurations, operator interfacing, orbital replacement unit (ORU) designs, end-effector designs, and training techniques. After a series of test activities, reports will be generated for input to the DTF and FTS designs. Author

N90-29825*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE GODDARD SPACE FLIGHT CENTER (GSFC) ROBOTICS TECHNOLOGY TESTBED
RICK SCHNURR, MAUREEN OBRIEN, and SUE COFER (Digital Equipment Corp., Landover, MD.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 491-500 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

Much of the technology planned for use in NASA's Flight Telerobotic Servicer (FTS) and the Demonstration Test Flight (DTF) is relatively new and untested. To provide the answers needed to design safe, reliable, and fully functional robotics for flight, NASA/GSFC is developing a robotics technology testbed for research of issues such as zero-g robot control, dual arm teleoperation, simulations, and hierarchical control using a high level programming language. The testbed will be used to investigate these high risk technologies required for the FTS and DTF projects. The robotics technology testbed is centered around the dual arm teleoperation of a pair of 7 degree-of-freedom (DOF) manipulators, each with their own 6-DOF mini-master hand controllers. Several levels of safety are implemented using the control processor, a separate watchdog computer, and other low level features. High speed input/output ports allow the control processor to interface to a simulation workstation: all or part of the testbed hardware can be used in real time dynamic simulation of the testbed operations, allowing a quick and safe means for testing new control strategies. The NASA/National Bureau of Standards Standard Reference Model for Telerobot Control System Architecture (NASREM) hierarchical control scheme, is being used as the reference standard for system design. All software developed for the testbed, excluding some of simulation workstation software, is being developed in Ada. The testbed is being developed in phases. The first phase, which is nearing completion, and highlights future developments is described. Author

N90-29826*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
TEST AND VALIDATION FOR ROBOT ARM CONTROL DYNAMICS SIMULATION
K. HAROLD YAE, SUNG-SOO KIM, EDWARD J. HAUG, WARREN SEERING, KAMALA SUNDARAM, BRUCE THOMPSON, JAMES TURNER, HON CHUN (Cambridge Research Associates, MA.), HAROLD P. FRISCH, and RICHARD SCHNURR *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 3 p 501-507 31 Jan. 1989
Avail: NTIS HC A23/MF A04 CSCL 05/8

The Flight Telerobotic Servicer (FTS) program will require an ability to develop, in a cost effective manner, many simulation models for design, analysis, performance evaluation, and crew training. Computational speed and the degree of modeling fidelity associated with each simulation must be commensurate with problem objectives. To demonstrate evolving state-of-the-art general purpose multibody modeling capabilities, to validate these by laboratory testing, and to expose their modeling shortcomings, two focus problems at the opposite ends of the simulation spectrum are defined: (1) Coarse Acquisition Control Dynamics. Create a real time man-in-the-control-loop simulator. Provide animated graphical display of robot arm dynamics and tactile feedback sufficient for cueing the operator. Interface simulator software with human operated tactile feedback controller; i.e., the Kraft mini-master. (2) Fine, Precision Mode Control Dynamics. Create a high speed, high fidelity simulation model for the design, analysis, and performance evaluation of autonomous 7 degree-of-freedom (DOF) trajectory control algorithms. This model must contain detail dynamic models for all significant dynamics elements within the robot arm, such as joint drive mechanisms. Author

N90-29830*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 4
GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 449 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989
(Contract NAS7-918)
(NASA-CR-186859; JPL-PUBL-87-7-VOL-4; NAS 1.26:186859)
Avail: NTIS HC A19/MF A03 CSCL 05/8

Papers presented at the NASA Conference on Space Telerobotics are compiled. The theme of the conference was man-machine collaboration in space. The conference provided a forum for researchers and engineers to exchange ideas on the research and development required for the application of telerobotic technology to the space systems planned for the 1990's and beyond. Volume 4 contains papers related to the following subject areas: manipulator control; telemanipulation; flight experiments (systems and simulators); sensor-based planning; robot kinematics, dynamics, and control; robot task planning and assembly; and research activities at the NASA Langley Research Center.

N90-29837*# Franklin and Marshall Coll., Lancaster, PA.
RESPONSE TO REFLECTED-FORCE FEEDBACK TO FINGERS IN TELEOPERATIONS
P. H. SUTTER, J. C. IATRIDIS, and N. V. THAKOR (Johns Hopkins Univ., Baltimore, MD.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 65-74 31 Jan. 1989 Sponsored in part by Johns Hopkins Univ., Baltimore, MD
Avail: NTIS HC A19/MF A03 CSCL 05/8

Reflected-force feedback is an important aspect of teleoperations. The objective is to determine the ability of the human operator to respond to that force. Telerobotics operation is simulated by computer control of a motor-driven device with capabilities for programmable force feedback and force measurement. A computer-controlled motor drive is developed that provides forces against the fingers as well as (angular) position control. A load cell moves in a circular arc as it is pushed by a finger and measures reaction forces on the finger. The force exerted by the finger on the load cell and the angular position are digitized and recorded as a function of time by the computer. Flexure forces of the index, long and ring fingers of the human hand in opposition to the motor driven load cell are investigated. Results of the following experiments are presented: (1) Exertion of maximum finger force as a function of angle; (2) Exertion of target finger force against a computer controlled force; and (3) Test of the ability to move to a target force against a force that is a function of position. Averaged over ten individuals, the maximum force that could be exerted by the index or long finger is about 50 Newtons, while that of the ring finger is about 40 Newtons. From the tests of the ability of a subject to exert a target force, it was concluded that reflected-force feedback can be achieved with the direct kinesthetic perception of force without the use of tactile or visual clues.
Author

N90-29843*# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany, F.R.).
TEST AND TRAINING SIMULATOR FOR GROUND-BASED TELEOPERATED IN-ORBIT SERVICING
BERND E. SCHAEFER *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 125-134 31 Jan. 1989
(Contract DFVLR-5-575-4359)
Avail: NTIS HC A19/MF A03 CSCL 05/8

For the Post-IOC(In-Orbit Construction)-Phase of COLUMBUS it is intended to use robotic devices for the routine operations of ground-based teleoperated In-Orbit Servicing. A hardware simulator for verification of the relevant in-orbit operations technologies, the Servicing Test Facility, is necessary which mainly will support the Flight Control Center for the Manned Space-Laboratories for operational specific tasks like system simulation, training of teleoperators, parallel operation simultaneously to actual in-orbit activities and for the verification of the ground operations segment for telerobotics. The present status of definition for the facility functional and operational concept is described. Author

N90-29846*# Italian Space Agency, Rome.
INFORMATION MANAGEMENT IN AN INTEGRATED SPACE TELEROBOT
S. DIPIPPO, G. PASQUARIELLO, and G. SYLOS LABINI *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 157-166 31 Jan. 1989 Prepared in cooperation with Istituto Elaborazione Segnali ed Immagini, Bari (Italy)
Avail: NTIS HC A19/MF A03 CSCL 09/2

The in-orbit operations, like space structures inspection, servicing and repairing, is expected to be one of the most significant technological area for application and development of Robotics and Automation in Space Station environment. The Italian National Space Plan (PSN) has started up its strategic programme SPIDER (Space Inspection Device for Extravehicular Repairs), which is scheduled in three phases, with the final goal of performing docking and precision repairing in the Space Station environment. SPIDER system is an autonomous integrated space robot, using mature Artificial Intelligence tools and technics for its operational control. The preliminary results of a study on the information architecture of the spacecraft are described. Author

N90-29853*# Naval Postgraduate School, Monterey, CA. Dept. of Computer Science.
VEHICLE PATH-PLANNING IN THREE DIMENSIONS USING OPTICS ANALOGS FOR OPTIMIZING VISIBILITY AND ENERGY COST
NEIL C. ROWE and DAVID H. LEWIS *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 217-226 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 05/8

Path planning is an important issue for space robotics. Finding safe and energy-efficient paths in the presence of obstacles and other constraints can be complex although important. High-level (large-scale) path planning for robotic vehicles was investigated in three-dimensional space with obstacles, accounting for: (1) energy costs proportional to path length; (2) turn costs where paths change trajectory abruptly; and (3) safety costs for the danger associated with traversing a particular path due to visibility or invisibility from a fixed set of observers. Paths optimal with respect to these cost factors are found. Autonomous or semi-autonomous vehicles were considered operating either in a space environment around satellites and space platforms, or aircraft, spacecraft, or smart missiles operating just above lunar and planetary surfaces. One class of applications concerns minimizing detection, as for example determining the best way to make complex modifications to a satellite without being observed by hostile sensors; another example is verifying there are no paths (holes) through a space defense system. Another class of applications concerns maximizing detection, as finding a good trajectory between mountain ranges of a planet while staying reasonably close to the surface, or finding paths for a flight between two locations that maximize the average number of triangulation points available at any time along the path. Author

N90-29858*# Lockheed Engineering and Sciences Co., Houston, TX.
OPTIMAL PAYLOAD RATE LIMIT ALGORITHM FOR ZERO-G MANIPULATORS
M. L. ROSS and D. A. MCDERMOTT *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 263-272 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 05/8

An algorithm for continuously computing safe maximum relative velocities for two bodies joined by a manipulator is discussed. The maximum velocities are such that if the brakes are applied at that instant, the ensuing travel between the bodies will be less than or equal to a predetermined amount. An improvement in the

way this limit is computed for space manipulators is shown. The new method is explained, test cases are posed, and the results of these tests are displayed and discussed. Author

N90-29866*# Carnegie-Mellon Univ., Pittsburgh, PA. The Robotics Inst.
PRECEDENCE RELATIONSHIP REPRESENTATIONS OF MECHANICAL ASSEMBLY SEQUENCES
L. S. HOMENDEMELLO and A. C. SANDERSON (Rensselaer Polytechnic Inst., Troy, NY.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 353-362 31 Jan. 1989 Sponsored in part by the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico, Brazil; JPL; and Carnegie Mellon Univ.
Avail: NTIS HC A19/MF A03 CSCL 05/8

Two types of precedence relationship representations for mechanical assembly sequences are presented: precedence relationships between the establishment of one connection between two parts and the establishment of another connection, and precedence relationships between the establishment of one connection and states of the assembly process. Precedence relationship representations have the advantage of being very compact. The problem with these representations was how to guarantee their correctness and completeness. Two theorems are presented each of which leads to the generation of one type of precedence relationship representation guaranteeing its correctness and completeness for a class of assemblies. Author

N90-29869*# Oak Ridge National Lab., TN.
THE LABORATORY TELEROBOTIC MANIPULATOR PROGRAM
J. N. HERNDON, S. M. BABCOCK, P. L. BUTLER, H. M. COSTELLO, R. L. GLASSELL, R. L. KRESS, D. P. KUBAN, J. C. ROWE, and D. M. WILLIAMS *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 385-393 31 Jan. 1989 Sponsored in part by NASA, Langley Research Center
(Contract DE-AC05-84OR-21400)
Avail: NTIS HC A19/MF A03 CSCL 05/8

New opportunities for the application of telerobotic systems to enhance human intelligence and dexterity in the hazardous environment of space are presented by the NASA Space Station Program. Because of the need for significant increases in extravehicular activity and the potential increase in hazards associated with space programs, emphasis is being heightened on telerobotic systems research and development. The Laboratory Telerobotic Manipulator (LTM) program is performed to develop and demonstrate ground-based telerobotic manipulator system hardware for research and demonstrations aimed at future NASA applications. The LTM incorporates traction drives, modularity, redundant kinematics, and state-of-the-art hierarchical control techniques to form a basis for merging the diverse technological domains of robust, high-dexterity teleoperations and autonomous robotic operation into common hardware to further NASA's research. Author

N90-29874*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PROCEEDINGS OF THE NASA CONFERENCE ON SPACE TELEROBOTICS, VOLUME 5
GUILLERMO RODRIGUEZ, ed. and HOMAYOUN SERAJI, ed. 31 Jan. 1989 428 p Conference held in Pasadena, CA, 31 Jan. - 2 Feb. 1989
(Contract NAS7-918)
(NASA-CR-186860; JPL-PUBL-89-7-VOL-5; NAS 1.26:186860)
Avail: NTIS HC A19/MF A03 CSCL 05/8

Papers presented at the NASA Conference on Space Telerobotics are compiled. The theme of the conference was man-machine collaboration in space. The conference provided a forum for researchers and engineers to exchange ideas on the research and development required for the application of telerobotics technology to the space systems planned for the 1990's and beyond. Volume 5 contains papers related to the following subject areas: robot arm modeling and control, special topics in telerobotics, telerobotic space operations, manipulator control, flight experiment concepts, manipulator coordination, issues in artificial intelligence systems, and research activities at the Johnson Space Center.

N90-29875*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
TELEROBOTIC ACTIVITIES AT JOHNSON SPACE CENTER
CHARLES R. PRICE *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 3-7 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 05/8

The Johnson Space Center telerobotic efforts span three major thrusts: (1) sustaining and expanding the capability of the Shuttle manipulator; (2) developing and integrating the multiple telerobotic system of the Space Station; and (3) fostering and applying research in all areas of telerobotics technology within the government, private, and academic sectors. Author

N90-29879*# Tulane Univ., New Orleans, LA. Dept. of Electrical Engineering.
A CONTROL APPROACH FOR ROBOTS WITH FLEXIBLE LINKS AND RIGID END-EFFECTORS
ENRIQUE BARBIERI and UMIT OZGUNER (Ohio State Univ., Columbus.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 41-50 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 06/8

Multiarm flexible robots with dexterous end effectors are currently being considered in such tasks as satellite retrieval, servicing and repair where a two phase problem can be identified: Phase 1, robot positioning in space; Phase 2, object retrieval. Some issues in Phase 1 regarding modelling and control strategies for a robotic system comprised of along flexible arm and a rigid three-link end effector are presented. The control objective is to maintain the last (rigid) link stationary in space in the presence of an additive disturbance caused by the flexible energy in the first link after a positioning maneuver has been accomplished. Several configuration strategies can be considered, and optimal decentralized servocompensators can be designed. Preliminary computer simulations are included for a simple proportional controller to illustrate the approach. Author

N90-29881*# Aerospace Corp., El Segundo, CA.
PERFORMANCE CONSTRAINTS AND COMPENSATION FOR TELEOPERATION WITH DELAY
J. S. MCLAUGHLIN and B. D. STAUNTON *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 63-72 31 Jan. 1989 Sponsored by AF
Avail: NTIS HC A19/MF A03 CSCL 09/2

A classical control perspective is used to characterize performance constraints and evaluate compensation techniques for teleoperation with delay. Use of control concepts such as open and closed loop performance, stability, and bandwidth yield insight to the delay problem. Teleoperator performance constraints are viewed as an open loop time delay lag and as a delay-induced closed loop bandwidth constraint. These constraints are illustrated with a simple analytical tracking example which is corroborated by a real time, 'man-in-the-loop' tracking experiment. The experiment also provides insight to those controller characteristics which are unique to a human operator. Predictive displays and feedforward commands are shown to provide open loop compensation for delay lag. Low pass filtering of telemetry or feedback signals is interpreted as closed loop compensation used to maintain a sufficiently low bandwidth for stability. A new closed loop compensation approach is proposed that uses a reactive (or force feedback) hand controller to restrict system bandwidth by impeding operator inputs. Author

N90-29882*# Lockheed Engineering and Management Services Co., Inc., Houston, TX.
FLIGHT TELEROBOTIC SERVICER CONTROL FROM THE ORBITER
TEXAS M. WARD and DON L. HARLAN *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 73-80 31 Jan. 1989
(Contract NAS9-17900)
Avail: NTIS HC A19/MF A03 CSCL 05/8

The research and work conducted on the development of a testbed for a display and control panel for the Flight Telerobotic Servicer (FTS) are presented. Research was conducted on both software and hardware needed to control the FTS. A breadboard was constructed and placed into a mockup of the aft station of the Orbiter spacecraft. This breadboard concept was then evaluated using a computer graphics representation of the Tinman FTS. Extensive research was conducted on the software requirements and implementation. The hardware selected for the breadboard was 'flight like' and in some cases fit and function evaluated. The breadboard team studied some of the concepts without pursuing in depth their impact on the Orbiter or other missions. Assumptions are made concerning payload integration.
Author

N90-29885*# Massachusetts Inst. of Tech., Cambridge.
INTERSET: A NATURAL LANGUAGE INTERFACE FOR TELEOPERATED ROBOTIC ASSEMBLY OF THE EASE SPACE STRUCTURE
DANIEL K. BOORSMA *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 103-108 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 09/2

A teleoperated robot was used to assemble the Experimental Assembly of Structures in Extra-vehicular activity (EASE) space structure under neutral buoyancy conditions, simulating a telerobot performing structural assembly in the zero gravity of space. This previous work used a manually controlled teleoperator as a test bed for system performance evaluations. From these results several Artificial Intelligence options were proposed. One of these was further developed into a real time assembly planner. The interface for this system is effective in assembling EASE structures using windowed graphics and a set of networked menus. As the problem space becomes more complex and hence the set of control options increases, a natural language interface may prove to be beneficial to supplement the menu based control strategy. This strategy can be beneficial in situations such as: describing the local environment, maintaining a data base of task event histories, modifying a plan or a heuristic dynamically, summarizing a task in English, or operating in a novel situation.
Author

N90-29886*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ESTABLISHING VIABLE TASK DOMAINS FOR TELEROBOT DEMONSTRATIONS
WAYNE ZIMMERMAN *In its* Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 111-120 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 09/2

A suite of telerobotic tasks has been compiled and assessed for the purpose of selecting viable tasks for near and far term laboratory demonstrations. The primary intent of developing the task is to provide some technical guidelines, with supporting data, for focusing laboratory demonstrations toward application domains that address a wide array of potential telerobot tasks and required technologies. This wide application would then result in a rich technology development environment to meet the broad task requirements of a system such as the Flight Telerobot Servicer. The methodology and results of the telerobot task assessment are described, including a ranking of the final select suite of major tasks. The presented along with guidelines for both interpreting the task ranking results and setting programmatic objectives based on these results. Detailed data about the task candidates and their respective levels of complexity, task primitive actions, and the actual relative measures of task worth as associated with key tradeoff variables such as cost, available research resources, technology availability, and importance to the user community are also presented.
Author

N90-29898*# Stanford Univ., CA. Aerospace Robotics Lab.
COMPUTED TORQUE CONTROL OF A FREE-FLYING COOPERAT ING-ARM ROBOT
ROSS KONINGSTEIN, MARC ULLMAN, and ROBERT H. CANNON, JR. *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 235-243 31 Jan. 1989
(Contract NCC2-333)
Avail: NTIS HC A19/MF A03 CSCL 05/8

The unified approach to solving free-floating space robot manipulator end-point control problems is presented using a control formulation based on an extension of computed torque. Once the desired end-point accelerations have been specified, the kinematic equations are used with momentum conservation equations to solve for the joint accelerations in any of the robot's possible configurations: fixed base or free-flying with open/closed chain grasp. The joint accelerations can then be used to calculate the arm control torques and internal forces using a recursive order N algorithm. Initial experimental verification of these techniques has been performed using a laboratory model of a two-armed space robot. This fully autonomous spacecraft system experiences the drag-free, zero G characteristics of space in two dimensions through the use of an air cushion support system. Results of these initial experiments are included which validate the correctness of the proposed methodology. The further problem of control in the large where not only the manipulator tip positions but the entire system consisting of base and arms must be controlled is also presented. The availability of a physical testbed has brought a keener insight into the subtleties of the problem at hand.
Author

N90-29899*# Tsukuba Space Center (Japan).
NEXT GENERATION SPACE ROBOT
TSUTOMU IWATA, MITSUSHIGE ODA, and RYOICHI IMAI *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 245-252 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 05/8

The recent research effort on the next generation space robots is presented. The goals of this research are to develop the fundamental technologies and to acquire the design parameters of the next generation space robot. Visual sensing and perception, dexterous manipulation, man machine interface and artificial intelligence techniques such as task planning are identified as the key technologies.
Author

N90-29910*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
A COMPARISON OF THE SHUTTLE REMOTE MANIPULATOR SYSTEM AND THE SPACE STATION FREEDOM MOBILE SERVICING CENTER
EDITH C. TAYLOR and MICHAEL ROSS (Lockheed Engineering and Sciences Co., Houston, TX.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 353-361 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 05/8

The Shuttle Remote Manipulator System is a mature system which has successfully completed 18 flights. Its primary functional design driver was the capability to deploy and retrieve payloads from the Orbiter cargo bay. The Space Station Freedom Mobile Servicing Center is still in the requirements definition and early design stage. Its primary function design drivers are the capabilities: to support Space Station construction and assembly tasks; to provide external transportation about the Space Station; to provide handling capabilities for the Orbiter, free flyers, and payloads; to support attached payload servicing in the extravehicular environment; and to perform scheduled and un-scheduled maintenance on the Space Station. The differences between the two systems in the area of geometric configuration, mobility, sensor

capabilities, control stations, control algorithms, handling performance, end effector dexterity, and fault tolerance are discussed. Author

N90-29912*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN INTELLIGENT, FREE-FLYING ROBOT
G. J. REUTER, C. W. HESS, D. E. RHOADES, L. W. MCFADIN, K. J. HEALEY, J. D. ERICKSON, and DALE E. PHINNEY (Lockheed Engineering and Sciences Co., Houston, TX.) *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 5 p 373-379 31 Jan. 1989 Previously announced in IAA as A90-10354
Avail: NTIS HC A19/MF A03 CSCL 22/2

The ground based demonstration of the extensive extravehicular activity (EVA) Retriever, a voice-supervised, intelligent, free flying robot, is designed to evaluate the capability to retrieve objects (astronauts, equipment, and tools) which have accidentally separated from the Space Station. The major objective of the EVA Retriever Project is to design, develop, and evaluate an integrated robotic hardware and on-board software system which autonomously: (1) performs system activation and check-out; (2) searches for and acquires the target; (3) plans and executes a rendezvous while continuously tracking the target; (4) avoids stationary and moving obstacles; (5) reaches for and grapples the target; (6) returns to transfer the object; and (7) returns to base. Author

10

MECHANICAL SYSTEMS

Design and operation of mechanical equipment, including gyroscopes and pointing mechanisms. Includes lubrication and lubricants.

A90-38179
A SIMPLIFIED SIZING AND MASS MODEL FOR AXIAL FLOW TURBINES
STEVEN L. HUDSON (Sandia National Laboratories, Albuquerque, NM) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1091-1096. refs
(Contract DE-AC04-76DP-00789)
Copyright

A mass model has been developed and used to study axial flow turbines for space power systems. Hydrogen, helium-xenon, hydrogen-water-vapor, air, and potassium vapor working fluids have been investigated to date. The impact of construction material, inlet temperature, rotational speed, pressure ratio, and power level on turbine mass and volume has been analyzed. The turbine model is described, and results of parametric studies showing general design trends characteristic of any axial flow machine are reported. Axial flow turbine designs using helium-xenon mixtures and potassium vapor working fluids which are used in Brayton and Rankine space power systems, respectively, are compared. I.E.

A90-47611#
POINTING PERFORMANCE OF A SPACE STATION FREEDOM PAYLOAD POINTING SYSTEM
ROBERT O. HUGHES and JOHN M. LOMBARDO (General Electric Co., Astro-Space Div., Philadelphia, PA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 339-347. refs
(AIAA PAPER 90-3351) Copyright

Expected Space Station Freedom (SSF) disturbances and Payload Pointing System (PPS) pointing performance are characterized and analyzed. NASTRAN flexible models of the SSF and nonlinear models of the attached PPS are developed. Pointing performance is most sensitive to gimbal frictional effects and much less sensitive to disturbance sources and sensitive to disturbance sources and SSF dynamic characteristics. For near-zero tracking rates, pointing errors can exceed a budgeted error allocation of 20 arcsec by more than a factor of three. Author

N90-21093# Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).
DESIGN OF A DIGITAL MODEL FOLLOWING CONTROLLER OF REACTION WHEEL TORQUES
GILBERTO DACUNHATRIVELATO and MARCELO LOPESDEOLIVEIRAESOUZA Dec. 1988 9 p In PORTUGUESE; ENGLISH summary Presented at the 7th SBA Congresso Brasileiro de Automatica, Sao Jose dos Campos, Brazil, 15-19 Aug. 1988
(INPE-4753-PRE/1425) Avail: NTIS HC A02/MF A01

The design of a digital model following controller of reaction wheel torques (used in attitude control of artificial satellites) is presented. This controller is intended to reduce the effects of wheel disturbing torques, and wheel sensor noises on the wheel torque. The controller structure used, the criteria for choosing the wheel sampling time, the controller gain, the sensor quantization level, and the current quantization level is summarized while considering the wheel torque requirements. Finally, the digitally simulated system response to zero and step reference torques, and the corresponding hardware implemented responses are discussed. These tests show that such a controller reduces considerably those effects and satisfies those requirements, and the design criteria used are satisfactory. Author

N90-22079*# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
THE 24TH AEROSPACE MECHANISMS SYMPOSIUM
Washington Apr. 1990 370 p Symposium held at Kennedy Space Center, FL, 18-20 Apr. 1990; sponsored by NASA, Washington, California Inst. of Tech., Pasadena, and LMSC, Sunnyvale, CA
(NASA-CP-3062; NAS 1.55:3062) Avail: NTIS HC A16/MF A03 CSCL 20/11

The proceedings of the symposium are reported. Technological areas covered include actuators, aerospace mechanism applications for ground support equipment, lubricants, latches, connectors, and other mechanisms for large space structures.

N90-22095*# Hughes Aircraft Co., El Segundo, CA. Space and Communications Group.
EXPERIENCE WITH SYNTHETIC FLUORINATED FLUID LUBRICANTS
PETER L. CONLEY and JOHN J. BOHNER *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 213-230 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 13/9

Since the late 1970's, the wet lubricant of choice for space mechanisms has been one of the family of synthetic perfluoro polyalkylether (PFPE) compounds, namely Fomblin Z-25 (Bray-815Z) or DuPont's Krytox 143xx series. While offering the advantages of extremely low vapor pressures and wide temperature ranges, these oils and derived greases have a complex chemistry compared to the more familiar natural and synthetic hydrocarbons. Many aerospace companies have conducted test programs to characterize the behavior of these compounds in a space environment, resulting in a large body of hard knowledge as well as considerable space lore concerning the suitability of the lubricants for particular applications and techniques for successful application. The facts are summarized and a few myths about the compounds are dispelled, and some performance guidelines for the mechanism design engineer are provided. Author

N90-22096*# National Research Council of Canada, Victoria (British Columbia). Tribology and Mechanics Lab.
TRIBOMATERIAL FACTORS IN SPACE MECHANISM BRAKE PERFORMANCE

H. M. HAWTHORNE *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 231-241 Apr. 1990 Sponsored in part by Spar Aerospace Ltd.
Avail: NTIS HC A16/MF A03 CSCL 13/9

The asbestos/phenolic pads of Shuttle Remote Manipulator System (SRMS) brakes are unsuitable for use in long life space mechanisms because their friction decreases on extended sliding in high vacuum. Dehydration of the material and accumulation of wear debris in the conforming interface of this tribosystem induces the permanent friction changes. Other polymer and some ceramic based materials exhibit similar frictional torque behavior due to the development of minimal contact patches by the interfacial debris. In contrast, high friction occurs when other ceramics form many small contacts throughout fine debris beds. Generating this latter interfacial structure during run-in ensures that the in-vacuo friction remains stable thereafter. Such materials with low wear rates are potential candidates for friction elements in SSRMS and similar mechanisms. Author

N90-22097*# Honeywell, Inc., Glendale, AZ. Satellite Systems Operations.
POSITIVE LUBRICATION SYSTEM
DENNIS W. SMITH and FRED L. HOOPER *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 243-258 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 13/9

As part of the development of an autonomous lubrication system for spin bearings, a system was developed to deliver oil to grease-lubricated bearings upon demand. This positive oil delivery system (PLUS) consists of a pressurized reservoir with a built-in solenoid valve that delivers a predictable quantity of oil to the spin bearing through a system of stainless steel tubes. Considerable testing was performed on the PLUS to characterize its performance and verify its effectiveness, along with qualifying it for flight. Additional development is underway that will lead to the fully autonomous active lubrication system. Author

N90-22098*# TRW Space Technology Labs., Redondo Beach, CA.
ACTIVE CONTROL OF BEARING PRELOAD USING PIEZOELECTRIC TRANSLATORS
TED W. NYE *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 259-271 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 14/2

In many spacecraft applications, mechanisms are required to perform precision pointing operations or to sometimes dither about or track a moving object. These mechanisms perform in a predictable and repeatable manner in benign temperature environments. Severe thermal gradients experienced in actual space applications however, cause assemblies to expand and contract around their bearings. This results in unpredictable changes in bearing preload, and hence bearing friction. This becomes a limitation for servos controlling pointing accuracy. Likewise, uncontrollable vibrations may couple into fixed preload (hence, fixed stiffness) mechanisms and limit pointing accuracy. Consequently, a complex problem faced today is how to design mechanisms that remain insensitive to changing thermal and vibrational spacecraft environments. Research presented involves the simplified modeling and test results of an actuator module that used piezoelectrically preload controlled bearings. The feasibility of actively controlling bearing preload was demonstrated. Because bearing friction is related to preload, a thermally active system designed with aluminum components and a 440 C bearing, was friction tested at temperatures ranging from 0 to 70 C (32 to 158 F).. Effectiveness of the translators were demonstrated by mapping a controllable friction range throughout tested temperatures. It was learned that constant preload for this system could be maintained over an approximate 44 C (79 F) temperature span. From testing, it was also discovered that at the more deviate temperatures, expansions were so large that radial clearances were taken up and the duplex bearing became radially preloaded. Thus, active control of bearing preload is feasible but may be limited by inherent geometry constraints and materials used in the system. Author

N90-22101*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AX-5 SPACE SUIT BEARING TORQUE INVESTIGATION
STUART LOEWENTHAL, VIC VYKUKAL, ROBERT MACKENDRICK, and PHILIP CULBERTSON, JR. (Sterling Federal Systems, Inc., Palo Alto, CA.) *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 301-312 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 05/8

The symptoms and eventual resolution of a torque increase problem occurring with ball bearings in the joints of the AX-5 space suit are described. Starting torques that rose 5 to 10 times initial levels were observed in crew evaluation tests of the suit in a zero-g water tank. This bearing problem was identified as a blocking torque anomaly, observed previously in oscillatory gimbal bearings. A large matrix of lubricants, ball separator designs and materials were evaluated. None of these combinations showed sufficient tolerance to lubricant washout when repeatedly cycled in water. The problem was resolved by retrofitting a pressure compensated, water exclusion seal to the outboard side of the bearing cavity. The symptoms and possible remedies to blocking are discussed. Author

N90-22102*# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
DESIGN OF A TELESCOPING TUBE SYSTEM FOR ACCESS AND HANDLING EQUIPMENT
ALAN C. LITTLEFIELD *In its* The 24th Aerospace Mechanisms Symposium p 313-327 Apr. 1990
Avail: NTIS HC A16/MF A03 CSCL 05/8

Spacecraft processing presents unique problems for the design of ground support equipment. A telescoping tube system consists of a number of nested structural tubes that can be extended and retracted (telescoped) while supporting a load. A typical telescoping tube system provides lateral, torsional, and vertical support for an access platform. Several concepts for improved telescoping tubes were developed with emphasis placed on reliability, ease of maintenance, and cost effectiveness. The most promising prototype design utilizes adjustable rollers running on tracks bolted to the tube sections. A wire rope deployment system ensures that all tube sections are controlled during extension and retraction. Track shimming and roller adjustment allow for fabrication of a high precision tube assembly that does not require extensive machining or unusually large shop equipment. The use of rolling contact eliminates the contamination problems encountered with sliding tubes in previous designs. The prototype design is suitable for indoor or outdoor use. A prototype tube assembly was fabricated and tested for strength, stiffness, maintainability, and endurance. Author

N90-24462# European Space Agency, Paris (France).
FOURTH EUROPEAN SPACE MECHANISMS AND TRIBOLOGY SYMPOSIUM
W. R. BURKE, comp. Mar. 1990 306 p In ENGLISH and FRENCH Symposium held in Cannes, France, 20-22 Sep. 1989; sponsored in cooperation with Aerospatiale, CNES, and ESA (ESA-SP-299; ISBN-92-9092-038-6; ISSN-0379-6566; ETN-90-96977) Copyright Avail: NTIS HC A14/MF A02

Various aspects of spacecraft design and research are addressed. Rendezvous and docking are considered. Manipulators and robot grippers are discussed. Tribology is given particular attention. The areas of tribology discussed include consideration of surface modifications, mechanisms such as the wear of cryomechanisms and gold-plated contacts and the study of ball bearings for space use. Scanning and pointing mechanisms are described. Extravehicular mechanisms, suits, and tools are discussed. Deployment mechanisms are described. Attachment and drive mechanisms are described.

N90-24463# Lockheed Aircraft Corp., Palo Alto, CA.
DESIGN CONSIDERATIONS FOR PRECISION AND RELIABILITY IN SPACE MECHANISMS
KENNETH R. LORELL *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 3-10 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Design considerations able to meet the requirements imposed by the improved sensitivity of focal-plane instrumentation and infrared systems are discussed. For infrared systems, the performance of the instrumentation requires that the entire optical train be cooled to cryogenic temperatures. For visible wavelength systems, the antenna, or primary mirror, must be made as large as possible. Different design solutions adopted in cryogenic and in large aperture optical system spececraft are outlined. Dynamic range and sensitivity, smoothness of operation, power consumption and thermal-energy dissipation are taken into consideration in the analysis of these systems. The Cryogenic Limb Array Etalon Spectrometer (CLAES) is used as an example of the new design approach necessary. The difficulties inherent in testing such sophisticated and sensitive instruments are discussed. ESA

N90-24468# Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).
GALACTICAL ULTRA WIDE ANGLE SCHMIDT SYSTEM
T. MISKI and K.-H. WEBER *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 39-44 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The Galactical Ultrawideangle Schmidt System (GAUSS) camera is described. The camera is designed for operation in a wavelengh range extending far into vacuum ultraviolet. A three axis stabilized platform with a control range of plus or minus five degrees integrated into the camera design is described. The stages involved in developing the camera are outlined. The unit is designed to be carried on the D2 Spacelab mission accommodated on the D2 Utility Support Structure (USS). Difficulties in meeting contradicting requirements of high precision and wide temperature ranges for a variety of mechanisms with quite different performances are discussed. ESA

N90-24469# Institut National des Sciences Appliquees, Lyon (France). Lab. de Mecanique des Contacts.
INTERFACE TRIBOLOGY AND SPACE CONDITIONS
Y. BERTHIER, L. FLAMAND, M. GODET, and L. PETITJEAN (Centre National d'Etudes Spatiales, Toulouse, France) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 47-51 Mar. 1990 Sponsored by CNES
Copyright Avail: NTIS HC A14/MF A02

The mechanical and physical factors which govern contact conditions and which are different in space and in vacuum are discussed in the light of interface tribology. The role of lubricants is discussed. A quick review of interface tribology is presented. A program to be carried out on a special test device modified to operate under vacuum, and capable of simulating the effect of contact geometry, load, speed and environment on the behavior of low vapor pressure oils and greases is described. The possibility of extrapolating laboratory results to industrial applications is discussed. ESA

N90-24470# Centre Suisse de Documentation dans le Domaine de la Microtechnique, Neuchatel.
TRIBOLOGICAL PROPERTIES OF PVD-APPLIED MOS2 COATINGS USED ON SPACE MECHANISMS
M. MAILLAT, C. MENOUD, H. E. HINTERMANN, and J. F. PATIN (Aerospatiale, Cannes, France) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 53-57 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Coatings of the dry lubricant molybdenum disulfide applied by sputtering on space mechanisms are discussed. Some tribological behavior is described in relation to the mechanism operation. Friction and wear measurements carried out using pin and disk tribometers are discribed. The roles played by relative humidity, contamination by wear particles, and in-vacuo running-in are discussed. The role that the MoS2 lubricant plays on a one operation single-shot mechanism such as a solar array hold-on and release mechanism is contrasted with the role of lubricant in longlife mechanisms such as ball bearings. ESA

N90-24471# European Space Tribology Lab., Risley (England). AEA Technology.
THE ADVANTAGES AND LIMITATIONS OF SPUTTERED MOLYBDENUM DISULPHIDE AS A SPACE LUBRICANT
E. W. ROBERTS *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 59-65 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The sensitivity of thin films of molybdenum disulfide to the conditions under which they are employed is discussed. These conditions, which encompass such variables as load, sliding speed and vacuum pressure can seriously affect the ultra-low-friction behavior of the lubricant film. The tribological properties of sputtered MoS2 under the varied conditions of operation likely to be experienced in space are studied. Gaining a better understanding of its advantages and limitations as a spacecraft lubricant is the goal of the study. ESA

N90-24472# Nissan Motor Co. Ltd., Tokyo (Japan). Materials Research Lab.
INVESTIGATION OF LUBRICATION CHARACTERISTICS OF MOS2 FILMS IN SPACE ENVIRONMENT
M. ARITA, Y. YASUDA, T. AIKAWA, M. AKIYAMA, and N. OHMAE (Osaka Univ., Japan) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 67-71 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Degradation of surface materials due to exposure to atomic oxygen (AOx) irradiation is discussed. Molybdenum disulfide bonded films used as lubricating agents are exposed to an AOx beam. The effects of exposure on their lubricating performance is examined using a pin/disk sliding test under vacuum conditions. Exposure to the AOx beams is shown to induce significant changes in lubricating performance. Atomic oxygen reacts with MoS2, producing molybdenum oxides MoS2 and MoS3 at the surface. It is concluded that these chemical reactions must be taken into account if long-lived operation is to be assured. ESA

N90-24473# British Aerospace Public Ltd. Co., Bristol (England).
MULTI-APPLICATION SCANNING MECHANISM
M. E. HUMPHRIES and M. P. HYAM *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 75-80 Mar. 1990 Sponsored by United Kingdom MET Office
Copyright Avail: NTIS HC A14/MF A02

A scanning mechanism suitable for a variety of scientific payloads is described. Concept selection and the design and development testing of an engineering model of the mechanism are described. The design concept is based on a scan platform mounted on bearings within a housing, the platform being driven through an anti backlash gear train by a brushless dc motor. A closed loop control system, using a high resolution position transducer and microprocessor, drives the platform in a predetermined scan pattern. The modular design of mechanism allows for optional selection of a momentum compensation wheel and a reversible, double-acting bearing off-load device that can protect the bearings of the scan platform and the momentum wheel. ESA

N90-24474# Marconi Space Systems Ltd., Portsmouth (England).
A COMMUNICATIONS ANTENNA POINTING SYSTEM (CAPS): A MODULAR APPROACH
P. J. WHITEMAN *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 81-85 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

CAPS, a modular antenna pointing mechanism concept is presented. The design is capable of meeting a wide range of requirements with minimum modification. Ways in which the development and qualification of the mechanism were carried out while minimizing costs are described. The mechanical aspects of

the antenna pointing mechanism are described. The need for communication satellites to be able to point beams at any selected spot on the Earth is stressed. The demand for pointing mechanisms capable of working in a space environment while supporting a two meter reflector is predicted to increase. ESA

N90-24476# Aerospatiale, Cannes (France).
WEARING OF CRYOMECHANISMS AT 4 K
GERARD LUCIANO *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 95-99 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Pollution due to wear of the mechanisms controlling the motion of spaceborne optics is addressed. Cleanliness of the optical components being crucial to the image quality produced, ways to minimize optical pollution due to coupling gears and other mechanisms are discussed. Comparative tests are carried out on several types of mechanisms in order to choose that which has the most long lasting, clean operation. Applications of this research to the development of the optical bench used in the infrared camera flown aboard the Infrared Space Observatory (ISO) are discussed. ESA

N90-24477# Toshiba Corp., Kanagawa (Japan).
STUDY OF BALL BEARINGS FOR SPACE USE
T. KAWAMURA, T. HONDA, N. KAWASHIMA, M. NISHIMURA, and K. SEKI (National Aerospace Lab., Tokyo, Japan) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 101-107 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The performance of ball bearings coated with sputtered molybdenum disulfide and assembled with a retainer of self-lubricating composite is described. A life test carried out at 150C is performed in vacuum. A second life test in which the rotational speed was varied from 3 to 2000 RPM is carried out in a vacuum. A third life test is performed with high radial load (784N, 1586N) in vacuum. It is shown that in the early stages of testing, the bearing is mainly lubricated by the molybdenum disulfide films, after one million revolutions, the bearing is mainly lubricated by the transferred films of the retainer material. ESA

N90-24479# Ecole Centrale de Lyon (France). Lab. de Technologie des Surfaces.
WEAR OF GOLD-PLATED CONTACTS: MICROSCOPIC ASPECTS, ROLE OF OXYGEN
M. BELIN, T. LEMOGNE, and J. M. MARTIN *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 117-121 Mar. 1990 Sponsored in part by Centre National d'Etudes et Telecommunications
Copyright Avail: NTIS HC A14/MF A02

The wear mechanisms of gold plated contacts during mating and unmating are discussed. Modifications of the mechanical and electrical properties due to the wear are described. The effects are simulated on two tribometers operating in different conditions. The physical properties of contact during friction are investigated in relation with analytical data obtained on wear debris and wear scars. The influence of the gas atmosphere is investigated. Tests are performed with different partial pressures of oxygen to determine the precise role of oxygen in the degradation process. ESA

N90-24487# Teldix Luftfahrt-Ausruestungs G.m.b.H., Heidelberg (Germany, F.R.).
THE LARGE WHEEL ACTUATOR LDR 100-0: DEVELOPMENT STATUS AND TEST RESULTS
H. HEIMEL *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 169-174 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

A large wheel intended to provide an inertial actuator for attitude control and navigation of large space platforms is described. With an angular momentum capacity of 1000 Nms, it is particularly aimed at the needs of the resource module of the Columbus Free Flying Laboratory. Details of the manufacturing and testing stages of this engineering model are presented. Tests results and performance data are listed. Further developmental steps needed to produce large wheel actuator flight models in the future are discussed. ESA

N90-24495# European Space Tribology Lab., Risley (England). AEA Technology.
THE PERFORMANCE OF PTFE, LEAD, AND MOS2 AS LUBRICANT FILMS FOR BALL BEARINGS OPERATING IN VACUUM AT 20 K
S. G. GOULD and E. W. ROBERTS *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 223-228 Mar. 1990 Sponsored by ESTEC
Copyright Avail: NTIS HC A14/MF A02

The performance of dry-lubricated angular contact ball bearings in a vacuum at 20K is investigated and compared with in-vacuo performance at room temperature. Comparative tests are performed using three dry lubricants, MoS2, lead, and polytetrafluoroethylene (PTFE). The torque performance of the MoS2 and lead lubricants at cryogenic temperature is undistinguishable from that at room temperature. With PTFE lubrication, both the torque and torque noise increase substantially on cooldown. The torque performance of combined MoS2 and PTFE lubrication also deteriorates on cooldown. ESA

N90-24500# Centre National d'Etudes Spatiales, Toulouse (France).
SPOT 4 MAGNETIC TAPE RECORDER MECHANISMS
A. BORRIEN, E. VIALATOUX, J. L. LHERMET, and A. DIDIER (Schlumberger Industries, Velizy, France) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 257-265 Mar. 1990 In FRENCH; ENGLISH summary
Copyright Avail: NTIS HC A14/MF A02

A magnetic tape recorder mechanism developed for the French national Earth observation program is described. The system requirements of the mechanism and the main technical characteristics of the machine are presented. The different recorder subsystems and their technical functions are described. The components of the tape plate system subject to high mechanical effort, fatigue and overload in the thermal environment encountered during the mission are identified. The experimental program elaborated for the evaluation and qualification of these components is described. ESA

N90-24501# Centre Suisse de Documentation dans le Domaine de la Microtechnique, Neuchatel.
THICK AND COMPACT MOS2 COATINGS
C. MUELLER, C. MENOUD, M. MAILLAT, and H. E. HINTERMANN *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 267-271 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

DC magnetron sputtering of MoS2 on materials such as AISI 440C steel, Ti-Al-alloys, ceramics and fiberglass is described. The coating properties depend on the orientation of the substrates with respect to the target in the coating chamber. Long wear-life is obtained in tribological tests even with machined, unpolished substrate surfaces. Savings made possible by this fact in parts manufacturing costs are described. The long-wearing characteristics of MoS2 coatings allow for extensive ground testing without increasing the risk of failure during erection in orbit. ESA

N90-24502# Marconi Space Systems Ltd., Portsmouth (England).
HEMISPHERICAL POINTING MECHANISM
KARL GALLAGHER *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 273-279 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The design, development, assembly and testing of a Hemispherical Pointing Mechanism (HPM) are described. The equipment is designed for pointing the Inter Orbital Communications (IOC) antenna on the European Recoverable Carrier (EURECA) spacecraft. The EURECA mission is to include microgravity experiments. The HPM design includes features to reduce microgravity disturbance to the host spacecraft caused by operation

of the HPM. The specifications of the mechanism and the results of vibration, environmental, wear and thermal vacuum tests carried out on the mechanism are described. ESA

N90-24503# Sener S.A., Las Arenas (Spain).
COLUMBUS SCIENTIFIC AIRLOCK
C. COMPOSTIZO and C. ARIZA *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 281-288 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The scientific airlock subsystem developed for the Columbus Attached Pressurized Module (APM) is described. The airlock design is an evolution of the airlock developed by Fokker within the Spacelab program. The Columbus in-orbit long life requirement calls for in orbit maintainability of the airlock. The parts of the airlock which have been completely redesigned are identified. The major modifications have been to the activation of the airlock mechanisms and its electrical control. The maintenance philosophy including in-orbit maintenance is presented. ESA

N90-24505# Centre Suisse de Documentation dans le Domaine de la Microtechnique, Neuchatel.
TRIBOLOGY OF MOS2: EFFECT OF FILM THICKNESS
M. MAILLAT, L. CHOLLET, H. E. HINTERMANN, D. COSTA, and F. LEVY (Ecole Polytechnique Federale de Lausanne, Switzerland) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 295-298 Mar. 1990 Sponsored by Fondation Suisse pour la Recherche en Microtechnique
Copyright Avail: NTIS HC A14/MF A02

MoS2 coatings obtained by sputtering are tested on a pin-on-disc friction machine. The thicknesses of the coatings range from 0.032 to 2.3 micrometers. The coatings show a structure and performance dependant on the substrate temperature during deposition. Under particular deposition and test conditions, their sliding life increases proportionally with their thickness. Coatings deposited on heated substrates show lower tribological performances than coatings deposited on cooled substrates. ESA

N90-25325*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A NONCONTACTING MOTION MONITORING SYSTEM FOR AN ASTRONAUT TRANSLATION AID
TOM D. FINLEY Apr. 1990 13 p
(NASA-TM-102640; NAS 1.15:102640) Avail: NTIS HC A03/MF A01 CSCL 14/2

The development of a noncontacting motion sensing system designed to monitor the movement of a cart along a track in the low earth orbit space environment is described. The system uses Hall effect sensors to detect the position of small permanent magnets located along the track. The measurement criteria are described, the system design is discussed, and estimates of the system error are given. The system will be used on the Crew and Equipment Translation Aid (CETA) experiment scheduled for the STS37 flight in November 1990. It will allow the position, velocity, and acceleration of the cart to be determined as it moves along the track. Author

N90-27756# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.). Transport and Orbital Systems Div.
THE INSTRUMENT POINTING SYSTEM: PRECISION ATTITUDE CONTROL IN SPACE
RALF HARTMANN and ALBRECHT WOELKER *In* AGARD, Space Vehicle Flight Mechanics 11 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Spacelab Instrument Pointing System (IPS) is a three axes gimbal system providing pointing and stabilization in the arcsec range to a variety of space experiments with a mass of up to 7000 kg. The IPS demonstrated its control performance during the maiden flight in July 1985, the Spacelab 2 mission on board the Space Shuttle Challenger. The most challenging problem for attitude control in space is the disturbance compensation in the presence of structural flexibilities. Kalman filtering based on optical sensor and gyro measurements as well as flexible mode attenuation and feedforward control were indispensable to achieve high precision. To further enhance the IPS pointing performance and versatility, a new, more autonomous computer and sensor concept has been conceived providing the capacity for a higher degree of automation as well as improved pointing and closed loop tracking control. The autonomy and control capacity of the enhanced IPS establish the basis to accommodate the IPS as long-term available tracking and pointing platform on the International Space Station Freedom (ISF). Author

N90-28063*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LIQUID LUBRICATION IN SPACE
ERWIN V. ZARETSKY Jul. 1990 26 p
(NASA-RP-1240; E-5094; NAS 1.61:1240) Avail: NTIS HC A03/MF A01 CSCL 13/9

The requirement for long-term, reliable operation of aerospace mechanisms has, with a few exceptions, pushed the state of the art in tribology. Space mission life requirements in the early 1960s were generally 6 months to a year. The proposed U.S. space station schedule to be launched in the 1990s must be continuously usable for 10 to 20 years. Liquid lubrication systems are generally used for mission life requirements longer than a year. Although most spacecraft or satellites have reached their required lifetimes without a lubrication-related failure, the application of liquid lubricants in the space environment presents unique challenges. The state of the art of liquid lubrication in space as well as the problems and their solutions are reviewed. Author

N90-29651# National Aerospace Lab., Tokyo (Japan).
LUBRICATION CHARACTERISTICS OF ROLLING BEARINGS LUBRICATED BY SELF-LUBRICATING COMPOSITE RETAINERS. PART 1: SELECTION OF BEARINGS FOR EARTH SENSORS
KATSUMI SEKI, YUKIO MIYAKAWA, and MAKOTO NISHIMURA Apr. 1989 13 p In JAPANESE; ENGLISH summary
(NAL-TR-1019; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

More than 90 percent of rolling bearings for space use are lubricated by solid lubricant films transferred from retainers to balls and races; successful operation of space driving mechanisms depends on the selection of retainer materials made of self-lubricating composites together with the selection of solid lubricant films deposited in advance on the surfaces of balls and races for the initial state of operation. The process and the results of the selection tests carried out for ball bearings used in the Earth sensors which were operated from February 1981 to April 1982 on the Engineering Test Satellite 4 are described. Among 8 candidate materials tested in the form of a retainer, the combination of sputtered MoS2 films and retainers composed of PTFE, glass fiber and molybdenum showed by far the best tribological response. When applied to angular-contact type ball bearings (7204), this combination lubricated them for more than 10,000 hours at 2,000 rpm under a thrust load of 50 N in 10(exp 6) Pa. The bearings actually used in flight were lubricated by PTFE coatings and retainers made from PTFE, glass fiber, and lead oxide for fear that an MoS2 film would be worn off during tests conducted on Earth before the launch. Test results indicated this particular combination is more effective in air than in vacuo. The addition of MoS2 to the composites did not improve their lubricating ability, suggesting that PTFE performs the main role in transfer film lubrication. Author

11

THERMAL ENVIRONMENTS & CONTROL

Descriptions of analysis for passive or active thermal control techniques. External and internal thermal experiments and analyses. Trade studies of thermal requirements.

A90-32373#
THERMALLY INDUCED BENDING VIBRATION OF THIN-WALLED BOOM WITH CLOSED SECTION CAUSED BY RADIANT HEATING
MASAHIKO MUROZONO and SEINOSUKE SUMI (Kyushu University, Fukuoka, Japan) Kyushu University, Faculty of Engineering, Memoirs (ISSN 0023-6160), vol. 49, Dec. 1989, p. 273-290. refs

The present paper describes a theoretical analysis of the thermally induced bending vibration of the thin-walled boom with tip mass subjected to solar radiant heating. The governing equation and the time-dependent boundary conditions are formulated assuming that the boom is heated by the unidirectional solar radiation and that net heat input depends on the angle of incidence of heat radiation with respect to the boom axis. The methods of solution consist of applying the Laplace transform with respect to time to the equation and to the boundary conditions, and of obtaining the response by a numerical inversion of the transformed solution. Stability of the system is studied using the root locus, and the boundary curves, which divide the parameter plane into regions of stability and instability according to the direction of radiation and four system parameters, are also studied. Author

A90-37855
ADVANCED HEAT PIPE TECHNOLOGY FOR SPACE HEAT TRANSPORT AND REJECTION TECHNOLOGIES
G. Y. EASTMAN, D. M. ERNST, R. M. SHAUBACH, and J. E. TOTH (Thermacore, Inc., Lancaster, PA) Space Power - Resources, Manufacturing and Development (ISSN 0883-6272), vol. 9, no. 1, 1990, p. 15-26. refs
Copyright

Consideration is given to the use of heat pipes in heat transfer subsystems, focusing on recent developments in heat pipe technology and the possible applications of these developments. Aspects of recently developed heat pipes are examined, including high evaporative power density capability, the accomadation of two-phase flow in wick structures, and high heat flux capability. The application of heat pipes to obtain high axial heat transport rates is described. Also, a pumper two-phase heat exchanger, the start-up of liquid metal heat pipes, and new materials for heat pipe applications are discussed. R.B.

A90-38040
GROUND TEST UNIT SYSTEM ANALYSIS - SPACE STATION FREEDOM ACTIVE THERMAL CONTROL SYSTEM
A. FOX (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 63-67.
Copyright

The Space Station Freedom baseline active thermal control system (ATCS), a two-phase, pumped ammonia fluid loop, is discussed. It provides a 35 F and a 70 F heat sink (thermal bus) to collect the waste heat generated in the station modules and external electrical equipment and transport it to radiators for rejection to space. The 25-kW ground test unit collects heat through two cold plates, one cold rail and two heat exchangers, and rejects heat through two condensers and one subcooler to heat pipe radiator panels during thermal vacuum testing and to a separate refrigeration system during ambient testing. Pretest analyses of the unit reveal that up to 33 percent of the total pump flow must be diverted through the condensers and subcooler at low loads to provide sufficient subcooling under all operating conditions and that the expected subcooling loads are 0.9 to 1.7 kW. I.E.

A90-38269* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
COMPATIBILITY OF LARGE SPACE BASED POWER SYSTEMS WITH ENVIRONMENTAL SENSORS
G. MURPHY and H. GARRETT (JPL, Pasadena, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2631-2640. refs
Copyright

A methodology is presented for reviewing various interactions between power systems and the environment that affect the longevity, calibration, maintenance, and accuracy of sensors. The analysis uses the low-earth-orbit environment and interactions with the space station power system as a case study in system compatibility. Space-based power systems and sensor systems are described, compatibility modeling is discussed, and the analysis of the space station case is presented. Steps to be taken during design to promote compatibility are outlined. I.E.

A90-38301*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INITIAL CHARACTERIZATION OF A MODULAR HEAT EXCHANGER WITH AN INTEGRAL HEAT PIPE
JEFFREY G. SCHREIBER (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2891-2895. Previously announced in STAR as N89-25078. refs

As part of the Civil Space Technology Initiative (CSTI) Advanced Technology program, a conceptual design of the Stirling space engibe (SSE) was generated to develop the technology base needed to meet the long duration, high capacity power requirements for future NASA space missions. The free-piston Stirling engine (FPSE) was chosen as the growth option in the CSTI program. An existing FPSE was modified as a test bed for a modular heat exchanger evaluation. Evaluation of the individual heat pipes before installation in the engine is described. Author

A90-38304
THE COUPLING BETWEEN ELECTRICAL AND THERMAL SYSTEMS WITHIN THE SPACE STATION FREEDOM
HAIK BIGLARI, JIM JOHNSON (Boeing Aerospace and Electronics, Huntsville, AL), and CHARLES HALIJAK (Alabama, University, Huntsville) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2915-2920. refs
Copyright

The dynamic coupling which exists between the electrical power system and the thermal system of Space Station Freedom is discussed. Analytical models are derived based on the principle of conservation of energy and the controller action, which tries to maintain a particular temperature set point. An application generator is used for real-time simulation and modeling of the combined system. The model presented here provides a unified approach for global implementation of built-in test as well as local real-time fault detection and isolation for on-orbit operation. I.E.

A90-38376#
CONCEPTUAL THERMAL DESIGN FOR A SPACECRAFT EMPLOYING A HIGH-POWER MULTIBEAM PHASED ARRAY
W. H. KELLY and J. H. REISENWEBER (COMSAT Laboratories, Clarksburg, MD) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 9 p. Research sponsored by the Communications Satellite Corp. (AIAA PAPER 90-1670) Copyright

The thermal design of a high-power multibeam phased-array module, and its inclusion on a three-axis-stabilized spacecraft as the communications payload, are discussed. A conceptual spacecraft thermal design has been developed which employs fixed conductance heat pipes, a capillary pumped loop, and embedded heat pipe radiators. The problems associated with removing heat from a highly concentrated source and rejecting it to space via a remote radiator are described. The importance of minimizing the solid-state amplifier internal thermal resistane in terms of the overall thermal control system weight is established. Thermal test verification issues and concerns associated with capillary pumped loops and heat pipes in a gravity environment are identified and discussed. Author

A90-38377#
SPACENET I, II 5 YEARS IN ORBIT - REVIEW OF THE THERMAL TRENDS OBSERVABLE IN A PASSIVE THERMAL DESIGN OF 2 COMMUNICATION SATELLITES
C. R. NAEGELI (GTE Spacenet, McLean, VA) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 16 p. refs
(AIAA PAPER 90-1671) Copyright

Spacenet I and II have been in orbit for nearly six years. During this time, their thermal performance has been evaluated. Particular attention was paid to the long-term trend of satellite component temperatures. This paper presents the results of the correlation study of in-flight telemetry and thermal model predictions to describe the seasonal trends. Long term trends are explained using the classical approach to time series analysis by employing a moving average model. OSR solar absorptance degradation curves are described which fit the data base through 1989 with very high correlation coefficients and small standard errors. Author

A90-38378*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THERMAL ANALYSIS OF A STRONGBACK STRUCTURE FOR A HIGH-FREQUENCY MICROWAVE ANTENNA CONCEPT IN GEOSYNCHRONOUS ORBIT
JEFFERY T. FARMER, DEBORAH M. WAHLS, ROBERT L. WRIGHT (NASA, Langley Research Center, Hampton, CA), and A. LOUIS TAHERNIA (George Washington University, Hampton, VA) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 12 p. refs
(AIAA PAPER 90-1673) Copyright

The effects of the geosynchronous thermal environment on the performance of a tetrahedral truss strongback structure for a high-frequency microwave antenna concept for earth science monitoring have been studied. Two orbit conditions (an equinox orbit with a 72-minute eclipse and a solstice orbit with no eclipse) and a range of thermal control approaches were investigated under steady state and transient conditions. The thermal control approaches included aluminum surface coatings with high and low solar-absorptivity-to-infrared-emissivity ratios, multi-layer insulation, a sun shield, and various truss element materials. The effects of both earth shadowing and shadowing by the antenna reflector on temperatures were also examined. Temperatures and corresponding structural distortion results are presented. Author

A90-38387*# Creare, Inc., Hanover, NH.
HIGH HEAT FLUX SINGLE PHASE HEAT EXCHANGER
JAVIER A. VALENZUELA and MICHAEL G. IZENSON (Creare, Inc., Hanover, NH) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 10 p. refs
(Contract NAS9-18167)
(AIAA PAPER 90-1684) Copyright

This paper presents the results obtained to date in a program to develop a high heat flux, single-phase heat exchanger for spacecraft thermal management. The intended application is a net generation interface heat exchanger to couple the crew module water thermal bus to the two-phase ammonia main thermal bus in the Space Station Freedom. The large size of the interface heat exchanger is dictated by the relatively poor water-side heat transfer characteristics. The objective of this program is to develop a single-phase heat transfer approach which can achieve heat fluxes and heat transfer coefficients comparable to those of the evaporation ammonia side. A new heat exchanger concept has been developed to meet these objecties. The main feature of this heat exchanger is that it can achieve very high heat fluxes with a pressure drop one to two orders of magnitude lower than those of previous microchannel or jet impingement high heat flux heat exchangers. This paper describes proof-of-concept experiments performed in air and water and presents analytical model of the heat exchanger. Author

A90-38390#
A LIGHTWEIGHT GAS COOLER FOR SPACE POWER APPLICATION
ALAN V. VON ARX, KENNETH J. WESTON, and MYROSLAW MARKO (Rockwell International Corp., Canoga Park, CA) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 6 p.
(AIAA PAPER 90-1687) Copyright

This paper discusses the methodology used in selecting the design features and accompanying analysis for a lightweight and reliable gas cooler to be used in space power applications. Its key attributes are fully inspectable welds for high reliability and offset fins and parallel flow paths combined with a cylindrical shape for minimum pressure drop and weight. The purpose of the gas cooler is to transfer waste heat from the working fluid in a Brayton cycle to a liquid loop which ultimately rejects the heat to space. A number of parameters including the offset fin dimensions, number of parallel paths, and fluid velocities were adjusted to optimize the heat exchanger design. It was concluded that a gas cooler having a mass of 14 kg can be designed which meets the duty requirement with acceptable pressure losses. Author

A90-38437*#
SUMMARY OF RESULTS FROM THE TESTING OF THREE PROTOTYPE THERMAL BUS SYSTEMS FOR SPACE STATION FREEDOM
T. K. BRADY (NASA, Johnson Space Center, Houston, TX) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 11 p. refs
(AIAA PAPER 90-1740) Copyright

Three Space Station Freedom (SSF) prototype two-phase thermal bus systems, utilizing ammonia as the working fluid, underwent extensive evaluation during 1988 and 1989. All three test articles were exercised in a similar ambient test program to characterize performance under simulated SSF operating conditions. Additionally, thermal buses were integrated with heat pipe radiators and tested in a thermal vacuum (T/V) environment. Testing has shown that two-phase thermal bus performance can be generally bound in an ambient test program; however, integrated T/V testing with heat pipe radiators similar to those that will be used on SSF is required to fully characterize system performance. Author

A90-38458#
PERFORMANCE EVALUATION OF THE GRUMMAN PROTOTYPE SPACE ERECTABLE RADIATOR SYSTEM
RICHARD F. BROWN, ERIC GUSTAFSON, FRANCINE GISONDO, and MARK HUTCHISON (Grumman Corp., Space Systems Div., Bethpage, NY) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 10 p. refs
(AIAA PAPER 90-1766) Copyright

The Grumman Space Erectable System Ground Test Article, consisting of a set of 48 x 1 ft monogroove heat pipe radiators, was thermal/vacuum tested. Five radiator panels were integrated with a two-phase thermal bus, and one radiator panel was tested in a standalone mode with electrical heat input. Overall, the tests were successful, with the radiators demonstrating the ability to operate in 1-g over the entire range of steady-state and transient conditions that are required for operation on the Space Station. Author

A90-45299
COMPROMISE - A MULTIOBJECTIVE HIERARCHICAL APPROACH TO THE DESIGN OF SPACECRAFT THERMAL CONTROL SYSTEMS
C. L. STRUBLE, E. BASCARAN, R. B. BANNEROT, and F. MISTREE (Houston, University, TX) IN: Computers in engineering 1989; Proceedings of the ASME International Computers in Engineering Conference and Exposition, Anaheim, CA, July 30-Aug. 3, 1989. Volume 2. New York, American Society of Mechanical Engineers, 1989, p. 423-428. Research supported by the BF Goodrich Co. refs
Copyright

The Thermal Optimization and Selection System, which allows a designer to specify the relative importance of multiple design criteria for optimizing working fluid and thermal cycles in spacecraft thermal control systems, is described. The system can analyze both vapor compression and pumped two-phase thermal cycles and multiple working fluids. Selection and design are perfomed concurrently by formulating the problem as a coupled decision support problem, allowing both quantitative and qualitative technical information to be modeled. A case study of the approach is reported. C.D.

A90-45479
CAPILLARY PUMPED LOOPS FOR AEROSPACE APPLICATION
JOSEPH M. GOTTSCHLICH (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Sept. 25-28, 1989. 8 p. Research sponsored by USAF. refs
(SAE PAPER 892318) Copyright

The Capillary Pumped Loop (CPL) is a two-phase aerospace thermal transport system with many advantageous performance characteristics. While retaining the passive nature of the heat pipe, it has demonstrated an order of magnitude greater thermal transport capacity over high performance arterial heat pipes. In this survey paper, the CPL is described and its brief history discussed. A postulated analytical design model based on thermodynamic principles is presented. Both demonstrated and potential performance advantages are given. Finally, opportunities for future research are suggested. Author

A90-47683*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A MODEL-BASED APPROACH TO THE SYMBOLIC CONTROL OF SPACE SUBSYSTEMS
B. J. GLASS (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1042-1049. refs
(AIAA PAPER 90-3430) Copyright

A multilayered approach to the symbolic control of complex electromechanical assemblies, such as spaceborne thermal, power, and life subsystems, is discussed. An example of this approach is given in some recent tests of the Thermal Expert System (TEXSYS) in control of the Boeing Aerospace Thermal Bus System (BATBS), a prototype two-phase Space Station Freedom thermal bus. The BATBS hardware requires read-update-act cycles of under a minute, and it is subject to dynamic reconfiguration while operating. These performance requirements are addressed by layering model-based expert system software on a conventional numerical data acquisition and control system. TEXSYS test results demonstrate both nominal control and fault recovery actions with the BATBS. Dynamic modification of the symbolic model used in this approach is compared to that of a classical numerical adaptive controller. Author

A90-47740#
EFFECT OF THERMAL RADIATION TORQUES ON THE TDRS SPACECRAFT
CHRISTIAN M. HARRIS and GEORGE A. KYROUDIS (TRW, Inc., Space and Technology Group, Redondo Beach, CA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1602-1614. refs
(AIAA PAPER 90-3492) Copyright

This paper discusses a source of disturbance torque which is rarely considered during the design phase of a spacecraft attitude control system. The disturbance torque is manifested by asymmetric thermal radiation from the spacecraft exterior surfaces. Recent in-flights experience with the TDRS-F3 and TDRS-F4 spacecraft demonstrates that thermal radiation torques can be the dominant disturbance source. The basic thermal radiation torque equations are derived and applied to the TDRS-F3 spacecraft configuration. The analytical results closely agree with the observed momentum accumulation flight data. Finally, it is shown how thermal radiation torques impact the design of a solar sail for the TDRS Replacement Spacecraft (TDRS-F7). Author

A90-49311
THERMAL DESIGN OF THE TOPEX/POSEIDON INSTRUMENT MODULE
P. E. CLEVELAND and C. E. BRAUN (Fairchild Space Co., Germantown, MD) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901241) Copyright

The primary mission objective of the TOPEX/POSEIDON spacecraft is to realize precise measurements of the topography of the ocean surface by radar altimetry from a precision, circular orbit. Overall spacecraft configuration, the instrument module (IM) requirements and design drivers, the mission environments, the IM design parameters and approach, the IM thermal design, and the analytical temperature predictions versus requirements are described. IM thermal design requirements include a high radiation environment at 64.45 degrees inclination, an orbit of 1335 km, a periodic sinusoidal yawing about the nadir axis, an outer surface continuity requirement, the splitting of the IM structure in half to accommodate integration of the primary instrument at a separate facility, instrument proximity requirements, and strict rate-of-change and temperature gradient requirements. R.E.P.

A90-49338
EUROPEAN TWO-PHASE HEAT TRANSPORT TECHNOLOGY TEST BED RESULTS
N. DUNBAR (British Aerospace /Space Systems/, Ltd., Stevenage, England), R. SIEPMANN (Dornier GmbH, Friedrichshafen, Federal Republic of Germany), and W. SUPPER (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 13 p.
(SAE PAPER 901271) Copyright

The ESA has coordinated the development of critical components for a pumped two-phase heat transport system under the Columbus preparatory support technology program. These components are an evaporator cold plate, the evaporative heat exchanger that is an interface part to an external loop, heat rejection interfaces/condensers, an active accumulator/control reservoir, and vapor quality sensors. The components are incorporated into a flexible and instrumented test bed designed to evaluate the performance of a complete representative loop with heat loads up to 15 kW and primary loop lengths up to 40 meters. Test evaluation results demonstrate two-phase operation over a heat load range of 0.5 kW to over 10 kW and operation at flow rates between 17 and 450 liters per hour. R.E.P.

A90-49339
TEST LOOPS FOR TWO-PHASE THERMAL MANAGEMENT SYSTEM COMPONENTS
A. A. M. DELIL and J. F. HEEMSKERK (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p. refs
(SAE PAPER 901272) Copyright

Two mechanically pumped two-phased test rigs were built in order to experimentally study critical issues of spacecraft two-phase

thermal management system. The systems are: (1) a 5 kW, 31 mm ID, freon loop, focusing on the critical components of the ESA Two-Phase Heat Transport Systems; and (2) a 300 W, 4.93 mm ID, ammonia loop, to support the development of the ESA Capillary Pumped Loop Experiment (for the in-orbit demonstration of two-phase heat transport system technology) and to experimentally support two-phase thermal modeling and scaling activities. The rigs are described in detail. Typical test results are presented. Author

A90-49340
DEVELOPMENT OF PUMPS FOR TWO-PHASE FLUID LOOPS
N. MOROZUMI, H. SAKATA, M. KOMORI, S. OSHIMA, K. MIMURA (Toshiba Corp., Kawasaki, Japan) et al. SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p. refs
(SAE PAPER 901273) Copyright

Two-phase fluid loops (TPFL) are a thermal management system for future space platforms. A scroll pump has been designed and fabricated for a 5kW heat rejection TPFL in order to achieve a continuous and quiet operation of the system, which is required for space use. This scroll pump has four scroll vanes, two fixed and two orbiting ones, to reduce pulsation of flow. This paper reports the performance test results of a breadboard model (BBM). Author

A90-49343
IMPACTS OF RACK CONFIGURATION ON COLUMBUS AVIONICS AIR LOOP ARCHITECTURE AND CONTROL
FRANCESCO ACCARDI, CESARE LOBASCIO, RENATO D'AURIA, and RUGGERO VENERI (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901283) Copyright

Air cooling of the avionics units (Subsystem equipment and Payloads) of the Columbus Pressurized Modules (PM) is performed via avionics loops, providing heat collection from dedicated racks and rejecting the collected heat load by means of an avionics heat exchanger (AHX). An overview of possible rack architectures, air loop accommodations and control solutions which are candidates for the Columbus PMs is presented. In particular, the architectures of the European single and double rack and of the U.S. double rack in Space Station Freedom (SSF), have been compared and the relevant options of accommodation in the avionics loops and functional interfaces have been investigated. Some discrepancies, such as the different application of the air cooling standard, have been identified that make the interchangeability of racks on the SSF PMs difficult. Possible solutions to the problem and impacts on the design have been presented. Author

A90-49344
CONDENSING HEAT EXCHANGERS AS MAIN COMPONENTS IN LSS FOR MANNED SPACEFLIGHT
FRIEDRICH PETTER and CHRISTINE PLANERT (Nord-Micro Elektronik Feinmechanik AG, Frankfurt am Main, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 9 p.
(SAE PAPER 901284) Copyright

Condensing heat exchangers are used for the thermal and humidity control within spaceflight LSS. Heat loads are transferred to a coolant loop, and humidity is removed by condensation and separation from the air flow. For minimum mass and volume at a maximum of effectiveness, adaptable plate-fin configurations are superior. Efficient separation of the condensate under zero-g conditions is achieved by enhancement of wettability of condenser surfaces with a hydrophilic coating, and the drain-off through a so-called slurper section. Exemplary, the Hermes ECLSS condensing heat exchanger and the EVA sublimator unit are presented. The advanced design comprises a new type of hydrophilic coating and several construction details, resulting in a significant mass reduction. Author

A90-49361
STRUCTURAL/PARAMETRIC IDENTIFICATION OF THERMAL CONTROL COATING DEGRADATION PROCESS BASED ON RESEARCH OF THEIR OPTICAL PROPERTIES IN SPACECRAFT ENVIRONMENTAL CONDITIONS - METHOD AND RESULTS
OLGA B. ZHUKOVA-KHOVANSKAIA, IU. V. TRIFONOV, and VLADIMIR L. BARANTSEVICH (Vsesoiuznyi Nauchno-Issledovatel'skii Institut Elektromekhaniki, Moscow, USSR) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p. refs
(SAE PAPER 901309) Copyright

Research methods for an experimental and analytical thermal control coatings (TCC) degradation process based on flight test data are discussed. A diagnostic experiment is set up using spacecraft onboard systems to identify radiation parameter values based on indirect information on transient temperature changes of the TCC test specimens and to perform a long-term prediction of the TCC's integrated absorptance variations. An alternative approach for strategy implementation which aims at increased accuracy and information capacity is also proposed. Computation techniques and algorithms based on multidimensional random search and iterative regularization methods are presented, and research results and data on the applicability of various types of TCC are given. L.K.S.

A90-49398
EURECA THERMAL CONTROL DESIGN AND PERFORMANCE
GAETANO POIDOMANI, RENATO MARTINO, and JOHN M. KELLEY (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p.
(SAE PAPER 901366) Copyright

Eureca, the European Retrievable Carrier, is a multipurpose carrier with a dedicated payload for different experiments including microgravity, astronomy, earth observation, solar physics, and technology mission applications, scheduled to be launched and retrieved by the NASA STS in 1991. The satellite is a sun-pointing three-axis-stabilized modular spacecraft weighing up to 4000 kg, with a payload of 1000 kg in low orbit (inclination of 28.5) for 6 months. The satellite construction, configuration, and spacecraft services requirements and constraints are described. Special attention is given to the Eureca thermal control design, which is subdivided into an active thermal control and a passive thermal control. L.K.S.

A90-49399
THERMAL DESIGN AND ANALYSIS OF COLUMBUS PRESSURIZED MODULES
SILVIO DOLCE, FRANCESCA CIAMPOLINI, and CHARLES DODD (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p.
(SAE PAPER 901369) Copyright

The design solutions presented in the thermal control subsystem proposal are discussed, including modifications deriving from updated ESA requirements and preliminary feedback from negotiations. Attached Pressurized Module (APM) thermal hydraulic requirements, APM active thermal control architecture, and APM water loop control processes are described. Analyses of the pressurized module of the Man-Tended Free Flier (PM-MTFF) hydraulic requirements, PM-MTFF active thermal control architecture, PM-MTFF water and freon loop control processes, APM and PM-MTFF thermal control analysis, and component designs are also presented. L.K.S.

A90-49400
INTEGRATED AIR/WATER COOLING CONCEPTS FOR SPACE LABORATORY MODULES
G. SARRI, H. P. LEISEIFER, and B. PATTI (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p. refs
(SAE PAPER 901370) Copyright

The Columbus Pressurized Module's air loop architecture is discussed vis a vis possible alternative solutions, taking the reconfiguration of air cooling loops and the water loop interfaces into account. It is noted that the thermal and environmental control of such permanently operating space laboratories in conjunction with the International Space Station Freedom would include enhanced crew size, power dissipation due to a broad range of experiments, flexibility with respect to payload reconfiguration, and rack interchangeability. These requirements and related conceptual design solutions are analyzed in the light of overall system aspects. L.K.S.

A90-49402
PRELIMINARY SPACECRAFT THERMAL DESIGN ON A MS-DOS MICROCOMPUTER
E. J. M. COLBERT (Johns Hopkins University, Laurel, MD) and N. M. TETI (Swales and Associates, Inc., Beltsville, MD) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 7 p.
(SAE PAPER 901373) Copyright

Existing mainframe thermal software is reviewed, with emphasis on the Simplified Space Payload Thermal Analyzer (SSPTA) application consisting of six subprograms running on DEC VAX/VMS systems. These functions are being shifted to MS-DOS 80386 microcomputers, while lengthy simulations are done on DEC VAXstations. An MS-DOS thermal software for the Midcourse Space Experiment spacecraft is presented. The current VAX version of SSPTA is running in the 80386 mode under MS-DOS with many enhancements. The bin system for data storage is replaced by a file system which increases the processing speed of the SSPTA subprograms. An ORBPLOT routine developed to provide a graphical display of the spacecraft orbit with respect to the earth and sun is outlined. It is noted that minicomputers such as VAX/VMS systems are still needed to complete detailed analyses. V.T.

A90-49403
VERIFICATION/VALIDATION OF ESATAN FLUID CAPABILITY AGAINST RETRAN
J. BIRCHLEY, G. WARD (U.K. Atomic Energy Authority, Winfrith, England), C. KIRTLEY (GEC Alsthom, Engineering Research Centre, Whetstone, England), and A. LEBRU (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 17 p. refs
(SAE PAPER 901374) Copyright

The Fluid Heat Transport Systems (FHTS) extension to the ESATAN thermal analyzer was released to industry in 1989. A significant effort has been directed towards obtaining, as far as possible, an error free code which gives results in reasonable agreement with reference data. The first steps to ensure confidence in FHTS have been taken by system testing during software acceptance and by means of a comparison with RETRAN, a US code unique in possessing a US safety evaluation report for reactor licensing applications. RETRAN output data was taken as the a priori reference data to verify FHTS. Two sets of test cases have been defined, one concerning single-phase problems (basically the Columbus water loop), the second set containing models with two-phase conditions (a simple idealized loop and boundary conditions). The paper highlights the difficulties encountered during the comparison work, presents the major results and discusses the main issues involved in FHTS verification/validation. Author

A90-52014
A FINITE ELEMENT SPECTRAL METHOD WITH APPLICATION TO THE THERMOELASTIC ANALYSIS OF SPACE STRUCTURES
OMRI RAND and DAN GIVOLI (Technion - Israel Institute of Technology, Haifa) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 30, Aug. 5, 1990, p. 291-306. Research supported by the Technion's V.P.R. Fund and Chicago Endowment Fund. refs
Copyright

A combined spectral finite element method is devised for use in finding the thermal and thermoelastic dynamic response of truss structures to time-periodic loading. The thermal problem is strongly nonlinear due to the presence of heat radiation. The problems considered are typical in the analysis of space structures. In the method proposed, the spatial domain is first discretized using a consistent finite-element formulation. Then the resulting semidiscrete equations in time are solved analytically by using a spectral method that is symbolically coded. Some numerical examples are presented which demonstrate the performance of the method and its ability to identify some key characteristics in space structure problems. Author

N90-21294*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THERMAL CONTROL SYSTEM CORROSION STUDY
ROBERT YEE, ROLFE A. FOLSOM, and PHILLIP E. MUCHA Feb. 1990 55 p
(NASA-TM-102220; A-89226; NAS 1.15:102220) Avail: NTIS HC A04/MF A01 CSCL 20/4

During the development of an expert system for autonomous control of the Space Station Thermal Control System (TCS), the thermal performance of the Brassboard TCS began to gradually degrade. This degradation was due to filter clogging by metallic residue. A study was initiated to determine the source of the residue and the basic cause of the corrosion. The investigation focused on the TCS design, materials compatibility, Ames operating and maintenance procedures, and chemical analysis of the residue and of the anhydrous ammonia used as the principal refrigerant. It was concluded that the corrosion mechanisms involved two processes: the reaction of water alone with large, untreated aluminum parts in a high pH environment and the presence of chlorides and chloride salts. These salts will attack the aluminum oxide layer and may enable galvanic corrosion between the aluminum and the more noble stainless steel and other metallic elements present. Recommendations are made for modifications to the system design, the materials used, and the operating and maintenance procedures, which should largely prevent the recurrence of these corrosion mechanisms. Author

N90-21790*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
DEVELOPMENT AND INTEGRATION OF THE CAPILLARY PUMPED LOOP GAS AND HITCHHIKER FLIGHT EXPERIMENTS
D. BUTLER and R. MCINTOSH Apr. 1990 17 p.
(NASA-TM-100756; REPT-90B00081; NAS 1.15:100756) Avail: NTIS HC A03/MF A01 CSCL 22/2

The Capillary Pumped Loop (CPL) is a thermal control system with high density heat acquisition and transport capability. A small spaceflight version of the CPL was built and flown as a GAS experiment on STS 51-D in April 1985 and STS 51-G in June 1985, and as a Hitchhiker-G experiment on STS 61-C in January 1986. The purpose of the experiments was to demonstrate the capability of a capillary pumped system under microgravity conditions for use in the thermal control of large scientific instruments, advanced orbiting spacecraft, and space station components. The development, integration, and test activities of the CPL are described. Author

N90-21961*# Prairie View Agricultural and Mechanical Coll., TX. Dept. of Mechanical Engineering.
FLOW BOILING WITH ENHANCEMENT DEVICES FOR COLD PLATE COOLANT CHANNEL DESIGN Semiannual Report
RONALD D. BOYD, SR. and ALVIN SMITH 27 Feb. 1990 157 p
(Contract NAG9-310)
(NASA-CR-186358; NAS 1.26:186358) Avail: NTIS HC A08/MF A01 CSCL 20/4

The use of flow boiling for thermal energy transport is intended to provide an alternative for accommodating higher heat fluxes in commercial space systems. The objectives are to: (1) examine the variations in both the mean and local (axial and circumferential) heat transfer coefficients for a circular coolant channel with either

smooth walls, spiral fins, or both spiral fins and a twisted tape; (2) examine the effects of channel diameter and subcooling; and (3) develop an improved reduction analysis and/or suggest possible heat transfer correlation of the present data. Freon-11 is the working fluid. Two-dimensional (circumferential and axial) wall temperature distributions were measured for coolant channels with the above noted internal geometries. The flow regimes which are being studied are: (1) single phase; (2) subcooled flow boiling; and (3) stratified flow boiling. The inside diameter of all test sections is near 1.0 cm. Cicumferentially averaged heat transfer coefficients at several axial locations were obtained for selected coolant channels for a mass velocity of 210 kg/sq m s, an exit pressure of 0.19 MPa (absolute), and an inlet subcooling of 20.8 C. Overall (averaged over the entire channel) heat transfer coefficients were compared for the above channel geometries. This comparison showed that the channel with large pitch spiral fins had higher heat transfer coefficients at all power levels. B.H.A.

N90-21974*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ANALYSIS OF THERMAL ENERGY STORAGE MATERIAL WITH CHANGE-OF-PHASE VOLUMETRIC EFFECTS
THOMAS W. KERSLAKE and MOUNIR B. IBRAHIM (Cleveland State Univ., OH.) Feb. 1990 34 p Presented at the 1990 International Solar Energy Conference, Miami, FL, 1-4 Apr. 1990; sponsored by ASME
(NASA-TM-102457; E-5244; NAS 1.15:102457) Avail: NTIS HC A03/MF A01 CSCL 20/4

NASA's Space Station Freedom proposed hybrid power system includes photovoltaic arrays with nickel hydrogen batteries for energy storage and solar dynamic collectors driving Brayton heat engines with change-of-phase Thermal Energy Storage (TES) devices. A TES device is comprised of multiple metallic, annular canisters which contain a eutectic composition LiF-CaF2 Phase Change Material (PCM) that melts at 1040 K. A moderately sophisticated LiF-CaF2 PCM computer model is being developed in three stages considering 1-D, 2-D, and 3-D canister geometries, respectively. The 1-D model results indicate that the void has a marked effect on the phase change process due to PCM displacement and dynamic void heat transfer resistance. Equally influential are the effects of different boundary conditions and liquid PCM natural convection. For the second stage, successful numerical techniques used in the 1-D phase change model are extended to a 2-D (r,z) PCM containment canister model. A prototypical PCM containment canister is analyzed and the results are discussed. Author

N90-24488# Sener S.A., Las Arenas (Spain).
CLAMPING DEVICE FOR PRESSURIZED MODULE RADIATOR PANEL
J. J. GONZALEZVALLEJO, J. ARINO, and L. GUTIERREZ *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 175-180 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

A clamping system for the pressurized module radiator panels of the Columbus Space Station is described. The main functions of the clamping system are to support flight loads on the radiator, and provide the radiator panel with a quasi-isostatic, high stiffness supporting system while allowing panel dilation due to thermal changes. In-orbit radiator removal and installation either by means of a remote manipulator or by an astronaut working in an extravehicular atmosphere are taken into consideration in the design of the clamping system. ESA

N90-25510*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
NASA SYSTEMS AUTONOMY DEMONSTRATION PROJECT: ADVANCED AUTOMATION DEMONSTRATION OF SPACE STATION FREEDOM THERMAL CONTROL SYSTEM
JEFFREY DOMINICK, JOHN BULL, and KATHLEEN J. HEALEY *In its* Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 113-116 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 22/2

The NASA Systems Autonomy Demonstration Project (SADP) was initiated in response to Congressional interest in Space station automation technology demonstration. The SADP is a joint cooperative effort between Ames Research Center (ARC) and Johnson Space Center (JSC) to demonstrate advanced automation technology feasibility using the Space Station Freedom Thermal Control System (TCS) test bed. A model-based expert system and its operator interface were developed by knowledge engineers, AI researchers, and human factors researchers at ARC working with the domain experts and system integration engineers at JSC. Its target application is a prototype heat acquisition and transport subsystem of a space station TCS. The demonstration is scheduled to be conducted at JSC in August, 1989. The demonstration will consist of a detailed test of the ability of the Thermal Expert System to conduct real time normal operations (start-up, set point changes, shut-down) and to conduct fault detection, isolation, and recovery (FDIR) on the test article. The FDIR will be conducted by injecting ten component level failures that will manifest themselves as seven different system level faults. Here, the SADP goals, are described as well as the Thermal Control Expert System that has been developed for demonstration. Author

N90-26279*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TWO-DIMENSIONAL MODEL OF A SPACE STATION FREEDOM THERMAL ENERGY STORAGE CANISTER
THOMAS W. KERSLAKE and MOUNIR B. IBRAHIM (Cleveland State Univ., OH.) Aug. 1990 11 p Presented at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; sponsored in part by AIChE, SAE, ACS, AIAA, ASME, and IEEE
(NASA-TM-103124; E-5474; NAS 1.15:103124) Avail: NTIS HC A03/MF A01 CSCL 20/4

The Solar Dynamic Power Module being developed for Space Station Freedom uses a eutectic mixture of LiF-CaF2 phase change salt contained in toroidal canisters for thermal energy storage. Results are presented from heat transfer analyses of the phase change salt containment canister. A 2-D, axisymmetric finite difference computer program which models the canister walls, salt, void, and heat engine working fluid coolant was developed. Analyses included effects of conduction in canister walls and solid salt, conduction and free convection in liquid salt, conduction and radiation across salt vapor filled void regions and forced convection in the heat engine working fluid. Void shape, location, growth or shrinkage (due to density difference between the solid and liquid salt phases) were prescribed based on engineering judgement. The salt phase change process was modeled using the enthalpy method. Discussion of results focuses on the role of free-convection in the liquid salt on canister heat transfer performance. This role is shown to be important for interpreting the relationship between ground based canister performance (in l-g) and expected on-orbit performance (in micro-g). Attention is also focused on the influence of void heat transfer on canister wall temperature distributions. The large thermal resistance of void regions is shown to accentuate canister hot spots and temperature gradients. Author

N90-27738*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THERMAL-DISTORTION ANALYSIS OF AN ANTENNA STRONGBACK FOR GEOSTATIONARY HIGH-FREQUENCY MICROWAVE APPLICATIONS
JEFFREY T. FARMER, DEBORAH M. WAHLS, and ROBERT L. WRIGHT Washington Sep. 1990 22 p
(NASA-TP-3016; L-16739; NAS 1.60:3016) Avail: NTIS HC A03/MF A01 CSCL 22/1

The global change technology initiative calls for a geostationary platform for Earth science monitoring. One of the major science instruments is the high frequency microwave sounder (HFMS) which uses a large diameter, high resolution, high frequency microwave antenna. This antenna's size and required accuracy dictates the need for a segmented reflector. On-orbit disturbances may be a significant factor in its design. A study was performed to examine the effects of the geosynchronous thermal environment on the

performance of the strongback structure for a proposed antenna concept for this application. The study included definition of the strongback and a corresponding numerical model to be used in the thermal and structural analyses definition of the thermal environment, determination of structural element temperature throughout potential orbits, estimation of resulting thermal distortions, and assessment of the structure's capability to meet surface accuracy requirements. Analyses show that shadows produced by the antenna reflector surface play a major role in increasing thermal distortions. Through customization of surface coating and element expansion characteristics, the segmented reflector concept can meet the tight surface accuracy requirements. Author

N90-27772# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Thermal Control and Life Support Div.
SPACECRAFT THERMAL CONTROL DESIGN DATA, VOLUME 5. SECTION R: CRYOGENIC COOLING. SECTION S: EXISTING SATELLITES
Nov. 1989 721 p Revised Prepared in cooperation with Univ. Politecnica de Madrid, Spain
(ESA-PSS-03-108-ISSUE-1-VOL-5; ISSN-0379-4059; ETN-90-96985) Copyright Avail: NTIS HC A99/MF A04

The aim of the handbook is to assist the thermal design engineer by presenting him in a single document with all the information relevant to spacecraft thermal-control design. An introduction to cryogenic cooling is given and the following are discussed: refrigerating systems; VCS (vapor cooled shield) Dewars; superfluid helium; materials at cryogenic temperature; and safety with cryogenic systems. Existing satellites are described including: International Ultraviolet Explorer (IUE), Orbital Test Satellite (OTS), LANDSAT D, Infrared Astronomical Satellite (IRAS), and SPOT. ESA

N90-27773# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Thermal Control and Life Support Div.
SPACECRAFT THERMAL CONTROL DESIGN DATA. VOLUME 6: INDEX
W. R. BURKE Nov. 1989 85 p Prepared in cooperation with Univ. Politecnica de Madrid, Spain
(ESA-PSS-03-108-ISSUE-1-VOL-6; ISSN-0379-4059; ETN-90-96986) Avail: NTIS HC A05/MF A01

The aim of the handbook is to assist the thermal design engineer by presenting him in a single document with all the information relevant to spacecraft thermal control design. Thermal control components and systems described are indexed alphabetically. ESA

N90-28670*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE EFFECTS OF ATOMIC OXYGEN ON THE THERMAL EMITTANCE OF HIGH TEMPERATURE RADIATOR SURFACES
SHARON K. RUTLEDGE, DEBORAH L. HOTES, and PHILLIP E. PAULSEN (Cleveland State Univ., OH.) 1989 25 p Presented at the Spring Meeting of the Materials Research Society, San Diego, CA, 24-29 Apr. 1989
(NASA-TM-103224; E-5640; NAS 1.15:103224) Avail: NTIS HC A03/MF A01 CSCL 11/4

Radiator surfaces on high temperature space power systems such as SP-100 space nuclear power system must maintain a high emittance level in order to reject waste heat effectively. One of the primary materials under consideration for the radiators is carbon-carbon composite. Since carbon is susceptible to attack by atomic oxygen in the low earth orbital environment, it is important to determine the durability of carbon composites in this environment as well as the effect atomic oxygen has on the thermal emittance of the surface if it is to be considered for use as a radiator. Results indicate that the thermal emittance of carbon-carbon composite (as low as 0.42) can be enhanced by exposure to a directed beam of atomic oxygen to levels above 0.85 at 800 K. This emittance enhancement is due to a change in the surface morphology as a result of oxidation. High aspect ratio cones are formed on the surface which allow more efficient trapping of incident radiation. Erosion of the surface due to oxidation is similar to that for carbon, so that at altitudes less than approximately 600 km, thickness loss of the radiator could be significant (as much as 0.1 cm/year). A protective coating or oxidation barrier forming additive may be needed to prevent atomic oxygen attack after the initial high emittance surface is formed. Textured surfaces can be formed in ground based facilities or possibly in space if emittance is not sensitive to the orientation of the atomic oxygen arrival that forms the texture. Author

12

POWER SYSTEMS

Analyses, systems and trade studies of electric power generation, storage, conditioning and distribution.

A90-32963#
RELIABILITY AND VULNERABILITY STUDIES OF THE SP-100 DUAL-LOOP THERMOELECTRIC-ELECTROMAGNETIC PUMP
MOHAMED S. EL-GENK (New Mexico, University, Albuquerque) and WILLIAM J. RIDER Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, May-June 1990, p. 305-314. Research supported by the University of New Mexico. refs
Copyright

A parametric analysis evaluating the reliability, as well as the vulnerabilibty to secondary coolant overheating, of the SP-100 space nuclear power system's thermoelectric-electromagnetic pump, is presently undertaken on the basis of a transient model of the pump's dual-loop configuration. The results obtained indicate that the pump ceases to operate when the secondary coolant temperature either equals that of the primary coolant or exceeds 1255 K, irrespective of the primary coolant temperature. Insulating the pump's magnetic structure from the secondary coolant ducts improves duct performance, and reduces its vulnerability to external heating of the secondary coolant to temperatures above 1000 K. O.C.

A90-33933* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
OVERVIEW OF BATTERY USAGE IN NASA/GSFC LEO AND GEO SPACECRAFTS
THOMAS Y. YI (NASA, Goddard Space Flight Center, Greenbelt, MD) (NASA, Space Electrochemical Research and Technology Conference, 2nd, Cleveland, OH, Apr. 11-13, 1989) Journal of Power Sources (ISSN 0378-7753), vol. 29, Feb. 1990, p. 283-286.
Copyright

A survey of the batteries used in the LEO and GEO missions at the Goddard Space Flight Center is described. For each spacecraft, a tentative launch date is given, along with relevant battery parameters including battery size and description, depth-of-discharge, predicted mission temperature, and life requirement. Author

A90-37859* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE NUCLEAR REACTOR SHIELDS FOR MANNED AND UNMANNED APPLICATIONS
BARBARA I. MCKISSOCK and HARVEY S. BLOOMFIELD (NASA, Lewis Research Center, Cleveland, OH) Space Power - Resources, Manufacturing and Development (ISSN 0883-6272), vol. 9, no. 1, 1990, p. 57-65. Previously announced in STAR as N89-25272. refs
Copyright

Missions which use nuclear reactor power systems require radiation shielding of payload and/or crew areas to predetermined dose rates. Since shielding can become a significant fraction of the total mass of the system, it is of interest to show the effect

of various parameters on shield thickness and mass for manned and unmanned applications. Algorithms were developed to give the thicknesses needed if reactor thermal power, separation distances, and dose rates are given as input. The thickness algorithms were combined with models for four different shield geometries to allow tradeoff studies of shield volume and mass for a variety of manned and unmanned missions. Shield design tradeoffs presented in this study include the effects of: higher allowable dose rates; radiation hardened electronics; shorter crew exposure times; shield geometry; distance of the payload and/or crew from the reactor; and changes in the size of the shielded area. Specific NASA missions that were considered in this study include unmanned outer planetary exploration, manned advanced/evolutionary Space Station, and advanced manned lunar base. Author

A90-38029
IECEC-89; PROCEEDINGS OF THE TWENTY-FOURTH INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE, WASHINGTON, DC, AUG. 6-11, 1989. VOLUMES 1, 2, 3, 4, 5, & 6
WILLIAM D. JACKSON, ED. (HMJ Corp., Chevy Chase, MD) and DOROTHY A. HULL, ED. Conference sponsored by IEEE, AIChE, AIAA, et al. New York, Institute of Electrical and Electronics Engineers, 1989, p. Vol. 1, 703 p.; vol. 2, 672 p.; vol. 3, 442 p.; vol. 4, 460 p.; vol. 5, 528 p.; vol. 6, 446 p. For individual items see A90-38030 to A90-38308.
Copyright

The present conference on aerospace power systems discusses topics in such systems' integration and prospective missions, space thermal management, computer simulation of space power systems (SPSs), SPS autonomy, the NASA Space Station Freedom (SSF) electric power systems, SSF power module elements, SSF power management and distribution, space environmental effects, superconducting support technologies, and innovative and advanced space power concepts. Also treated are space power distribution, advanced rotating machines, thermoelectric and thermoelectrochemical systems, photovoltaics, advanced solar cell arrays, spacecraft solar dynamic power systems, MHD conversion systems, burst space power, thermionic components, and space nuclear reactors. Also discussed are storage batteries, high temperature batteries, magnetic bearings, flywheels, fuel cells, biomass energy conversion, solar thermal renewable resources, cogeneration systems, wind turbine systems, geothermal energy conversion, Stirling cycle engines, and fusion systems. O.C.

A90-38035
AN ADVANCED POWER SYSTEM COMPONENT TEST BED MODULE FOR TESTING ADVANCED TECHNOLOGY AT THE SPACE STATION
JOHN E. DIXSON, STEVE LENHART (Ford Aerospace Corp., Palo Alto, CA), PETER WATERMAN (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA), and WAYNE WALLIN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 31-37.
Copyright

An overview is presented of a study undertaken for the NASA-LeRC on an advanced power system component testbed designed to be attached to the Space Station. The study was a continuation of NASA's efforts to identify and exploit the benefits of the Space Station to provide a platform for science and technology development. A candidate set of advanced technology experiments was devised in the photovoltaic, energy storage, solar dynamic and electric propulsion disciplines. The testbed and the proposed experiments are described. I.E.

A90-38054* Auburn Univ., AL.
POWER FLOW FOR SPACECRAFT POWER SYSTEMS
S. M. HALPIN, L. L. GRIGSBY, G. B. SHEBLE, and R. M. NELMS (Auburn University, AL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 143-148. Research supported by Auburn University.
(Contract NAGW-1192)
Copyright

A method for constructing the generalized system-level admittance matrix for use with a Newton-Raphson power flow is presented. The network modeling technique presented does not use the standard pi-equivalent models, which assume a lossless return path, for the transmission line and transformer. If the return path cannot be assumed lossless, then the standard algorithms for constructing the system admittance matrix cannot be used. The method presented here uses concepts from linear graph theory to combine network modules to form the system-level admittance matrix. The modeling technique is presented, and the resulting matrix is used with a standard Newton-Raphson power flow to calculate all system voltages and current (power) flows. I.E.

A90-38055* Auburn Univ., AL.
HARMONIC ANALYSIS OF SPACECRAFT POWER SYSTEMS USING A PERSONAL COMPUTER
FRANK WILLIAMSON and GERALD B. SHEBLE (Auburn University, AL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 149-152. Research supported by Auburn University. refs
(Contract NAGW-1192)
Copyright

The effects that nonlinear devices such as ac/dc converters, HVDC transmission links, and motor drives have on spacecraft power systems are discussed. The nonsinusoidal currents, along with the corresponding voltages, are calculated by a harmonic power flow which decouples and solves for each harmonic component individually using an iterative Newton-Raphson algorithm. The sparsity of the harmonic equations and the overall Jacobian matrix is used to an advantage in terms of saving computer memory space and in terms of reducing computation time. The algorithm could also be modified to analyze each harmonic separately instead of all at the same time. I.E.

A90-38056 Texas A&M Univ., College Station.
DETECTION OF INCIPIENT AND LOW CURRENT FAULTS IN ELECTRIC DISTRIBUTION SYSTEMS
B. MICHAEL AUCOIN and B. DON RUSSELL (Texas A & M University, College Station) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 153-158. Research supported by EPRI, NSF, NASA, et al. refs
Copyright

Research at Texas A & M in incipient fault detection is reviewed, and the digital and analytical techniques used to discriminate faults from normal system activity are described. The results of staged fault tests are reviewed and detection approaches are presented. The application of these techniques to spaceborne power systems is discussed. It is concluded that the application of these approaches to spaceborne power system fault detection is possible and valuable. I.E.

A90-38057
A KNOWLEDGE-BASED APPROACH TO OPTIMIZE THE SUPPLY AND USAGE OF ELECTRICITY ONBOARD THE SPACE STATION
MOUNIR BOUZGUENDA and SAIFUR RAHMAN (Virginia Polytechnic Institute and State University, Blacksburg) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 159-164.
Copyright

During about one third of the Space Station's orbit the solar

array output is zero and the payload is served by storage devices. It has been found that when a 24-hr cycle is used, some loads onboard the station cannot be scheduled during the desired times. It therefore becomes necessary to reduce the cycle length and dispatch period so that a greater number of loads can be served without increasing the size of the power source. An approach to optimize the supply and usage of electricity over a shorter time frame is discussed. Supply/demand windows of various lengths are implemented for the typical load profile. As a result fewer rescheduling tasks are needed and a closer match between the supply and demand is obtained. The optimal supply/demand can be refined in terms of the excess and shortage of electricity. This technique is implemented using PROLOG and FORTRAN. I.E.

A90-38059
CONTROL TECHNIQUES IN THE DESIGN OF AN AUTOMATED POWER MANAGEMENT AND DISTRIBUTION TEST BED SYSTEM FOR THE SPACE STATION
E. AGHABARARI, L. FERMANDOIS, and M. WETTE (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 171-176.
Copyright

A control system concept is presented for space power application with particular reference to Space Station Freedom. To define some specific requirements for the control development, a power system testbed is introduced. A control architecture for the testbed is defined both in hardware and software, and the main software algorithms for the design and development of the testbed are discussed. The use of control techniques in the design of an autonomous power system is briefly explained. A control system hierarchy and system decomposition approach was selected for the controllers as well as control algorithms. Low-level controllers were given a limited role in power management and fault detection for the distributed power system in their area. I.E.

A90-38061* Martin Marietta Corp., Denver, CO.
A SURVEY OF FAULT DIAGNOSIS TECHNOLOGY
JOEL RIEDESEL (Martin Marietta Corp., Denver, CO) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 183-188. refs
(Contract NAS8-36433)
Copyright

Existing techniques and methodologies for fault diagnosis are surveyed. The techniques run the gamut from theoretical artificial intelligence work to conventional software engineering applications. They are shown to define a spectrum of implementation alternatives where tradeoffs determine their position on the spectrum. Various tradeoffs include execution time limitations and memory requirements of the algorithms as well as their effectiveness in addressing the fault diagnosis problem. I.E.

A90-38062*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
EXERCISE OF THE SSM/PMAD BREADBOARD
BRYAN WALLS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 189-194. refs

The Space Station Module Power Management and Distribution (SSM/PMAD) Breadboard is a test facility designed for advanced development of space power automation. Originally designed for 20-kHz power, the system is being converted to work with direct current (dc). Power levels are on a par with those expected for a Space Station module. Some of the strengths and weaknesses of the SSM/PMAD system in design and function are examined, and the future directions foreseen for the system are outlined. I.E.

A90-38063* Martin Marietta Corp., Denver, CO.
AN ARCHITECTURE FOR AUTOMATED FAULT DIAGNOSIS
BARRY R. ASHWORTH (Martin Marietta Corp., Denver, CO) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 195-200. refs
(Contract NAS8-36433)
Copyright

A description is given of the SSM/PMAD power system automation testbed, which was developed using a systems engineering approach. The architecture includes a knowledge-based system and has been successfully used in power system management and fault diagnosis. Architectural issues which effect overall system activities and performance are examined. The knowledge-based system is discussed along with its associated automation implications, and interfaces throughout the system are presented. I.E.

A90-38064#
SCOPING ARRAY AUTOMATION
TERRY M. TRUMBLE (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 201-206.

A baseline is provided for the establishment of both a design philosophy and approach for the development of an autonomous array. The type of degradation or failure discussed is limited to natural causes. These are due to changes over time in the performance of devices and those induced by space radiation, debris, and other space environmental extremes such as thermal cycles. The types of problems to be expected, the sensors required to selectively identify these problems, the compensation or correction proposed for these problems and the need for on-array computer control to implement these solutions are discussed. I.E.

A90-38070* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DESIGN OF THE SPACE STATION FREEDOM POWER SYSTEM
RONALD L. THOMAS (NASA, Lewis Research Center, Cleveland, OH) and GEORGE J. HALLINAN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 245-250.
Copyright

The design of Space Station Freedom's electric power system (EPS) is reviewed, highlighting the key design goals of performance, low cost, reliability and safety. Tradeoff study results that illustrate the competing factors responsible for many of the more important design decisions are discussed. When Freedom's EPS is compared with previous space power designs, two major differences stand out. The first is the size of the EPS, which is larger than any prior system. The second major difference between the EPS and other space power designs is the indefinite expected life of Freedom; 30 years has been used for life-cycle-cost calculations. I.E.

A90-38072* Rockwell International Corp., Canoga Park, CA.
EVOLUTIONARY GROWTH FOR SPACE STATION FREEDOM ELECTRICAL POWER SYSTEM
MATTHEW FISK MARSHALL (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), KERRY MCLALLIN, and MIKE ZERNIC (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 257-262. Previously announced in STAR as

N89-28570. refs
Copyright

Over an operational lifetime of at least 30 yr, Space Station Freedom will encounter increased Space Station user requirements and advancing technologies. The Space Station electrical power system is designed with the flexibility to accommodate these emerging technologies and expert systems and is being designed with the necessary software hooks and hardware scars to accommodate increased growth demand. The electrical power system is planned to grow from the initial 75 kW up to 300 kW. The Phase 1 station will utilize photovoltaic arrays to produce the electrical power; however, for growth to 300 kW, solar dynamic power modules will be utilized. Pairs of 25 kW solar dynamic power modules will be added to the station to reach the power growth level. The addition of solar dynamic power in the growth phase places constraints in the initial Space Station systems such as guidance, navigation, and control, external thermal, truss structural stiffness, computational capabilities and storage, which must be planned-in, in order to facilitate the addition of the solar dynamic modules. Author

A90-38073*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE STATION FREEDOM ELECTRICAL POWER SYSTEM HARDWARE COMMONALITY WITH THE UNITED STATES POLAR PLATFORM
LORRA L. RIEKER and FRANCIS M. HARABURDA (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 263-270. refs

Information is presented on how the concept of commonality is being implemented with respect to electric power system hardware for the Space Station Freedom and the U.S. Polar Platform. Included is a historical account of the candidate common items which have the potential to serve the same power system functions on both Freedom and the Polar Platform. The Space Station program and objectives are described, focusing on the test and development responsibilities. The program definition and preliminary design phase and the design and development phase are discussed. The goal of this work is to reduce the program cost. I.E.

A90-38074* Arinc Research Corp., Annapolis, MD.
SPACE STATION FREEDOM POWER - A RELIABILITY, AVAILABILITY, AND MAINTAINABILITY ASSESSMENT OF THE PROPOSED SPACE STATION FREEDOM ELECTRIC POWER SYSTEM
S. R. TURNQUIST, M. TWOMBLY (Arinc Research Corp., Annapolis, MD), and D. HOFFMAN (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 271-276.
Copyright

A preliminary reliability, availability, and maintainability (RAM) analysis of the proposed Space Station Freedom electric power system (EPS) was performed using the unit reliability, availability, and maintainability (UNIRAM) analysis methodology. Orbital replacement units (ORUs) having the most significant impact on EPS availability measures were identified. Also, the sensitivity of the EPS to variations in ORU RAM data was evaluated for each ORU. Estimates were made of average EPS power output levels and availability of power to the core area of the space station. The results of assessments of the availability of EPS power and power to load distribution points in the space stations are given. Some highlights of continuing studies being performed to understand EPS availability considerations are presented. I.E.

A90-38075* Rockwell International Corp., Canoga Park, CA.
SPACE STATION FREEDOM PHOTOVOLTAIC POWER MODULE DESIGN STATUS
AMADOR P. JIMENEZ (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) and MARK A. HOBERECHT (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 277-281. Previously announced in STAR as N89-25273.
Copyright

Electric power generation for the Space Station Freedom will be provided by four photovoltaic (PV) power modules using silicon solar cells during phase I operation. Each PV power module requires two solar arrays with 32,800 solar cells generating 18.75 kW of dc power for a total of 75 kW. A portion of this power will be stored in nickel-hydrogen batteries for use during eclipse, and the balance will be processed and converted to 20 kHz ac power for distribution to end users through the power management and distribution system. The design incorporates an optimized thermal control system, pointing and tracking provision with the application of gimbals, and the use of orbital replacement units to achieve modularization. The design status of the PV power module, as derived from major trade studies, is discussed at hardware levels ranging from component to system. Details of the design are presented where appropriate. Author

A90-38076* Lockheed Missiles and Space Co., Sunnyvale, CA.
SPACE STATION FREEDOM SOLAR ARRAY DESIGN DEVELOPMENT
CINDY WINSLOW, KEVIN BILGER (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA), and COSMO BARAONA (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 283-287.
(Contract NAS3-25082)
Copyright

The Space Station Freedom solar array program is required to provide a 75-kW power module that uses eight solar array (SA) wings over a four-year period in low earth orbit (LEO). Each wing will be capable of providing 23.4 kW at the 4-yr design point. The design of flexible-substrate SAs that must survive exposure to the space environment, including atomic oxygen, for an operating life of fifteen years is discussed. The tradeoff study and development areas being investigated include solar cell module size, solar cell weld pads, panel stiffener frames, materials inherently resistant to atomic oxygen, and weight reduction design alternatives. I.E.

A90-38077* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ENERGY STORAGE AND THERMAL CONTROL SYSTEM DESIGN STATUS
STEPHEN N. SIMONS (NASA, Lewis Research Center, Cleveland, OH), BRYAN C. WILLHOITE (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), and GERT VAN OMMERING (Ford Aerospace Corp., Palo Alto, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 289-294. Previously announced in STAR as N89-24427.
Copyright

The Space Station Freedom electric power system (EPS) will initially rely on photovoltaics for power generation and Ni/H2 batteries for electrical energy storage. The current design for the development status of two major subsystems in the PV Power Module is discussed. The energy storage subsystem comprised of high capacity Ni/H2 batteries and the single-phase thermal control system that rejects the excess heat generated by the batteries and other components associated with power generation andstorage is described. Author

A90-38079* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SOLAR DYNAMIC POWER MODULE DESIGN

RICHARD R. SECUNDE, THOMAS L. LABUS (NASA, Lewis Research Center, Cleveland, OH), and RONALD G. LOVELY (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 299-307. Previously announced in STAR as N89-25269. refs
Copyright

Studies have shown that the use of solar dynamic (SD) power for the growth areas of the Space Station Freedom program will result in life cycle cost savings when compared to power supplied by photovoltaic sources. In the SD power module, a concentrator collects and focuses solar energy into a heat receiver which has integral thermal energy storage. A Power Conversion Unit (PCU) based on the closed Brayton cycle removes thermal energy from the receiver and converts that energy to electrical energy. Since the closed Brayton cycle is a single phase gas cycle, the conversion hardware (heat exchangers, turbine, compressor, etc.) can be designed for operation in low earth orbit, and tested with confidence in test facilities on earth before launch into space. The concentrator subassemblies will be aligned and the receiver/PCU/radiator combination completely assembled and charged with gas and cooling liquid on earth before launch to, and assembly on, orbit. Author

A90-38080* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE STATION FREEDOM POWER MANAGEMENT AND DISTRIBUTION DESIGN STATUS
S. JAVIDI (NASA, Lewis Research Center, Cleveland, OH), E. GHOLDSTON, and P. STROH (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 309-313.
Copyright

The design status of the power management and distribution electric power system for the Space Station Freedom is presented. The current design is a star architecture, which has been found to be the best approach for meeting the requirement to deliver 120 V dc to the user interface. The architecture minimizes mass and power losses while improving element-to-element isolation and system flexibility. The design is partitioned into three elements: energy collection, storage and conversion, system protection and distribution, and management and control. I.E.

A90-38081* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DEVELOPMENT AND REFINEMENT OF TEST BED SIMULATIONS
N. V. DRAVID, D. R. MILLER (NASA, Lewis Research Center, Cleveland, OH), A. G. PATTERSON (Analex Corp., Fairview Park, OH), and F. J. GOMBOS (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 315-320. Previously announced in STAR as N89-27702. refs
Copyright

Lewis Research Center of NASA, with support from Rocketdyne, has engaged in a nonreal-time computer simulation effort for the Space Station Freedom Electric Power System (EPS). EASYS, a simulation package, is used as the primary tool for this activity. Early in the design of the EPS, two test beds were set up at Lewis. The Integrated Test Bed (ITB) that combines and upgrades these test beds is in the planning stage. The test beds are designed to functionally represent many of the components of the EPS and their interconnections. The simulation effort is primarily directed towards these test beds. Model verification is performed using test bed data. Author

A90-38082* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DEVELOPMENT OF ADA LANGUAGE CONTROL SOFTWARE FOR THE NASA POWER MANAGEMENT AND DISTRIBUTION TEST BED
TED WRIGHT, MICHAEL MACKIN (NASA, Lewis Research Center, Cleveland, OH), and DAVE GANTOSE (Sverdrup Technology, Inc., Middleburg Heights, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 321-326.
Copyright

The Ada language software developed to control the NASA Lewis Research Center's Power Management and Distribution testbed is described. The testbed is a reduced-scale prototype of the electric power system to be used on space station Freedom. It is designed to develop and test hardware and software for a 20-kHz power distribution system. The distributed, multiprocessor, testbed control system has an easy-to-use operator interface with an understandable English-text format. A simple interface for algorithm writers that uses the same commands as the operator interface is provided, encouraging interactive exploration of the system. I.E.

A90-38083*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EVALUATION OF POWER CONTROL CONCEPTS USING THE PMAD SYSTEMS TEST BED
R. F. BEACH, G. L. KIMNACH, T. A. JETT, and L. M. TRASH (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 327-332. refs

The Lewis Research Center's Power Management and Distribution (PMAD) System testbed and its use in the evaluation of control concepts applicable to the NASA Space Station Freedom electric power system (EPS) are described. The facility was constructed to allow testing of control hardware and software in an environment functionally similar to the space station electric power system. Control hardware and software have been developed to allow operation of the testbed power system in a manner similar to a supervisory control and data acquisition (SCADA) system employed by utility power systems for control. The system hardware and software are described. I.E.

A90-38085
120 VDC POWER SYSTEMS FOR COLUMBUS SPACE PROGRAMME
VOLKER LEISTEN (AEG AG, Wedel, Federal Republic of Germany) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 339-346. refs
Copyright

A brief description of the three different Columbus elements is followed by a presentation of the main requirements to the electrical power system (EPS). The main part of the work is dedicated to the actual technical concepts, covering such aspects as effective utilization of solar array power, energy storage, power distribution and power management. A summary of areas which require further efforts prior to or during the first phase of hardware development is given. I.E.

A90-38086
SPECIFIC ISSUES ASSOCIATED WITH HIGH POWER LEVELS IN SPACE
M. FRANK ROSE (Auburn University, AL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989,

p. 347-354. Research supported by Auburn University. refs
Copyright

Future trends are discussed which indicate that orders of magnitude increases in power will be necessary over the long term if advanced space missions are to be pursued. As these demands increase, techniques which could be employed at lower power levels are no longer usable. Key issues which affect the design of high-power systems in space are discussed with respect to constraints imposed by the platform, environment and mission. I.E.

A90-38087*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
REVIEW OF THE ENVIRONMENTAL EFFECTS ON THE SPACE STATION FREEDOM PHOTOVOLTAIC POWER MODULE
HENRY K. NAHRA (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 355-360. Previously announced in STAR as N89-24418. refs

An overview is provided of the environment in the low earth orbit (LEO), the interaction of this environment with the photovoltaic (PV) power system of the Space Station Freedom is reviewed, and the environmental programs are described that are designed to investigate the interaction of the LEO environment with the photovoltaic power system. Such programs will support and impact the design of the subsystems of the PV module in order to survive the design lifetime in the LEO natural and induced environment. Author

A90-38088* Lockheed Missiles and Space Co., Sunnyvale, CA.
PHOTOVOLTAIC ARRAY ENVIRONMENTAL PROTECTION PROGRAM
KEVIN M. BILGER, HELEN B. GJERDE (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA), and BERNARD L. SATER (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 361-369. refs
(Contract NAS3-25079)
Copyright

During the photovoltaic array environmental protection program, a coating material, application technique, and design approach intended to protect flexible solar array blankets during a nominal fifteen-year operating lifetime were developed. Numerous thin-film coatings for protecting the Kapton polyimide material used in the construction of the Space Station Freedom flexible solar array blanket were evaluated. The critical solar array design features and protection measures are discussed with special emphasis on the effects of solar array fabrication and flexible printed circuit manufacturing processes on coating durability. The results of the mechanical and environmental test evaluation, including oxygen plasma, neutral oxygen beam, and UV/charged-particle combined exposure, are discussed. These results led to the selection of a silicon dioxide thin-film coating to protect the solar array blanket from the low-earth-orbit atomic oxygen environment. I.E.

A90-38091
ENVIRONMENTALLY-INDUCED DISCHARGES IN SOLAR ARRAYS
N. JOHN STEVENS and R. P. STILLWELL (TRW Space and Technology Group, Redondo Beach, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 385-391. refs
Copyright

An investigation of the behavior of solar array segments in active environments has been conducted to quantify their behavior. The study was directed toward understanding the characteristics of geomagnetic charging in geosynchronous orbits and high-voltage behavior in dense thermal plasma environments at lower altitudes. The charging characteristics were found to be due to the material characteristics of the cover glass and surrounding dielectric materials. Electric field concentrations in the gap regions between the cells were found to be the primary source of discharges. There were three types of discharges identified: two associated with charge loss from the cover glass and the third associated with stored charge depletion from the solar array structure and the measurement circuit. The discharges associated with high-voltage operations in dense plasmas exhibited only the third category of discharge. I.E.

A90-38106
POSSIBLE USES OF NUCLEAR POWER IN CONSTELLATED LOW EARTH ORBITING SPACE STATIONS
E. F. MARWICK IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 485-487. refs
Copyright

A nuclear-reactor-powered, constellated, low-earth-orbit (LEO), electrodynamically tethered space station scheme is discussed. The station aligns itself vertically and generates a large amount of electricity, the most important use of which is the production of prograde thrust that can raise the system's altitude or balance lowering of altitude resulting from: (1) capturing lower altitude suborbital velocity rockets from earth; (2) raising such captured lower altitude rockets to higher elevations by using nonconducting tethers; (3) releasing an upward tethered rocket drag; and (4) capturing crashloads from earth. I.E.

A90-38116
STATE ESTIMATION USING ADMITTANCE MATRICES
GEORGE L. KUSIC (Pittsburgh, University, PA) and WILLIAM H. ALLEN (Space Telescope Corp., Baltimore, MD) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 545-550. refs
Copyright

A method for power system state estimation from real-time measurements is presented. When the online measurement set includes voltage magnitude plus real and reactive power injections at each bus, a single matrix inversion directly yields the state of the power system without iteration. The calculated state is dependent on the error tolerance of the physical measurements. When the voltage magnitude at the buses is unknown, but real and reactive bus power injections are specified or measured, the method is used for an iterative power flow calculation. The updated value of the state vector is used in the matrix inversion of the next iteration. The strong convergence of the load flow method is shown for several standard IEEE test cases. I.E.

A90-38118* Pennsylvania State Univ., New Kensington.
THE EFFECTS OF NONLINEAR LOADING UPON THE SPACE STATION FREEDOM 20 KHZ POWER SYSTEM
R. THOMAS LESKOVICH (Pennsylvania State University, Monaca) and IRVING G. HANSEN (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 555-560. refs
Copyright

The Space Station Freedom power distribution system, which consists of dual redundant 20-kHz, 440-V RMS, single-phase power systems, is discussed. The effect of a typical space station nonlinear load on the measurement of RMS current and voltage at various points in the space station power system has been investigated using the Electromagnetic Transients Program (EMTP). The load current distortion at the user interface, its effect on the distribution system, and its relationship to power factor have been studied. Modeling results are compared to test data. The

differences under nonlinear loading are evaluated and presented as a measure of distribution voltage distortion and current measurement accuracy. I.E.

A90-38122* Martin Marietta Corp., Denver, CO.
AUTOMATED POWER DISTRIBUTION SYSTEM HARDWARE
PAUL M. ANDERSON, JAMES A. MARTIN (Martin Marietta Corp., Astronautics Group, Denver, CO), and CINDY THOMASON (NASA, Marshall Space Flight Center, Huntsville, AL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 579-584.
(Contract NAS8-36583)
Copyright

An automated power distribution system testbed for the space station common modules has been developed. It incorporates automated control and monitoring of a utility-type power system. Automated power system switchgear, control and sensor hardware requirements, hardware design, test results, and potential applications are discussed. The system is designed so that the automated control and monitoring of the power system is compatible with both a 208-V, 20-kHz single-phase AC system and a high-voltage (120 to 150 V) DC system. I.E.

A90-38126* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DEVELOPMENT AND TESTING OF A 20 KHZ COMPONENT TEST BED
ROBERT M. BUTTON (NASA, Lewis Research Center, Cleveland, OH), ANDREW S. BRUSH (NASA, Lewis Research Center, Cleveland; Sverdrup Technology, Inc., Middleburg Heights, OH), and RICHARD C. SUNDBERG (General Dynamics Corp., Space Systems Div., San Diego, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 605-610. Previously announced in STAR as N89-25403. refs
(Contract NAS3-25266)
Copyright

A history of the General Dynamics Space Systems Division 20-kHz breadboard is presented, including its current configuration and its role in the SSF program. Highlights and results are presented of a series of tests conducted on the 20 kHz breadboard. The first test presented is the 20 kHz Breadboard Acceptance test. This test verified the operation of the delivered Breadboard and also characterized the main components of the system. Next, an in-depth efficiency testing effort is presented. The tests attempted to apportion all the power losses in the 20 Hz Breadboard Main Inverter Units. Distortion test data are presented, showing the distortion characteristics of a Mapham inverter. Lastly, current work on the 20 kHz Breadboard is presented including Main Inverter Unit paralleling tests. Conclusions are summarized and references given. Author

A90-38154* TRW, Inc., Redondo Beach, CA.
ADVANCED PHOTOVOLTAIC SOLAR ARRAY PROGRAM STATUS
RICHARD M. KURLAND (TRW, Inc., Engineering and Test Div., Redondo Beach, CA) and PAUL M. STELLA (JPL, Pasadena, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 829-834. refs
(Contract JPL-957990)
Copyright

The Advanced Photolvoltaic Solar Array (APSA) Program is discussed. The objective of the program is to demonstrate a producible array system by the end of this decade with a beginning-of-life (BOL) specific power of 130 W/kg at 10 kW as an intermediate milestone toward the ultimate goal of 300 W/kg at 25 kW by the year 2000. The near-term goal represents a significant improvement over existing rigid panel flight arrays (25 to 45 W/kg) and the first-generation flexible blanket NASA/OAST SAFE I array of the early 1980s, which was projected to provide about 60 W/kg BOL. The prototype wing hardware is in the last stages of fabrication and integration. The current status of the program is reported. The array configuration and key design details are shown. Projections are shown for future performance enhancements that may be expected through the use of advanced structural components and solar cells. I.E.

A90-38155* ENTECH Corp., Dallas-Fort Worth Airport, TX.
THE MINI-DOME LENS SPACE CONCENTRATOR ARRAY - RECENT COMPONENT TEST RESULTS AND CURRENT ARRAY DEVELOPMENT STATUS
M. J. O'NEILL, A. J. MCDANAL, J. L. PERRY (Entech, Inc., Dallas, TX), D. J. FLOOD, M. F. PISZCZOR, and C. K. SWARTZ (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 835-840. Research supported by SDIO. refs
Copyright

The development of a high-performance, lightweight space photovoltaic concentrator array is described. The array is the first space photovoltaic concentrator system to use a refractive optical concentrator in the form of a dome-shaped, point-focus, Fresnel lens. In addition, it is the first such concentrator system to utilize prismatic cell covers to eliminate gridline obscuration losses. By combining these array features with state-of-the-art gallium arsenide cell technology, array areal power values (in watts per square meter) well in excess of present space power system levels are anticipated. In addition, the array has the potential for extremely high specific power values (in watts per kilogram). I.E.

A90-38157* Mechanical Technology, Inc., Latham, NY.
FREE PISTON SPACE STIRLING TECHNOLOGY PROGRAM
G. R. DOCHAT and M. DHAR (Mechanical Technology, Inc., Latham, NY) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 849-854. Research supported by NASA. refs
Copyright

MTI recently completed an initial technology feasibility program for NASA by designing, fabricating and testing a space power demonstrator engine (SPDE). This program, which confirms the potential of free-piston Stirling engines, provided the major impetus to initiate a free-piston Stirling space engine (SSE) technology program. The accomplishments of the SPDE program are reviewed, and an overview of the SSE technology program and technical status to date is provided. It is shown that progress in both programs continues to justify its potential for either nuclear or solar space power missions. I.E.

A90-38158* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TWO-TIERED DESIGN ANALYSIS OF A RADIATOR FOR A SOLAR DYNAMIC POWERED STIRLING ENGINE
DONALD C. HAINLEY (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 855-860. Previously announced in STAR as N89-26031.
Copyright

Two separate design approaches for a pumped loop radiator used to transfer heat from the cold end of a solar dynamic powered Stirling engine are described. The first approach uses a standard method to determine radiator requirements to meet specified end of mission conditions. Trade-off studies conducted for the analysis are included. Justification of this concept within the specified parameters of the analysis is provided. The second design approach determines the life performance of the radiator/Stirling system. In this approach, the system performance was altered by

reducing the radiator heat transfer area. Performance effects and equilibrium points were determined as radiator segments were removed. This simulates the effect of loss of radiator sections due to micro-meteoroid and space debris penetration. The two designs are compared on the basis of overall system requirements and goals. Author

A90-38159*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A PROGRAM FOR ADVANCING THE TECHNOLOGY OF SPACE CONCENTRATORS
GERALD J. NAUJOKAS (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) and JOSEPH M. SAVINO (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 861-866. Previously announced in STAR as N89-29484.

In 1985, the NASA Lewis Research Center formed a project, the Advanced Solar Dynamics Power Systems Project, for the purpose of advancing the technology of Solar Dynamic Power Systems for space applications beyond 2000. Since then, technology development activities have been initiated for the major components and subsystems such as the concentrator, heat receiver and engine, and radiator. Described here is a program for developing long lived (10 years or more), lighter weight, and more reflective space solar concentrators than is presently possible. The program is progressing along two parallel paths: one is concentrator concept development and the other is the resolution of those critical technology issues that will lead to durable, highly specular, and lightweight reflector elements. Outlined are the specific objectives, long-term goals, approach, planned accomplishments for the future, and the present status of the various program elements. Author

A90-38163*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CONCENTRATION OF OFF-AXIS RADIATION BY SOLAR CONCENTRATORS FOR SPACE POWER
KENT S. JEFFERIES (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 887-893. Previously announced in STAR as N89-24438. refs

Four types of off-axis radiation are discussed. These are: (1) small off-axis angles during walk-off, (2) large off-axis angles, (3) an extended off-axis source such as Earth albedo, and (4) miscellaneous off-axis sources including radio frequency sources and local point sources. A code named OFFSET has been developed to represent the solar concentrator being developed for Space Station Freedom. It is a detailed, ray-tracing model which represents 50 ray originating points on the Sun and reflections from 10 points on each of the 456 concentrator facets. Results of this code are generally similar to the PIXEL results although there are small differences due to the more detailed representations of the Sun and concentrator that were used in the OFFSET code. Author

A90-38164
MATERIAL COMPATIBILITY AND SIMULATION TESTING FOR THE BRAYTON ENGINE SOLAR RECEIVER FOR THE NASA SPACE STATION FREEDOM SOLAR DYNAMIC OPTION
HAL J. STRUMPF, ROBERT P. RUBLY, and MURRAY G. COOMBS (Allied-Signal Aerospace Co., Torrance, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 895-903.
Copyright

Experimental investigations have been conducted in the areas of material compatibility and solar simulation testing for the heat receiver assembly (HRA) in the Brayton engine for the solar dynamic option for Space Station Freedom. The HRA configuration is a cylindrical receiver lined with tubes; each tube is surrounded by phase change material (PCM). The Brayton-cycle working fluid flows inside the tubes. The material compatibility investigation involved the high-temperature cycling of a series of PCM-filled containment canisters. At various intervals, canisters were removed from the high-temperature furnace, sectioned, and analyzed. For the solar simulation testing, a section of a full-size receiver tube was fabricated and assembled. The test results were compared with the predictions derived from a detailed thermal model of the test section. The results substantiated the viability of the configuration from both the fabrication and operational points of view. I.E.

A90-38165* Boeing Aerospace Co., Seattle, WA.
A BRAYTON CYCLE SOLAR DYNAMIC HEAT RECEIVER FOR SPACE
L. M. SEDGWICK, H. L. NORDWALL, K. J. KAUFMANN (Boeing Aerospace and Electronics, Seattle, WA), and S. D. JOHNSON (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 905-909. refs
Copyright

The detailed design of a heat receiver developed to meet the requirements of the Space Station Freedom, which will be assembled and operated in low earth orbit beginning in the mid-1990's, is described. The heat receiver supplies thermal energy to a nominal 25-kW closed-Brayton-cycle power conversion unit. The receiver employs an integral thermal energy storage system utilizing the latent heat of a eutectic-salt phase-change mixture to store energy for eclipse operation. The salt is contained within a felt metal matrix which enhances heat transfer and controls the salt void distribution during solidification. I.E.

A90-38166
ADVANCED SOLAR BRAYTON SPACE POWER SYSTEMS
ANTHONY PIETSCH and DONALD J. BRANDES (Allied-Signal Aerospace Co., Garrett Fluid Systems Div., Tempe, AZ) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 911-916. refs
Copyright

The closed-Brayton-cycle space power system has been selected to supply electric power for the NASA space station and military space applications. These systems are based on well-proven superalloy metal technology that limits the turbine inlet temperature to the range of 1033 to 1144 K (1400 to 1600 F). Significant performance improvements can be attained by increasing the turbine inlet temperature to the range of 1367 to 1644 K (2000 to 2500 F). Current development in ceramic and composite materials for gas turbines show promise for increasing the temperature of the closed Brayton cycle system to this range. These technologies and the improvements in solar-powered closed Brayton cycle power system performance that can be gained are discussed. I.E.

A90-38167
COMPATIBILITY OF SELECTED SUPERALLOYS WITH MOLTEN LIF-CAF2 SALT
J. D. COTTON and L. M. SEDGWICK (Boeing Aerospace and Electronics, Seattle, WA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 917-921. refs
Copyright

A solar dynamic heat receiver incorporating thermal energy storage is being designed and will be fabricated and tested to advance this technology for use on the U.S. Space Station Freedom. Corrosion testing conducted to determine the most

compatible materials for this application is described. Several high-temperature alloys have been tested for compatibility with molten static LiF-CaF2 at 871 C. The alloys displayed good resistance to corrosion by the salt in a vacuum environment. Inconel 617 displayed the least reaction while Haynes 188 was subject to very slight intergranular attack. Several different metal felts were also tested, and no visible signs of interaction were detected. I.E.

A90-38168*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NUMERICAL MODEL OF SOLAR DYNAMIC RADIATOR FOR PARAMETRIC ANALYSIS
JENNIFER L. RHATIGAN (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 923-930. Previously announced in STAR as N89-22653. refs

Growth power requirements for Space Station Freedom will be met through addition of 25 kW solar dynamic (SD) power modules. Extensive thermal and power cycle modeling capabilities have been developed which are powerful tools in Station design and analysis, but which prove cumbersome and costly for simple component preliminary design studies. In order to aid in refining the SD radiator to the mature design stage, a simple and flexible numerical model was developed. The model simulates heat transfer and fluid flow performance of the radiator and calculates area mass and impact survivability for many combinations of flow tube and panel configurations, fluid and material properties, and environmental and cycle variations. Author

A90-38169* Sanders Associates, Inc., Nashua, NH.
THE CAVITY HEAT PIPE STIRLING RECEIVER FOR SPACE SOLAR DYNAMICS
JAMES B. KESSELI (Sanders Associates, Inc., Nashua, NH) and DOVIE E. LACY (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 931-936.
Copyright

The receiver/storage unit for the low-earth-orbiting Stirling system is discussed. The design, referred to as the cavity heat pipe (CHP), has been optimized for minimum specific mass and volume width. A specific version of this design at the 7-kWe level has been compared to the space station Brayton solar dynamic design. The space station design utilizes a eutectic mixture of LiF and CaF2. Using the same phase change material, the CHP has been shown to have a specific mass of 40 percent and a volume of 5 percent of that of the space station Brayton at the same power level. Additionally, it complements the free-piston Stirling engine in that it also maintains a relatively flat specific mass down to at least 1 kWe. The technical requirements, tradeoff studies, critical issues, and critical technology experiments are discussed. I.E.

A90-38170* Sundstrand Corp., Rockford, IL.
BRAYTON ADVANCED HEAT RECEIVER DEVELOPMENT PROGRAM
G. R. HEIDENREICH, R. S. DOWNING (Sundstrand Corp., Rockford, IL), and DOVIE E. LACEY (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 937-941. refs
Copyright

NASA Lewis Research Center is managing an advanced solar dynamic (ASD) space power program. The objective of the ASD program is to develop small and lightweight solar dynamic systems which show significant improvement in efficiency and specific mass over the baseline design derived from the Space Station Freedom technology. The advanced heat receiver development program is a phased program to design, fabricate and test elements of a 7-kWe heat-receiver/thermal-energy-storage subsystem. Receivers for both Brayton and Stirling heat engines are being developed under separate contracts. Phase I, described here, is the current eighteen month effort to design and perform critical technology experiments on innovative concepts designed to reduce mass without compromising thermal efficiency and reliability. I.E.

A90-38171
THERMAL PERFORMANCE OF SPECIFIC HEAT RECEIVER CONCEPTS FOR ADVANCED SOLAR DYNAMIC APPLICATIONS
ROGER A. CRANE and GANNESH BHARADHWAJ (South Florida, University, Tampa, FL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 943-951. refs
Copyright

The thermal performance of three concepts for thermal energy storage as applied to solar dynamic applications is described. It is recognized that designs providing large thermal gradients or large temperature swings during orbit are susceptible to early mechanical failure. Concepts incorporating heat pipe technology may encounter operational limitations over sufficiently large ranges. The thermal performance of basic designs is reviewed and their relative merits compared. The effect of thermal enhancement and metal utilization as applied to each design is examined, providing a partial characterization of the performance improvements to be achieved by developing these technologies. I.E.

A90-38172*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FLIGHT EXPERIMENT OF THERMAL ENERGY STORAGE
DAVID NAMKOONG (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 953-957. Previously announced in STAR as N89-24440.

Thermal energy storage (TES) enables a solar dynamic system to deliver constant electric power through periods of sun and shade. Brayton and Stirling power systems under current considerations for missions in the near future require working fluid temperatures in the 1100 to 1300+ K range. TES materials that meet these requirements fall into the fluoride family of salts. Salts shrink as they solidify, a change reaching 30 percent for some salts. Hot spots can develop in the TES container or the container can become distorted if the melting salt cannot expand elsewhere. Analysis of the transient, two-phase phenomenon is being incorporated into a three-dimensional computer code. The objective of the flight program is to verify the predictions of the code, particularly of the void location and its effect on containment temperature. The four experimental packages comprising the program will be the first tests of melting and freezing conducted under microgravity. Author

A90-38173
HIGH TEMPERATURE FLUORIDE COMPOSITES FOR LATENT THERMAL STORAGE IN ADVANCED SPACE SOLAR DYNAMIC POWER SYSTEM
Y. TAKAHASHI, Y. ABE, R. SAKAMOTO, K. TANAKA, and M. KAMIMOTO (Electrotechnical Laboratory, Tsukuba, Japan) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 959-963. refs
Copyright

Composite materials containing silicon carbide and fluorides that have been developed for latent thermal storage in advanced space solar dynamic power systems have been studied. One of the materials examined consists of lithium fluoride which is adapted

to a conventional closed gas turbine with 1000-1100 K inlet temperature. SiC composites using the eutectic of LiF-CaF2 (80.5-19.5 mol percent), which currently is receiving particular attention have also been developed. A higher temperature SiC composite consisting of magnesium fluoride has been developed for a gas turbine with 1500 K inlet temperature, for use in the advanced stage of a space solar dynamic power system. In addition to the material study, an experimental setup for studying thermal performance of space receiver component was designed, the details of which are described. I.E.

A90-38180
A THERMODYNAMIC DATA-BASE FOR THE DESIGN OF NAK RANKINE-CYCLE TURBINES
P. C. LU (Nebraska, University, Lincoln) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1097-1102. Research supported by Space Power, Inc. refs
Copyright

Thermodynamic properties of NaK of arbitrary composition are estimated, for the first time, from information on Na and K in data banks, in three regions: under the vapor dome, in the superheated region, and in the subcooled region. A computer program accepting various input pairs is now available. An extensive parametric study has been carried out by the present author using this program. Several possible design points for an NaK-78 (78.4 percent K) Rankine-cycle vapor turbine, with and without mechanical moisture removal, are presented as examples illustrating the use of the database. I.E.

A90-38184
CONCEPTUAL DESIGN OF A CATEGORY III MULTIMEGAWATT SPACE NUCLEAR POWER SYSTEM
RONALD E. FEDDERSEN (Grumman Space Systems, Bethpage, NY) and JOHN R. COINER, JR. (Babcock and Wilcox Co., Nuclear Power Div., Lynchburg, VA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1121-1124.
(Contract DE-AC07-88ID-12753)
Copyright

In the phase I effort completed in February 1989, six prime contractors conducted the tradeoff studies and analyses required to arrive at multimegawatt space reactor conceptual designs in three categories. The category I concept is capable of delivering tens of megawatts of electric power (MWe) for hundreds of seconds with effluents permitted. Category II has the same basic requirements as category I, but no effluents are permitted. Category III is the same as category I but must produce hundreds of megawatts. Some of the results of the category III conceptual design studies are summarized. Design requirements are reviewed, an overall system description is presented, major components are identified, and primary state points are quantified. The present concept's unique particle bed reactor is described. I.E.

A90-38185
APPLICATION OF CERMET FUELED REACTORS TO MULTIMEGAWATT SPACE POWER SYSTEMS
G. B. KRUGER (General Electric Co., Astro-Space Div., Valley Forge, PA) and J. LOBACH (General Electric Co., Astro-Space Div., San Jose, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1125-1130. Research supported by DOE.
Copyright

The open-cycle, multimegawatt burst power system is described in detail. The closed Brayton cycle, Rankine cycle and rocket propulsion applications are also discussed to illustrate the applicability of cermet fuel to a broad range of space power applications. The reactor, turbomachinery, superconducting generator, power conditioning, instrumentation and control, reliability, startup performance, and safety are covered. It is shown that the cermet fuel fast spectrum reactor provides an attractive, flexible space power system. I.E.

A90-38203
CRITERIA FOR ESTABLISHING NUCLEAR POWER SYSTEM RADIATION LEVELS FOR A SPACECRAFT
C. F. GUENTHER and W. R. BRUKWINSKI (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1251-1256. refs
Copyright

An approach for assessing the allowable radiation levels for a nuclear power source is presented. The orbital and nuclear threat environment in which a spacecraft must function is described, and the ability of electronic components to survive in a radiation environment is examined. Options that reduce unacceptable radiation levels emanating from a nuclear power source are discussed. These involves the use of shielding and distance. Shielding is most effective when applied at the reactor. However, the susceptibility of sensors and other particularly sensitive electronic components may in certain cases justify spot shielding. The shielding effectiveness and associated weight penalty depends on the specific reactor design characteristics. I.E.

A90-38249* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
RESULTS FROM BASELINE TESTS OF THE SPRE I AND COMPARISON WITH CODE MODEL PREDICTIONS
JAMES E. CAIRELLI, STEVEN M. GENG (NASA, Lewis Research Center, Cleveland, OH), and ROBERT C. SKUPINSKI (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 5. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2249-2256. Previously announced in STAR as N89-23527. refs
Copyright

The space power research engine (SPRE), a free-piston Stirling engine with linear alternator, is being tested at NASA-Lewis as a candidate for high capacity space power. Results are presented of baseline engine tests at design and off-design operating conditions. The test results are compared with code model prediction. Author

A90-38254*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPARISON OF CONCEPTUAL DESIGNS FOR 25 KWE ADVANCED STIRLING CONVERSION SYSTEMS FOR DISH ELECTRIC APPLICATIONS
RICHARD K. SHALTENS and JEFFREY G. SCHREIBER (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 5. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2305-2315. Previously announced in STAR as N89-26781. refs

The Advanced Stirling Conversion System (ASCS) Project is managed by NASA Lewis Research Center through a cooperative interagency agreement with DOE. Conceptual designs for the ASCS's were completed under parallel contracts in 1987 by Mechanical Technology Inc. (MTI) of Latham, NY, and Stirling Technology Company (STC) of Richland, WA. Each design features a free-piston Stirling engine, a liquid metal heat pipe receiver, and a means to provide about 25 kW of electric power to a utility grid while meeting DOE's long term performance and cost goals. An independent assessment showed that both designs are manufacturable and have the potential to easily meet DOE's long term cost goals. Author

A90-38266*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PROTOFLIGHT PHOTOVOLTAIC POWER MODULE SYSTEM-LEVEL TESTS IN THE SPACE POWER FACILITY
JUAN C. RIVERA and LUKE A. KIRCH (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2601-2615. Previously announced in STAR as N89-25267. refs

Work Package Four, which includes the NASA-Lewis and Rocketdyne, has selected an approach for the Space Station Freedom Photovoltaic (PV) Power Module flight certification that combines system level qualification and acceptance testing in the thermal vacuum environment: the 'protoflight' vehicle approach. This approach maximizes ground test verification to assure system level performance and to minimize risk of on-orbit failures. The preliminary plans for system level thermal vacuum environmental testing of the protoflight PV Power Module in the NASA-Lewis Space Power Facility (SPF) are addressed. Details of the facility modifications to refurbish SPF, after 13 years of downtime, are briefly discussed. The results of an evaluation of the effectiveness of system level environmental testing in screening out incipient part and workmanship defects and unique failure modes are discussed. Preliminary test objectives, test hardware configurations, test support equipment, and operations, are presented. Author

A90-38268
COUPLING OF ENVIRONMENTALLY-INDUCED DISCHARGE TRANSIENTS INTO SPACE POWER DISTRIBUTION SYSTEMS
N. JOHN STEVENS and CAROL S. UNDERWOOD (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2623-2630. refs
Copyright

The mechanism of space-plasma-induced discharge and its coupling with a large space power system are discussed. Data from both ground and flight experiments are reviewed to obtain an expected basis for the interactions. These concepts were applied to the Space Station solar array and distribution system. The effect of discharges was found to be a function of the discharge site. For most sites in the array, discharges would not seriously impact performance. A location at the negative end of the array where discharges could couple to the charge stored in system capacitors was identified. This latter case could impact performance. I.E.

A90-38280*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE NASA ADVANCED SOLAR DYNAMICS TECHNOLOGY PROGRAM
MARVIN WARSHAY and THADDEUS S. MROZ (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2711-2715.

The NASA Advanced Solar Dynamics Technology Program, aimed at developing power system technology for versatile, advanced, high-capacity spacecraft and surface power systems, is discussed. The goals of the program are to be achieved by pursuing high-risk but high-payoff technologies, namely, advanced solar concentrators, heat receivers, power conversion dynamic cycles, and radiators. The NASA program is discussed in terms of mission drivers, the technological goals for each of the system's major components, and program status. I.E.

A90-38281
ADVANCED SOLAR DYNAMIC POWER SYSTEMS FOR FUTURE SPACE MISSIONS
J. M. FRIEFELD and W. E. WALLIN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2717-2722. refs
Copyright

A design and analysis study has been conducted to evaluate the applicability of solar dynamic power generation systems to a wide variety of future space missions. The most promising approach is to limit peak power cycle temperatures to approximately 1090 K by the utilization of lithium fluoride as a thermal energy storage medium which allows energy to be stored at a moderate temperature (1121 K). It was found that the Stirling system has potentially the highest performance, assuming that future test results of space systems fulfill theoretical predictions. Brayton systems, such as those being developed for the space station Freedom, will provide competitive performance with lower development risk. I.E.

A90-38282
OFF-DESIGN MODELING AND PERFORMANCE OF THE SPACE STATION SOLAR DYNAMIC POWER SYSTEM
STEVE SPENCER and ROBERT BONS (Allied-Signal Aerospace Co., Garrett Fluid Systems Div., Tempe, AZ) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2723-2728.
Copyright

A solar dynamic closed Brayton cycle system being developed for the Space Station Freedom is discussed. The aim of the work described here was to select a solar dynamic power module (SDPM) design and establish its behavior over the required range of operating conditions. The design point sizing and major considerations involved in the development of a mathematical computer model that predicts the behavior of the system based on different orbits are presented. Some of the orbital results for use in designing components are given. The overall results indicate that the SDPM design as operated satisfies the system requirements with achievable components and for moderate operating environments. I.E.

A90-38283
A MOVING BOUNDARY MODEL FOR HEAT TRANSFER IN PHASE CHANGE MATERIAL
PRADIP MAJUMDAR and RAKESH K. SHARMA (Northern Illinois University, DeKalb, IL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2729-2733. refs
Copyright

A differential model for the moving boundary problem that can be used to study the performance of phase change materials of various compositions, during the heat absorption and heat rejection period, is discussed. The governing equations and necessary initial and boundary conditions are transformed into a set of integral equations. Numerical solutions to these equations are obtained using an iterative scheme. Results are presented in terms of solid and liquid phase temperature distributions and interface position as a function of time for different Stefan numbers. I.E.

A90-38298
LARGE-SIGNAL ANALYSIS OF SPACECRAFT POWER SYSTEMS
SEONG J. KIM, BO H. CHO (Virginia Polytechnic Institute and State University, Blacksburg), and JAE R. LEE (GE Aerospace, Princeton, NJ) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2873-2880.
Copyright

A large-signal analysis of the direct energy transfer power system is performed to predict the main bus dynamics in various

modes of operation. Stability criteria for the operating points on the solar-array I-V curve are identified in each mode. The large-signal trajectories of the system's operating point for a complete orbit cycle are analyzed, employing a qualitative graphical representation. The analyses are verified through computer simulation. The results of the analysis are presented and discussed in great detail. I.E.

A90-38300* General Electric Co., Philadelphia, PA.
SPACE NUCLEAR POWER APPLIED TO ELECTRIC PROPULSION
F. A. VICENTE, T. KARRAS, D. DAROOKA (General Electric Co., Astro-Space Div., Philadelphia, PA), and L. ISENBERG (JPL, Pasadena, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2885-2890.
Copyright

Space reactor power systems with characteristics ideal for advanced spacecraft systems applications are discussed. These characteristics are: high power-to-weight ratio (15 to 33 W/kg); high volume density (high ballistic coefficient); no preferential orientation in orbit; long operational life; high reliability; and total launch and operational safety. These characteristics allow the use of electric propulsion to raise spacecraft from low earth parking orbits to operational orbits, greatly increasing the useful orbit payload for a given launch vehicle by eliminating the need for a separation injection stage. A proposed demonstration mission is described. I.E.

A90-38307*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ESTIMATED PERFORMANCE AND FUTURE POTENTIAL OF SOLAR DYNAMIC AND PHOTOVOLTAIC POWER SYSTEMS FOR SELECTED LEO AND HEO MISSIONS
DAVID J. BENTS and CHENG Y. LU (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2949-2959. Previously announced in STAR as N89-25280. refs

Solar photovoltaic and thermal dynamic power systems for application to selected low-earth-orbit (LEO) and high-earth-orbit (HEO) missions are characterized in the regime 7 to 35 kWe. Input parameters to the characterization are varied to correspond to anticipated introduction of improved or new technologies. A comparative assessment is made of the two power system types for emerging technologies in cells and arrays, energy storage, optical surfaces, heat engines, thermal energy storage and thermal management. The assessment is made to common ground rules and assumptions. The four missions (Space Station, sun-synchronous, Van Allen belt, and GEO) are representative of the anticipated range of multikilowatt earth-orbit missions. The results give the expected performance, mass and drag of multikilowatt earth-orbiting solar power systems and show how the overall system figure of merit will improve as new component technologies are incorporated. Author

A90-39111* Virginia Polytechnic Inst. and State Univ., Blacksburg.
HIGH-FREQUENCY AC POWER DISTRIBUTION IN SPACE STATION
FU-SHENG TSAI and FRED C. Y. LEE (Virginia Polytechnic Institute and State University, Blacksburg) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 26, March 1990, p. 239-253. refs
(Contract NAG3-551)
Copyright

A utility-type 20-kHz ac power distribution system for the Space Station, employing resonant power-conversion techniques, is presented. The system converts raw dc voltage from photovoltaic cells or three-phase LF ac voltage from a solar dynamic generator into a regulated 20-kHz ac voltage for distribution among various loads. The results of EASY5 computer simulations of the local and global performance show that the system has fast response and good transient behavior. The ac bus voltage is effectively regulated using the phase-control scheme, which is demonstrated with both line and load variations. The feasibility of paralleling the driver-module outputs is illustrated with the driver modules synchronized and sharing a common feedback loop. An HF sinusoidal ac voltage is generated in the three-phase ac input case, when the driver modules are phased 120 deg away from one another and their outputs are connected in series. I.E.

A90-47111#
GROUND STUDIES OF IONOSPHERIC PLASMA INTERACTIONS WITH A HIGH VOLTAGE SOLAR ARRAY
H. KUNINAKA, K. KURIKI (Institute of Space and Astronautical Science, Sagamihara, Japan), Y. NOZAKI, and S. SATORI Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, July-Aug. 1990, p. 417-424. refs
Copyright

While the efficient transfer and generation of high levels of electrical power require high voltages, such as the 160 V contemplated for the NASA Space Station, these exacerbate the effect of space-plasma interactions on spacecraft. The effects are especially severe with solar arrays, when interconnects among solar cells are exposed to the space plasma. A similarity law derived from the governing equations for solar array ion collection is used to define a scaled ground experiment, and the existence of interactions associated with the ion force and surface degradation by sputtering is confirmed. These phenomena must be factored into the projection of spacecraft dynamics and high voltage solar array endurance. O.C.

A90-49310
PCM-IMPREGNATED POLYMER MICROCOMPOSITES FOR THERMAL ENERGY STORAGE
PHILIP STARK (Foster-Miller, Inc., Waltham, MA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 20 p. refs
(Contract F33615-88-C-2809)
(SAE PAPER 901240) Copyright

The encapsulation of phase change materials (PCMs) into the micropores of an ordered polymer film was investigated. Paraffin wax and high density polyethylene wax were infiltrated successfully into extruded films of the ordered polymer PBZT by a solvent exchange technique to yield microcomposites with PCM levels on the order of 40 volume percent. These microcomposite films exhibit excellent mechanical stability under cyclic freeze-thaw conditions. However, their thermal energy storage capacities, as characterized by differential scanning calorimetry, decrease significantly following freeze-thaw cycling. It appears that the ultrastructure of the PBZT and the thinness of the film (which results in high cooling rates during freeze-thaw cycling) promote the retention of the amorphous form of the PCM rather than the crystalline form. Since the amorphous form of the PCM does not contribute to the latent heat of fusion, the heat storage capacity of the microcomposite is reduced. Author

A90-51504
HEAT OF FUSION STORAGE FOR SOLAR DYNAMIC SPACE POWER SYSTEMS
STEFAN WEINGARTNER, JUERGEN BLUMENBERG (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany), and FRIEDRICH LINDNER (DLR, Institut fuer Technische Thermodynamik, Stuttgart, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 14, Aug. 1990, p. 215-222. refs
Copyright

Heat-of-fusion (HOF) thermal-energy storage (TES) forming part of a solar dynamic space power system is regarded as being the best way to provide a continuous power supply during the eclipsed portion of the orbit. An experimental and theoretical analysis has been carried out to investigate the relevance of microgravity to HOF storage. Phenomena caused by the volume change and

specific wetting properties have great influence on the performance and lifetime of the TES. Microgravity experiments are necessary for the development of an optimized and reliable HOF storage system to be applied in space. The Spacelab experiment presented here, scheduled for March 1992, will provide a sound basis for the development of such a storage system. A theoretical model, which can approximate the influences of the volume change, is compared qualitatively with measured melting and solidification curves. Author

A90-52073
DESIGNING SPACECRAFT HVPS SYSTEMS
JON JARVIS (Cambridge Consultants, Ltd., England) Space (ISSN 0267-954X), vol. 6, Sept.-Oct. 1990, p. 37, 38.
Copyright

The problems encountered when designing a high-voltage power supply (HVPS), required by some spacecraft applications, are discussed. Since a HVPS must be small and the high-voltage electronics is close to the sensitive micropower control electronics used for programming, there is a possibility of direct electrical breakdown or arcing. This can be avoided by an adequate spacing between conductors of significantly different potentials. For a HVPS to be more reliable, the instability caused by unintentional radio frequency interference from the high-voltage multiplier and driver transformer has to be minimized, i.e., the areas of loops carrying rapidly changing currents should be small. The selection of suitable components and materials presents another task. Some components may be difficult to obtain; others may have imposed restrictions. Conformal coatings are used extensively, but they can modify the performance of the circuitry, so that retuning may be required. Computer-aided design in the form of circuit simulation helps in optimizing the design of the HVPS. High efficiency can be achieved if the HVPS consumes as little power as possible.
B.P.

A90-52145#
THE SOLAR-POWER GENERATOR FOR THE HUBBLE SPACE TELESCOPE
L. GERLACH (ESTEC, Noordwijk, Netherlands) ESA Journal (ISSN 0379-2285), vol. 14, no. 2, 1990, p. 149-168. refs
Copyright

A review of the Space Telescope Solar-Power Generator, one element of the European contribution to the joint NASA/ESA Hubble Space Telescope (HST) program, is presented. The HST solar array system carries a total of 48,760 BSFR (back-side reflector with back surface field) silicon solar cells, and comprises two fully interchangeable double roll-out solar array wings, which can be deployed and retracted when required. The development of an atomic-oxygen (ATOX) resistant carrier substrate, a solar cell with an extremely smooth surface, and two alternative, specially shaped, ATOX-resistant types of solar-cell interconnector indicates that the HST solar generator can operate for at least ten years in the 614 km high orbit. R.E.P.

N90-20120*# Arinc Research Corp., Annapolis, MD.
SPACE STATION FREEDOM ELECTRIC POWER SYSTEM AVAILABILITY STUDY Final Report
SCOTT R. TURNQUIST Feb. 1990 139 p Prepared for Analex Corp., Cleveland, OH
(Contract NAS3-24564)
(NASA-CR-185181; NAS 1.26:185181; ARINC-4247-01-01-5032) Avail: NTIS HC A07/MF A01 CSCL 22/2

The results are detailed of follow-on availability analyses performed on the Space Station Freedom electric power system (EPS). The scope includes analyses of several EPS design variations, these are: the 4-photovoltaic (PV) module baseline EPS design, a 6-PV module EPS design, and a 3-solar dynamic module EPS design which included a 10 kW PV module. The analyses performed included: determining the discrete power levels that the EPS will operate at upon various component failures and the availability of each of these operating states; ranking EPS components by the relative contribution each component type gives to the power availability of the EPS; determining the availability impacts of including structural and long-life EPS components in the availability models used in the analyses; determining optimum sparing strategies, for storing space EPS components on-orbit, to maintain high average-power-capability with low lift-mass requirements; and analyses to determine the sensitivity of EPS-availability to uncertainties in the component reliability and maintainability data used. Author

N90-20454*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE ELECTROCHEMICAL RESEARCH AND TECHNOLOGY (SERT), 1989
RICHARD S. BALDWIN, ed. Washington Dec. 1989 351 p Conference held in Cleveland, OH, 11-13 Apr. 1989
(NASA-CP-3056; E-4708; NAS 1.55:3056) Avail: NTIS HC A16/MF A02 CSCL 10/1

The proceedings of NASA's second Space Electrochemical Research and Technology Conference are presented. The objectives of the conference were to examine current technologies, research efforts, and advanced ideas, and to identify technical barriers which affect the advancement of electrochemical energy storage systems for space applications. The conference provided a forum for the exchange of ideas and opinions of those actively involved in the field, with the intention of coalescing views and findings into conclusions on progress in the field, prospects for future advances, areas overlooked, and the directions of future efforts. Related overviews were presented in the areas of NASA advanced mission models. Papers were presented and workshops conducted in four technical areas: advanced concepts, hydrogen-oxygen fuel cells and electrolyzers, the nickel electrode, and advanced rechargable batteries.

N90-21113*# Toledo Univ., OH. Dept. of Electrical Engineering.
A COMPARATIVE STUDY OF ELECTRIC POWER DISTRIBUTION SYSTEMS FOR SPACECRAFT Final Report, 19 Jun. - 31 Dec. 1989
THOMAS A. STUART and ROGER J. KING Jan. 1990 134 p (Contract NAG3-708)
(NASA-CR-186531; NAS 1.26:186531) Avail: NTIS HC A07/MF A01 CSCL 22/2

The electric power distribution systems for spacecraft are compared concentrating on two interrelated issues: the choice between dc and high frequency ac, and the converter/inverter topology to be used at the power source. The relative merits of dc and ac distribution are discussed. Specific converter and inverter topologies are identified and analyzed in detail for the purpose of detailed comparison. Finally, specific topologies are recommended for use in dc and ac systems. Author

N90-21795*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FREE-SPACE POWER TRANSMISSION
Washington Nov. 1989 189 p Workshop held in Cleveland, OH, 29-30 Mar. 1988
(NASA-CP-10016; E-4161; NAS 1.55:10016) Avail: NTIS HC A09/MF A02 CSCL 10/2

NASA Lewis Research Center organized a workshop on technology availability for free-space power transmission (beam power). This document contains a collection of viewgraph presentations that describes the effort by academia, industry, and the national laboratories in the area of high-frequency, high-power technology applicable to free-space power transmission systems. The areas covered were rectenna technology, high-frequency, high-power generation (gyrotrons, solar pumped lasers, and free electron lasers), and antenna technology.

N90-21812*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PHOTOVOLTAIC POWER FOR SPACE STATION FREEDOM
COSMO R. BARAONA 1990 8 p Presented at the 21st Photovoltaic Specialists Conference, Orlando, FL, 21-25 May 1990;

sponsored by IEEE
(NASA-TM-102569; E-5391; NAS 1.15:102569) Avail: NTIS HC A02/MF A01 CSCL 10/2

Space Station Freedom is described with special attention given to its electric power system. The photovoltaic arrays, the battery energy storage system, and the power management, and distribution system are also discussed. The current design of Freedom's power system and the system requirements, trade studies, and competing factors which lead to system selections are referenced. This will be the largest power system ever flown in space. This system represents the culmination of many developments that have improved system performance, reduced cost, and improved reliability. Key developments and their evolution into the current space station solar array design are briefly described. The features of the solar cell and the array including the development, design, test, and flight hardware production status are given. Author

N90-22306*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AUTONOMOUS POWER EXPERT SYSTEM
JERRY L. WALTERS, EDWARD J. PETRIK, MARY ELLEN ROTH, LONG VAN TRUONG, TODD QUINN, and WALTER M. KRAWCZONEK (Sverdrup Technology, Inc., Cleveland, OH.) *In* NASA, Goddard Space Flight Center, The 1990 Goddard Conference on Space Applications of Artificial Intelligence p 147-156 May 1990
Avail: NTIS HC A15/MF A02 CSCL 09/2

The Autonomous Power Expert (APEX) system was designed to monitor and diagnose fault conditions that occur within the Space Station Freedom Electrical Power System (SSF/EPS) Testbed. APEX is designed to interface with SSF/EPS testbed power management controllers to provide enhanced autonomous operation and control capability. The APEX architecture consists of three components: (1) a rule-based expert system, (2) a testbed data acquisition interface, and (3) a power scheduler interface. Fault detection, fault isolation, justification of probable causes, recommended actions, and incipient fault analysis are the main functions of the expert system component. The data acquisition component requests and receives pertinent parametric values from the EPS testbed and asserts the values into a knowledge base. Power load profile information is obtained from a remote scheduler through the power scheduler interface component. The current APEX design and development work is discussed. Operation and use of APEX by way of the user interface screens is also covered. Author

N90-22323*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ELECTRIC POWER SCHEDULING: A DISTRIBUTED PROBLEM-SOLVING APPROACH
PAMELA A. MELLOR, JAMES L. DOLCE, and JOSEPH C. KRUPP (Decision-Science Applications, Inc., Arlington, VA.) 1990 8 p Proposed for presentation at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; cosponsored by AIChE, SAE, ACS, AIAA, ASME, and IEEE
(NASA-TM-103149; E-5503; NAS 1.15:103149) Avail: NTIS HC A02/MF A01 CSCL 09/2

Space Station Freedom's power system, along with the spacecraft's other subsystems, needs to carefully conserve its resources and yet strive to maximize overall Station productivity. Due to Freedom's distributed design, each subsystem must work cooperatively within the Station community. There is a need for a scheduling tool which will preserve this distributed structure, allow each subsystem the latitude to satisfy its own constraints, and preserve individual value systems while maintaining Station-wide integrity. The value-driven free-market economic model is such a tool. Author

N90-22324*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AUTOMATING SECURITY MONITORING AND ANALYSIS FOR SPACE STATION FREEDOM'S ELECTRIC POWER SYSTEM
JAMES L. DOLCE, DEJAN J. SOBAJIC, and YOH-HAN PAO (Case Western Reserve Univ., Cleveland, OH.) 1990 10 p Proposed for presentation at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; cosponsored by AIChE, SAE, ACS, AIAA, ASME, and IEEE
(NASA-TM-103148; E-5502; NAS 1.15:103148) Avail: NTIS HC A02/MF A01 CSCL 09/2

Operating a large, space power system requires classifying the system's status and analyzing its security. Conventional algorithms are used by terrestrial electric utilities to provide such information to their dispatchers, but their application aboard Space Station Freedom will consume too much processing time. A new approach for monitoring and analysis using adaptive pattern techniques is presented. This approach yields an on-line security monitoring and analysis algorithm that is accurate and fast; and thus, it can free the Space Station Freedom's power control computers for other tasks. Author

N90-22325*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN EXPERT SYSTEM FOR SIMULATING ELECTRIC LOADS ABOARD SPACE STATION FREEDOM
GEORGE KUKICH (Analytical Engineering Corp., North Olmsted, OH.) and JAMES L. DOLCE 1990 7 p Proposed for presentation at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; cosponsored by AIChE, SAE, ACS, AIAA, ASME, and IEEE
(NASA-TM-103150; E-5504; NAS 1.15:103150) Avail: NTIS HC A02/MF A01 CSCL 09/2

Space Station Freedom will provide an infrastructure for space experimentation. This environment will feature regulated access to any resources required by an experiment. Automated systems are being developed to manage the electric power so that researchers can have the flexibility to modify their experiment plan for contingencies or for new opportunities. To define these flexible power management characteristics for Space Station Freedom, a simulation is required that captures the dynamic nature of space experimentation; namely, an investigator is allowed to restructure his experiment and to modify its execution. This changes the energy demands for the investigator's range of options. An expert system competent in the domain of cryogenic fluid management experimentation was developed. It will be used to help design and test automated power scheduling software for Freedom's electric power system. The expert system allows experiment planning and experiment simulation. The former evaluates experimental alternatives and offers advice on the details of the experiment's design. The latter provides a real-time simulation of the experiment replete with appropriate resource consumption. Author

N90-22488*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE STATION FREEDOM SOLAR ARRAY PANELS PLASMA INTERACTION TEST FACILITY
DONALD F. MARTIN and KENNETH D. MELLOTT 1989 14 p Presented at the Spacecraft Charging Technology Conference, Monterey, CA, 31 Oct. - 3 Nov. 1989; sponsored by Naval Postgraduate School
(NASA-TM-102475; E-5262; NAS 1.15:102475) Avail: NTIS HC A03/MF A01 CSCL 03/2

The Space Station Freedom Power System will make extensive use of photovoltaic (PV) power generation. The phase 1 power system consists of two PV power modules each capable of delivering 37.5 KW of conditioned power to the user. Each PV module consists of two solar arrays. Each solar array is made up of two solar blankets. Each solar blanket contains 82 PV panels. The PV power modules provide a 160 V nominal operating voltage. Previous research has shown that there are electrical interactions between a plasma environment and a photovoltaic power source. The interactions take two forms: parasitic current loss (occurs when the currect produced by the PV panel leaves at a high potential point and travels through the plasma to a lower potential point, effectively shorting that portion of the PV panel); and arcing

(occurs when the PV panel electrically discharges into the plasma). The PV solar array panel plasma interaction test was conceived to evaluate the effects of these interactions on the Space Station Freedom type PV panels as well as to conduct further research. The test article consists of two active solar array panels in series. Each panel consists of two hundred 8 cm x 8 cm silicon solar cells. The test requirements dictated specifications in the following areas: plasma environment/plasma sheath; outgassing; thermal requirements; solar simulation; and data collection requirements. B.H.A.

N90-22606*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PROGRAMMATIC STATUS OF NASA'S CSTI HIGH CAPACITY POWER STIRLING SPACE POWER CONVERTER PROGRAM
JAMES E. DUDENHOEFER 1990 9 p Proposed for presentation at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; cosponsored by AIChE, SAE, ACS, AIAA, ASME, and IEEE
(NASA-TM-103142; E-5494; NAS 1.15:103142) Avail: NTIS HC A02/MF A01 CSCL 21/8

An overview is presented of the NASA Lewis Research Center Free-Piston Stirling Space Power Converter Technology Development Program. This work is being conducted under NASA's Civil Space Technology Initiative (CSTI). The goal of the CSTI High Capacity Power element is to develop the technology base needed to meet the long duration, high capacity power requirements for future NASA space initiatives. Efforts are focused upon increasing system thermal and electric energy conversion efficiency at least fivefold over current SP-100 technology, and on achieving systems that are compatible with space nuclear reactors. The status of test activities with the Space Power Research Engine (SPRE) is discussed. Design deficiencies are gradually being corrected and the power converter is now outputting 11.5 kWe at a temperature ratio of 2 (design output is 12.5 kWe). Detail designs were completed for the 1050 K Component Test Power Converter (CTPC). The success of these and future designs is dependent upon supporting research and technology efforts including heat pipes, gas bearings, superalloy joining technologies and high efficiency alternators. An update of progress in these technologies is provided. Author

N90-22834*# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
SOLAR CONCENTRATOR ADVANCED DEVELOPMENT PROGRAM Final Report
DON KNASEL and DERIK EHRESMAN Oct. 1989 333 p Original contains color illustrations
(Contract NAS3-24670)
(NASA-CR-185173; NAS 1.26:185173) Avail: NTIS HC A15/MF A02; 1 functional color page CSCL 10/1

The Solar Concentrator Advanced Development Project has successfully designed, fabricated, and tested a full scale prototypical solar dynamic concentrator for space station applications. A Truss Hexagonal Panel reflector was selected as a viable solar concentrator concept to be used for space station applications. This concentrator utilizes a modular design approach and is flexible in attainable flux profiles and assembly techniques. The detailed design of the concentrator, which included structural, thermal and optical analysis, identified the feasibility of the design and specific technologies that were required to fabricate it. The needed surface accuracy of the reflectors surface was found to be very tight, within 5 mrad RMS slope error, and results in very close tolerances for fabrication. To meet the design requirements, a modular structure composed of hexagonal panels was used. The panels, made up of graphite epoxy box beams provided the strength, stiffness and dimensional stability needed. All initial project requirements were met or exceeded by hardware demonstration. Initial testing of structural repeatability of a seven panel portion of the concentrator was followed by assembly and testing of the full nineteen panel structure. The testing, which consisted of theodolite and optical measurements over an assembly-disassembly-reassembly cycle, demonstrated that the concentrator maintained the as-built contour and optical characteristics. The facet development effort within the project, which included developing the vapor deposited reflective facet, produced a viable design with demonstrated optical characteristics that are within the project goals. Author

N90-23125*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AUTOMATED ELECTRIC POWER MANAGEMENT AND CONTROL FOR SPACE STATION FREEDOM
JAMES L. DOLCE, PAMELA A. MELLOR, and JAMES A. KISH 1990 8 p Proposed for presentation at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; cosponsored by AIChE, SAE, ACS, AIAA, ASME, and IEEE
(NASA-TM-103151; E-5505; NAS 1.15:103151) Avail: NTIS HC A02/MF A01 CSCL 09/2

A comprehensive automation design is being developed for Space Station Freedom's electric power system. It strives to increase station productivity by applying expert systems and conventional algorithms to automate power system operation. An integrated approach to the power system command and control problem is defined and used to direct technology development in: diagnosis, security monitoring and analysis, battery management, and cooperative problem-solving for resource allocation. The prototype automated power system is developed using simulations and test-beds. Author

N90-23202# Committee on Science, Space and Technology (U.S. House).
NUCLEAR POWER IN SPACE
1989 185 p Hearing before the Subcommittee on Energy Research and Development of the Committee on Science, Space, and Technology, 101st Congress, 1st Session, No. 60, 30 Sep. 1989
(GPO-23-835) Avail: Subcommitttee on Energy Research and Development, House of Representatives, Washington, D.C. 20515 HC free

Written and verbal testimony presented before the House Subcommittee on Energy Research and Development is documented. Current research efforts related to space nuclear power are discussed including the SP-100 Space Reactor Program, development of radioisotope thermoelectric generators, and the Advanced Nuclear Systems Program. Funding, research and test facilities, specific space mission requirements, and the comparison of solar and nuclear power systems are addressed. Witnesses included representatives from DOD, NASA, DOE, universities, and private industry. M.G.

N90-24952*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
HIGH-TEMPERATURE SUPERCONDUCTORS FOR SPACE POWER TRANSMISSION LINES
JOHN R. HULL (Argonne National Lab., IL.) and IRA T. MYERS Aug. 1989 24 p Presented at the ASME Winter Annual Meeting Conference, San Francisco, CA, 10-15 Dec. 1989
(Contract W-31-109-ENG-38)
(NASA-TM-103459; NAS 1.15:103459; DE90-009725; CONF-891208-32) Avail: NTIS HC A03/MF A01 CSCL 20/12

Analysis of high temperature superconductors (HTS) for space power transmission lines shows that they have the potential to provide low weight alternatives to conventional power distribution systems, especially for line lengths greater than 100 m. The use of directional radiators, combined with the natural vacuum of space, offers the possibility of reducing or eliminating the heat flux from the environment that dominates loss in terrestrial systems. This leads to scaling laws that favor flat conductor geometries. From a total launch weight viewpoint, HTS transmission lines appear superior, even with presently attainable values of current density. DOE

N90-25172*# TRW Space Technology Labs., Redondo Beach, CA.
CONCEPTUAL DEFINITION OF A HIGH VOLTAGE POWER SUPPLY TEST FACILITY Final Technical Report
JOHN J. BIESS, TEH-MING CHU, and N. JOHN STEVENS Dec. 1989 83 p
(Contract NAS3-25089)
(NASA-CR-185216; NAS 1.26:185216) Avail: NTIS HC A05/MF A01 CSCL 22/2

NASA Lewis Research Center is presently developing a 60 GHz traveling wave tube for satellite cross-link communications. The operating voltage for this new tube is - 20 kV. There is concern about the high voltage insulation system and NASA is planning a space station high voltage experiment that will demonstrate both the 60 GHz communications and high voltage electronics technology. The experiment interfaces, requirements, conceptual design, technology issues and safety issues are determined. A block diagram of the high voltage power supply test facility was generated. It includes the high voltage power supply, the 60 GHz traveling wave tube, the communications package, the antenna package, a high voltage diagnostics package and a command and data processor system. The interfaces with the space station and the attached payload accommodations equipment were determined. A brief description of the different subsystems and a discussion of the technology development needs are presented. Author

N90-25174*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH. Dept. of Engineering Technology.
DYNAMIC ANALYSIS OF SPACE-RELATED LINEAR AND NON-LINEAR STRUCTURES
PAUL A. BOSELA, FRANCIS J. SHAKER, and DEMETER G. FERTIS (Akron Univ., OH.) 1990 9 p Presented at the Southeast Conference of Theoretical and Applied Mechanics, Atlanta, GA, 22 Mar. 1990
(Contract NAG3-1008)
(NASA-TM-103490; NAS 1.15:103490) Avail: NTIS HC A02/MF A01 CSCL 22/2

In order to be cost effective, space structures must be extremely light weight, and subsequently, very flexible structures. The power system for Space Station Freedom is such a structure. Each array consists of a deployable truss mast and a split blanket of photovoltaic solar collectors. The solar arrays are deployed in orbit, and the blanket is stretched into position as the mast is extended. Geometric stiffness due to the preload make this an interesting non-linear problem. The space station will be subjected to various dynamic loads, during shuttle docking, solar tracking, attitude adjustment, etc. Accurate prediction of the natural frequencies and mode shapes of the space station components, including the solar arrays, is critical for determining the structural adequacy of the components, and for designing a dynamic controls system. The process used in developing and verifying the finite element dynamic model of the photo-voltaic arrays is documented. Various problems were identified, such as grounding effects due to geometric stiffness, large displacement effects, and pseudo-stiffness (grounding) due to lack of required rigid body modes. Analysis techniques, such as development of rigorous solutions using continuum mechanics, finite element solution sequence altering, equivalent systems using a curvature basis, Craig-Bampton superelement approach, and modal ordering schemes were utilized. The grounding problems associated with the geometric stiffness are emphasized. Author

N90-25184*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN ANALYSIS OF SPACE POWER SYSTEM MASSES
BARBARA H. KENNY (Sverdrup Technology, Inc., Brook Park, OH.), RONALD C. CULL, and M. DAVID KANKAM 1990 8 p Proposed for presentation at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; cosponsored by AIChE, ANS, SAE, ACS, AIAA, ASME, and IEEE
(NASA-TM-103199; E-5597; NAS 1.15:103199) Avail: NTIS HC A02/MF A01 CSCL 21/8

Various space electrical power system masses are analyzed with particular emphasis on the power management and distribution (PMAD) portion. The electrical power system (EPS) is divided into functional blocks: source, interconnection, storage, transmission, distribution, system control and load. The PMAD subsystem is defined as all the blocks between the source, storage and load, plus the power conditioning equipment required for the source, storage and load. The EPS mass of a wide range of spacecraft is then classified as source, storage or PMAD and tabulated in a database. The intent of the database is to serve as a reference source for PMAD masses of existing and in-design spacecraft. The PMAD masses in the database range from 40 kg/kW to 183 kg/kW across the spacecraft systems studied. Factors influencing the power system mass are identified. These include the total spacecraft power requirements, total amount of load capacity and physical size of the spacecraft. It is found that a new utility class of power systems, represented by Space Station Freedom, is evolving. Author

N90-25187*# Sverdrup Technology, Inc., Cleveland, OH.
AUTONOMOUS POWER EXPERT SYSTEM Final Report
MARK J. RINGER and TODD M. QUINN Jul. 1990 8 p Presented at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; cosponsored by AIChE, ANS, SAE, ACS, AIAA, ASME, and IEEE
(Contract NAS3-25266)
(NASA-CR-185263; E-5609; NAS 1.26:185263) Avail: NTIS HC A02/MF A01 CSCL 21/8

The goal of the Autonomous Power System (APS) program is to develop and apply intelligent problem solving and control technologies to the Space Station Freedom Electrical Power Systems (SSF/EPS). The objectives of the program are to establish artificial intelligence/expert system technology paths, to create knowledge based tools with advanced human-operator interfaces, and to integrate and interface knowledge-based and conventional control schemes. This program is being developed at the NASA-Lewis. The APS Brassboard represents a subset of a 20 KHz Space Station Power Management And Distribution (PMAD) testbed. A distributed control scheme is used to manage multiple levels of computers and switchgear. The brassboard is comprised of a set of intelligent switchgear used to effectively switch power from the sources to the loads. The Autonomous Power Expert System (APEX) portion of the APS program integrates a knowledge based fault diagnostic system, a power resource scheduler, and an interface to the APS Brassboard. The system includes knowledge bases for system diagnostics, fault detection and isolation, and recommended actions. The scheduler autonomously assigns start times to the attached loads based on temporal and power constraints. The scheduler is able to work in a near real time environment for both scheduling and dynamic replanning. Author

N90-25509*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AUTOMATION IN THE SPACE STATION MODULE POWER MANAGEMENT AND DISTRIBUTION BREADBOARD
BRYAN WALLS and LOUIS F. LOLLAR *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 107-111 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 10/2

The Space Station Module Power Management and Distribution (SSM/PMAD) Breadboard, located at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama, models the power distribution within a Space Station Freedom Habitation or Laboratory module. Originally designed for 20 kHz ac power, the system is now being converted to high voltage dc power with power levels on a par with those expected for a space station module. In addition to the power distribution hardware, the system includes computer control through a hierarchy of processes. The lowest level process consists of fast, simple (from a computing

standpoint) switchgear, capable of quickly safing the system. The next level consists of local load center processors called Lowest Level Processors (LLP's). These LLP's execute load scheduling, perform redundant switching, and shed loads which use more than scheduled power. The level above the LLP's contains a Communication and Algorithmic Controller (CAC) which coordinates communications with the highest level. Finally, at this highest level, three cooperating Artificial Intelligence (AI) systems manage load prioritization, load scheduling, load shedding, and fault recovery and management. The system provides an excellent venue for developing and examining advanced automation techniques. The current system and the plans for its future are examined. Author

N90-25513*# Air Force Aero Propulsion Lab., Wright-Patterson AFB, OH.
SOLAR ARRAY AUTOMATION LIMITATIONS
TERRY M. TRUMBLE *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 127-130 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 10/1

Significant progress in the automation of the spacecraft electrical power systems has been made within the past few years. This is especially important with the development of the space station and the increasing demand on the electrical power systems for future satellites. The key element of the spacecraft power system, the solar arrays which supply the power, will have to grow to supply many tens of kilowatts of power within the next twenty years. This growth will be accompanied by the problems associated with large distributed power systems. The growth of the arrays, the on-array management problems and potential solutions to array degradation or failure are discussed. Multilowatt arrays for unmanned spacecraft with comments on the implications of array degradation for manned spacecraft are discussed. Author

N90-25521*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AUTONOMOUS POWER EXPERT FAULT DIAGNOSTIC SYSTEM FOR SPACE STATION FREEDOM ELECTRICAL POWER SYSTEM TESTBED
LONG V. TRUONG, JERRY L. WALTERS, MARY ELLEN ROTH, TODD M. QUINN, and WALTER M. KRAWCZONEK (Sverdrup Technology, Inc., Cleveland, OH.) *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 181-186 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 21/8

The goal of the Autonomous Power System (APS) program is to develop and apply intelligent problem solving and control to the Space Station Freedom Electrical Power System (SSF/EPS) testbed being developed and demonstrated at NASA Lewis Research Center. The objectives of the program are to establish artificial intelligence technology paths, to craft knowledge-based tools with advanced human-operator interfaces for power systems, and to interface and integrate knowledge-based systems with conventional controllers. The Autonomous Power EXpert (APEX) portion of the APS program will integrate a knowledge-based fault diagnostic system and a power resource planner-scheduler. Then APEX will interface on-line with the SSF/EPS testbed and its Power Management Controller (PMC). The key tasks include establishing knowledge bases for system diagnostics, fault detection and isolation analysis, on-line information accessing through PMC, enhanced data management, and multiple-level, object-oriented operator displays. The first prototype of the diagnostic expert system for fault detection and isolation has been developed. The knowledge bases and the rule-based model that were developed for the Power Distribution Control Unit subsystem of the SSF/EPS testbed are described. A corresponding troubleshooting technique is also described. Author

N90-25544*# TRW Space Technology Labs., Redondo Beach, CA.
DISCHARGE TRANSIENT COUPLING IN LARGE SPACE POWER SYSTEMS
N. JOHN STEVENS and R. P. STILLWELL *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 383-391 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 10/2

Experiments have shown that plasma environments can induce discharges in solar arrays. These plasmas simulate the environments found in low earth orbits where current plans call for operation of very large power systems. The discharges could be large enough to couple into the power system and possibly disrupt operations. Here, the general concepts of the discharge mechanism and the techniques of coupling are discussed. Data from both ground and flight experiments are reviewed to obtain an expected basis for the interactions. These concepts were applied to the Space Station solar array and distribution system as an example of the large space power system. The effect of discharges was found to be a function of the discharge site. For most sites in the array discharges would not seriously impact performance. One location at the negative end of the array was identified as a position where discharges could couple to charge stored in system capacitors. This latter case could impact performance. Author

N90-25547*# Decision-Science Applications, Inc., Arlington, VA.
AUTOMATED CONTROL OF HIERARCHICAL SYSTEMS USING VALUE-DRIVEN METHODS
GEORGE E. PUGH and THOMAS E. BURKE *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 415-422 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 09/2

An introduction is given to the Value-driven methodology, which has been successfully applied to solve a variety of difficult decision, control, and optimization problems. Many real-world decision processes (e.g., those encountered in scheduling, allocation, and command and control) involve a hierarchy of complex planning considerations. For such problems it is virtually impossible to define a fixed set of rules that will operate satisfactorily over the full range of probable contingencies. Decision Science Applications' value-driven methodology offers a systematic way of automating the intuitive, common-sense approach used by human planners. The inherent responsiveness of value-driven systems to user-controlled priorities makes them particularly suitable for semi-automated applications in which the user must remain in command of the systems operation. Three examples of the practical application of the approach in the automation of hierarchical decision processes are discussed: the TAC Brawler air-to-air combat simulation is a four-level computerized hierarchy; the autonomous underwater vehicle mission planning system is a three-level control system; and the Space Station Freedom electrical power control and scheduling system is designed as a two-level hierarchy. The methodology is compared with rule-based systems and with other more widely-known optimization techniques. Author

N90-25559*# Air Force Geophysics Lab., Hanscom AFB, MA.
PHOTOVOLTAIC ARRAY SPACE POWER PLUS DIAGNOSTICS EXPERIMENT
DONALD A. GUIDICE *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 515-519 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 10/1

The objective of the Photovoltaic Array Space Power Plus Diagnostics (PASP Plus) experiment is to measure the effects of the interaction of the low- to mid-altitude space environment on the performance of a diverse set of small solar-cell arrays (planar and concentrator, representative of present and future military technologies) under differing conditions of velocity-vector orientation and simulated (by biasing) high-voltage operation. Solar arrays to be tested include Si and GaAs planar arrays and several types of GaAs concentrator arrays. Diagnostics (a Langmuir probe and a pressure gauge) and a transient pulse monitor (to measure radiated and conducted EMI during arcing) will be used to determine the impact of the environment on array operation to help verify

various interactions models. Results from a successful PASP Plus flight will furnish answers to important interactions questions and provide inputs for design and test standards for photovoltaic space-power subsystems. Author

N90-26054*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPARISON OF CURRENTS PREDICTED BY NASCAP/LEO MODEL SIMULATIONS WITH ELEMENTARY LANGMUIR-TYPE BARE PROBE MODELS FOR AN INSULATED CABLE CONTAINING A SINGLE PINHOLE
JOEL T. GALOFARO Jul. 1990 39 p Original contains color illustrations
(NASA-TM-102486; E-5095; NAS 1.15:102486) Avail: NTIS HC A03/MF A01; 9 functional color pages CSCL 22/2

The behavior of a defect in the insulation of a short biased section of cable in a Low Earth Orbit (LEO) space environment was examined. Such studies are of the utmost importance for large space power systems where great quantities of cabling will be deployed. An insulated probe containing a pinhole was placed into a hypothetical high speed LEO plasma. The NASA Charging Analyzer Program (NASCAP/LEO) was used to explore sheath growth about the probe as a function of applied voltage and to predict I-V behavior. A set of independent current calculations using Langmuir's formulations for concentric spheres and coaxial cylinders were also performed. The case of concentric spheres was here extended to include the case of concentric hemispheres. Several simple Langmuir-type models were then constructed to bracket the current collected by the cable. The space-charge sheath radius and impact parameters were used to determine the proper current regime. I-V curves were plotted for the models and comparisons were made with NASCAP/LEO results. Finally, NASCAP/LEO potential contours and surface cell potential plots were examined to explain interesting features in the NASCAP/LEO I-V curve. Author

N90-26729*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PRELIMINARY DESIGNS FOR 25 KWE ADVANCED STIRLING CONVERSION SYSTEMS FOR DISH ELECTRIC APPLICATIONS Final Report
RICHARD K. SHALTENS and JEFFREY G. SCHREIBER 1990 19 p Presented at the 25th Intersociety Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; sponsored by AIChE, ANS, SAE, ACS, AIAA, ASME, and IEEE Prepared for DOE, Washington, DC
(Contract DE-AT04-85AL-33408)
(NASA-TM-103188; DOE/NASA/33408-4; E-5573; NAS 1.15:103188) Avail: NTIS HC A03/MF A01 CSCL 10/1

Under the Department of Energy's (DOE) Solar Thermal Technology Program, Sandia National Laboratories is evaluating heat engines for terrestrial Solar Distributed Heat Receivers. The Stirling engine has been identified by Sandia as one of the most promising engines for terrestrial applications. The Stirling engine also has the potential to meet DOE's performance and cost goals. The NASA Lewis Research Center is conducting Stirling engine technology development activities directed toward a dynamic power source for space applications. Space power systems requirements include high reliability, very long life, low vibration and high efficiency. The free-piston Stirling engine has the potential for future high power space conversion systems, either nuclear or solar powered. Although both applications appear to be quite different, their requirements complement each other. Preliminary designs feature a free-piston Stirling engine, a liquid metal heat transport system, and a means to provide nominally 25 kW electric power to a utility grid while meeting DOE's performance and long term cost goals. The Cummins design incorporates a linear alternator to provide the electrical output, while the STC design generates electrical power indirectly through a hydraulic pump/motor coupled to an induction generator. Both designs for the ASCS's will use technology which can reasonably be expected to be available in the early 1990's Author

N90-27293*# Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.
A HYBRID APPROACH TO SPACE POWER CONTROL
E. W. GHOLDSTON, D. F. JANIK, and K. A. NEWTON *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 155-163 May 1990
Avail: NTIS HC A25/MF A04 CSCL 10/3

Conventional control systems have traditionally been utilized for space-based power designs. However, the use of expert systems is becoming important for NASA applications. Rocketdyne has been pursuing the development of expert systems to aid and enhance control designs of space-based power systems. The need for integrated expert systems is vital for the development of autonomous power systems. Author

N90-27302*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
A KNOWLEDGE BASE ARCHITECTURE FOR DISTRIBUTED KNOWLEDGE AGENTS
JOEL RIEDESEL (Martin Marietta Corp., Huntsville, AL.) and BRYAN WALLS *In its* Fifth Conference on Artificial Intelligence for Space Applications p 241-256 May 1990
(Contract NAS8-36433)
Avail: NTIS HC A25/MF A04 CSCL 09/2

A tuple space based object oriented model for knowledge base representation and interpretation is presented. An architecture for managing distributed knowledge agents is then implemented within the model. The general model is based upon a database implementation of a tuple space. Objects are then defined as an additional layer upon the database. The tuple space may or may not be distributed depending upon the database implementation. A language for representing knowledge and inference strategy is defined whose implementation takes advantage of the tuple space. The general model may then be instantiated in many different forms, each of which may be a distinct knowledge agent. Knowledge agents may communicate using tuple space mechanisms as in the LINDA model as well as using more well known message passing mechanisms. An implementation of the model is presented describing strategies used to keep inference tractable without giving up expressivity. An example applied to a power management and distribution network for Space Station Freedom is given. Author

N90-27731*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
HUBBLE SPACE TELESCOPE SIX-BATTERY TEST BED
J. A. PAJAK, J. R. BUSH, JR., and J. R. LANIER, JR. Aug. 1990 99 p
(NASA-TM-103506; NAS 1.15:103506) Avail: NTIS HC A05/MF A01 CSCL 14/2

A test bed for a large space power system breadboard for the Hubble Space Telescope (HST) was designed and built to test the system under simulated orbital conditions. A discussion of the data acquisition and control subsystems designed to provide for continuous 24 hr per day operation and a general overview of the test bed is presented. The data acquisition and control subsystems provided the necessary monitoring and protection to assure safe shutdown with protection of test articles in case of loss of power or equipment failure over the life of the test (up to 5 years). Author

N90-27784*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ELECTRICAL CHARACTERIZATION OF A MAPHAM INVERTER USING PULSE TESTING TECHNIQUES
E. D. BAUMANN, I. T. MYERS, and A. N. HAMMOND (Sverdrup Technology, Inc., Brook Park, OH.) 1990 7 p Presented at the 25th Intersociety Energy Conversion Engineering Conference, Reno, NV, 12-17 Aug. 1990; cosponsored by AIChE, ANS, SAE, ACS, AIAA, ASME, and IEEE
(Contract FY1455-89-N-0655)
(NASA-TM-103254; E-5683; NAS 1.15:103254) Avail: NTIS HC A02/MF A01 CSCL 21/8

Electric power requirements for aerospace missions have reached megawatt power levels. Within the next few decades, it is anticipated that a manned lunar base, interplanetary travel, and surface exploration of the Martian surface will become reality. Several research and development projects aimed at demonstrating megawatt power level converters for space applications are currently underway at the NASA Lewis Research Center. Innovative testing techniques will be required to evaluate the components and converters, when developed, at their rated power in the absence of costly power sources, loads, and cooling systems. Facilities capable of testing these components and systems at full power are available, but their use may be cost prohibitive. The use of a multiple pulse testing technique is proposed to determine the electrical characteristics of large megawatt level power systems. Characterization of a Mapham inverter is made using the proposed technique and conclusions are drawn concerning its suitability as an experimental tool to evaluate megawatt level power systems. Author

13

ELECTRONIC SYSTEMS & EQUIPMENT

Design and operation of electrical equipment such as motors, switch gear, connectors and other fixtures.

A90-33669#
FUNDAMENTAL STUDY ON ALKALI METAL THERMOELECTRIC CONVERTER
TOSHIHISA MASUDA Electrotechnical Laboratory, Researches (ISSN 0366-9106), no. 904, Nov. 1989, 69 p. In Japanese, with abstract in English. refs

The alkali metal thermoelectric converter (AMTEC), which utilizes the sodium ion conducting beta-double prime-alumina, is a device for directly converting heat energy to electric energy. It is characterized by high conversion efficiencies of 20 to 40 percent, high power densities of 1 W/sq cm, no moving parts, low maintenance requirements, high durability, and efficiency independent of size. Because of these merits, AMTEC is one of the most promising candidates for dispersed small-scale power stations, remote power stations, and aerospace power systems. In this paper, the results of theoretical and experimental studies on AMTEC power generating characteristics, internal electrical resistances of single cells, and system analysis of AMTEC power-generating systems are reported. C.D.

A90-33670#
ANALYSIS OF OUTPUT PERFORMANCE CHARACTERISTICS OF CESIUM DIODE THERMIONIC ENERGY CONVERTERS
SADAAKI SHIMIZU Electrotechnical Laboratory, Researches (ISSN 0366-9106), no. 906, Dec. 1989, 145 p. In Japanese, with abstract in English. refs

The thermionic energy converter (TEC) is a device which can convert heat directly into electric work by thermionic emission. Here, the principle and application of the TEC are described, including a nuclear reactor application. The operating characteristics of the cesium diode TEC are examined, and comparison is made between the output current-voltage curves obtained experimentally and those calculated by the SIMCON computer code. Comparisons are also made for the electron temperature and ion density profiles across the interelectrode plasma. C.D.

A90-36913* General Electric Co., Erie, PA.
A 2.5 KW CASCADED SCHWARZ CONVERTER FOR 20 KHZ POWER DISTRIBUTION
RUSSELL E. SHETLER (General Electric Co., Erie, PA) and THOMAS A. STUART (Toledo, University, OH) IN: PESC '89 - Annual IEEE Power Electronics Specialists Conference, 20th, Milwaukee, WI, June 26-29, 1989, Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 987-993. Research supported by USAF. refs
(Contract NAG3-708)
Copyright

Because it avoids the high currents in a parallel loaded capacitor, the cascaded Schwarz converter should offer better component utilization than converters with sinusoidal output voltages. The circuit is relatively easy to protect, and it provides a predictable trapezoidal voltage waveform that should be satisfactory for 20-kHz distribution systems. Analysis of the system is enhanced by plotting curves of normalized variables vs. gamma(1), where gamma(1) is proportional to the variable frequency of the first stage. Light-load operation is greatly improved by the addition of a power recycling rectifier bridge that is back biased at medium to heavy loads. Operation has been verified on a 2.5-kW circuit that uses input and output voltages in the same range as those anticipated for certain future spacecraft power systems. I.E.

A90-38093
FLIGHT EXPERIENCE WITH LIPS-III
JAMES G. SEVERNS (U.S. Navy, Naval Research Laboratory, Washington, DC), ROBERT W. CONWAY (Allied-Signal, Inc., Morris Township, NJ), RICHARD M. HOBBS (Fairchild Space Co., Germantown, MD), and BRUCE J. FARADAY IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 399-404. refs
Copyright

The satellite LIPS III, the third in the series of living plume shield spacecraft, was launched into a low earth orbit late in the spring of 1987. Some 140 solar cell experiments were placed on LIPS, and data from these has been acquired for two years. The quality of the current-voltage characteristic measurements is reviewed, and some anomalies in the data are described. In particular, excursions of measured short-circuit current which well exceed experimental error are described. A model is proposed for prediction of earth solar reflectance, and correlation between the calculated reflectance and excursions of short-circuit current is shown graphically. It is concluded that these excursions are of solar origin and not caused by a malfunction of the spacecraft. I.E.

A90-38094#
THE EFFECTS OF SPACE ENVIRONMENT ON SILICON VERTICAL JUNCTION SOLAR CELLS ON THE LIPS III SATELLITE
RICHARD L. STATLER (U.S. Navy, Naval Research Laboratory, Washington, DC) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 405-410. Research supported by the U.S. Navy. refs

The preliminary analysis and results of a space experiment to evaluate the performance of a new generation of silicon vertical junction solar cells and three adhesives for attaching coverglass to the solar cells are presented. Two of the adhesives are used for the first time in coverglass applications where they are subjected to the space environment. SOLAREX vertical junction solar cells which are of 10 ohm-cm silicon with back surface fields (BSF) and back surface reflectors (BSR) are compared to SOLAREX planar junction cells of the same type. The results for up to 566 days in space indicate that the two types of solar cell show about the same rate of degradation in power output. There are no significant differences at this point in the performance of the three adhesives. I.E.

A90-38100
PREVENTING ION BOMBARDMENT CAUSED BREAKDOWN IN HIGH VOLTAGE SPACE POWER SYSTEMS AND APPLICATIONS TO SPACE POWER EXPERIMENTS ABOARD ROCKETS (SPEAR)
I. KATZ, G. A. JONGEWARD, M. J. MANDELL (Maxwell

Laboratories, Inc., La Jolla, CA), K. C. MAFFEI, and J. R. COOPER (Maxwell Laboratories, Inc., San Diego, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 447-451. Research sponsored by SDIO. refs
(Contract DNA001-87-C-0091)
Copyright

Ionospheric ions bombarding high-field electrodes have been shown to cause electrical breakdown in systems that would operate successfully in a perfect vacuum. Bushings have been engineered to block ion trajectories and to prevent surface charging in order to avoid breakdown. The complicated geometries associated with realistic space power systems act to reduce the ion current to individual components. The theory of these effects and the design of SPEAR I and SPEAR II payloads using these techniques are described. The high-voltage power systems are designed to operate at up to 100 kV, without insulation, exposed to the natural space environment. I.E.

A90-38124* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
20 KHZ MAIN INVERTER UNIT
S. HUSSEY (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 591-595.
(Contract NAS3-24653)
Copyright

A proof-of-concept main inverter unit has demonstrated the operation of a pulse-width-modulated parallel resonant power stage topology as a 20-kHz ac power source driver, showing simple output regulation, parallel operation, power sharing and short-circuit operation. The use of a two-stage dc input filter controls the electromagnetic compatibility (EMC) characteristics of the dc power bus, and the use of an ac harmonic trap controls the EMC characteristics of the 20-kHz ac power bus. I.E. 9@

A90-38127
AN IMPROVED MAPHAM'S INVERTER FOR HIGH FREQUENCY SPACE POWER CONVERSION
PRAVEEN JAIN and JOHN BOTTRILL (Canadian Astronautics, Ltd., Ottawa, Canada) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 611-616.
Copyright

An improved Mapham inverter for high-frequency space power conversion is presented. The inverter system employs a starting commutator to facilitate the startup of the conventional inverter under full-load conditions. The load conditions that would cause startup commutation failure are established, and the behavior of the improved inverter is studied. Simulation results verify the predicted startup performance. A generalized steady-state analysis of the inverter is presented, and performance curves are derived. I.E.

A90-38128* Wisconsin Univ., Madison.
PERFORMANCE TESTING OF A HIGH FREQUENCY LINK CONVERTER FOR SPACE STATION POWER DISTRIBUTION SYSTEM
S. K. SUL, I. ALAN, and T. A. LIPO (Wisconsin, University, Madison) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 617-623. refs
(Contract NAG3-786)
Copyright

The testing of a brassboard version of a 20-kHz high-frequency ac voltage link prototype converter dynamics for Space Station application is presented. The converter is based on a three-phase six-pulse bridge concept. The testing includes details of the operation of the converter when it is driving an induction machine source/load. By adapting a field orientation controller (FOC) to the converter, four-quadrant operation of the induction machine from the converter has been achieved. Circuit modifications carried out to improve the performance of the converter are described. The performance of two 400-Hz induction machines powered by the converter with simple V/f regulation mode is reported. The testing and performance results for the converter utilizing the FOC, which provides the capability for rapid torque changes, speed reversal, and four-quadrant operation, are reported. I.E.

A90-38134* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
POWER TRANSMISSION CABLE DEVELOPMENT FOR THE SPACE STATION FREEDOM ELECTRICAL POWER SYSTEM
GREGORY V. SCHMITZ (NASA, Lewis Research Center, Cleveland, OH) and JOHN J. BIESS (TRW Space and Technology Group, Redondo Beach, CA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1989, p. 657-661.
Copyright

Power transmission cable is presently being evaluated under a NASA Lewis Research Center advanced development contract for application in the Space Station Freedom (SSF) electrical power system (EPS). Evaluation testing has been performed by TRW and NASA Lewis Research Center. The results of this development contract are presented. The primary cable design goals are to provide (1) a low characteristic inductance to minimize line voltage drop at 20 kHz, (2) electromagnetic compatibility control of the 20-kHz ac power current, (3) a physical configuration that minimizes ac resistance and (4) release of trapped air for corona-free operation. I.E.

A90-38174
HIGH ENERGY DENSITY CAPACITORS FOR SPACE POWER CONDITIONING
M. FRANK ROSE (Auburn University, AL) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1059-1066. Research supported by Auburn University. refs
Copyright

Several advanced capacitor designs are described for average power space applications. Each type is fundamentally limited by breakdown phenomena. All are intrinsically limited to maximum fields on the order of 1000 MV/m. None of the units have been space rated for energy storage applications. Several problems which must be solved before their use in space are presented as well as the current state of the art and estimates of developmental potential. I.E.

A90-38275* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
20 KHZ, 25 KVA NODE POWER TRANSFORMER
S. HUSSEY (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2667-2671.
(Contract NAS3-24667)
Copyright

The electrical and mechanical design information and the electrical and thermal testing performed on the 440-208-V rms, 20-kHz, 25-kVa prototype node transformer are summarized. The calculated efficiency of the node transformer is 99.3 percent based on core loss and copper loss test data, and its maximum calculated load regulation is 0.7 percent. The node transformer has a weight of 19.7 lb and has a power density of 0.8 lb/kW. The hot-spot temperature rise is estimated to be 33 C above the cold plate

mounting base. This proof-of-concept transformer design is a viable candidate for the space station Freedom application. I.E.

A90-42239#
SPACE-RADIATION QUALIFICATION OF A MICROPROCESSOR IMPLEMENTED FOR THE INTEL 80186
R. H. MAURER, J. D. KINNISON, B. M. ROMENESKO, B. G. CARKHUFF, and R. B. KING (Johns Hopkins University, Laurel, MD) IN: Annual AIAA/Utah State University Conference on Small Satellites, 2nd, Logan, UT, Sept. 18-21, 1988, Proceedings. Logan, UT, Utah State University, 1988, 11 p. refs

An account is presented of the procedures required for space radiation environment-qualification of the 80186 16-bit microprocessor, whose 8-MHz capability renders it attractive for control of advanced experiments in LEO. Attention is given to results from single-event upset tests on the 80186. It is noted that the upset cross-section was not dependent on frequency in the 4-8-MHz range, and increased by 40 percent when the conductive heat sink was eliminated; this led to a 50-C temperature rise. These results are used to estimate the single-event upset rate for a typical LEO spacecraft mission. O.C.

A90-45179* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE OPTICAL MATERIALS AND SPACE QUALIFICATION OF OPTICS; PROCEEDINGS OF THE MEETING, ORLANDO, FL, MAR. 30, 31, 1989
ROBERT R. HALE, ED. (JPL, Pasadena, CA) Meeting sponsored by SPIE, New Mexico State University, JPL, et al. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 1118), 1989, 184 p. For individual items see A90-45180 to A90-45198.
(SPIE-1118) Copyright

The present conference on space optical materials discusses current metals and nonmetals-related processing R&D efforts, investigations of space optical effects, and the spaceborne qualification of optical components and systems. Attention is given to CVD SiC for optical applications, optical materials for space-based lasers, the high-efficiency acoustooptic and optoelectronic crystalline material Tl3AsSe3, HIPed Be for low-scatter cryogenic optics, durable solar-reflective surfacing for Be optics, thermal effects on Be mirrors, contamination effects on optical surfaces in the monolayer regime, and IR background signature survey experiment results. Also discussed are the contamination-control program for the EUE instrument, an optical multipass radiation system for the heating of levitated samples, optical sample-position sensing for electrostatic levitation, and the qualification of space lighting systems. O.C.

A90-45198
DEVELOPING AND QUALIFYING SPACE LIGHTING SYSTEMS
B. GUSCOTT, J. RICHTER, J. KISS, and S. HOLT (ILC Technology, Inc., Sunnyvale, CA) IN: Space optical materials and space qualification of optics; Proceedings of the Meeting, Orlando, FL, Mar. 30, 31, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 166-174. refs
Copyright

A development history is presented for lighting systems in the U.S. space program. Notable challenges to which designers successfully responded included the creation of a highly efficient metal-halide lamp capable of withstanding thermal and vibration environment requirements, the design of fluorescent luminaries able to withstand the 'ball-drop' test; and the identification of materials furnishing the requisite thermal and mechanical stability levels. The role played by quality assurance/quality control methods in the production of space-qualified hardware is stressed. O.C.

N90-20085*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AEROSPACE INDUCTION MOTOR ACTUATORS DRIVEN FROM A 20-KHZ POWER LINK
IRVING G. HANSEN Jan. 1990 5 p Presented at the 4th International Conference on Power Electronics and Variable Speed Drives, London, England, 17-19 Jul. 1990; sponsored by Institution of Electrical Engineers
(NASA-TM-102482; E-5272; NAS 1.15:102482) Avail: NTIS HC A01/MF A01 CSCL 21E

Aerospace electromechanical actuators utilizing induction motors are under development in sizes up to 40 kW. While these actuators have immediate application to the Advanced Launch System (ALS) program, several potential applications are currently under study including the Advanced Aircraft Program. Several recent advances developed for the Space Station Freedom have allowed induction motors to be selected as a first choice for such applications. Among these technologies are bi-directional electronics and high frequency power distribution techniques. Each of these technologies are discussed with emphasis on their impact upon induction motor operation. Author

N90-20307# University of Southern California, Los Angeles. Electronic Sciences Lab.
JOINT SERVICES ELECTRONICS PROGRAM RESEARCH IN ELECTRONICS Annual Report No. 2, 1 Jan. - 31 Dec. 1989
W. H. STEIER 5 Jan. 1990 59 p
(Contract F49620-88-C-0067)
(AD-A217745) Avail: NTIS HC A04/MF A01 CSCL 09/5

Reviews are presented in several areas of electronic science. Some topics of discussion are: Selective Area Epitaxial Growth of Photonic Structures by Metalorganic Chemical Vapor Deposition; Strain Induced Metastability in Heterostructures: Some Investigations of Molecular Beam Epitaxial Growth and Interconversion of Metastable States; Electrooptic Devices for Optical Information Processing and Computing Applications; Optoelectronic and Quantum Structures Using Pristine and Irradiated Organic Compounds; Research to Improve Long Wavelength Infrared Semiconductor Opto-Electronic Devices;. A Spectroscopic Study of Basic Processes in Electrically Excited Materials; Nonlinear Optical Waveguiding in Compound Semiconductors; Parallel Optical Processing in Photorefractive Materials; Spread Spectrum Receiver Design for Intense Jamming Environments; Basic Research in C3 Distributed Databases; Segmentation and 2-D Motion Estimation of Noisy Image Sequences; Mathematical Modelling and Control of Complex Systems - Application to Piezoelectrically Coated Large Space Structures; and Knowledge-Based Interpretation of Aerial Images. GRA

N90-24491# ETEL S.A., Motiers (Switzerland).
DESIGN AND USE OF BRUSHLESS DC MOTOR WITHOUT DETENT TORQUE
N. WAVRE *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 197-201 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Two applications of motors which cannot accept a residual detent torque due to the rotor magnets are presented. The first application concerns the joint mechanism of the Synchronous Meteorological Satellite/HERA project. The brushless torque motor drives a reversible harmonic drive with a high gear ratio of 500. The motor is designed to produce a stall torque of 3.0 Nm with a total imput power of 30 W for a total weight of 1.5 kg, with a no load speed of 500 rpm. The second application concerns the driving mechanism of an infrared sensor. The need to take all geometrical and magnetic parameters into consideration in designing space mechanisms is stressed. ESA

N90-24507# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
ELECTRICAL CONNECTOR FOR OPERATION IN SPACE
NEIL CABLE and Y. DOHAN (Souriau, Paray, France) *In its* Fourth European Space Mechanisms and Tribology Symposium p 305-309 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The design of electrical connectors able to operate in space vacuum conditions is discussed. These connectors are to be operated by a manipulator arm or by an astronaut during

extravehicular activities. The need for such connectors in the Columbus program which incorporates replacement units is stressed. Design guidelines established by ESTEC are presented. Verification of preferred concepts in space simulation tests is described. Test results show that suitable contact design and arrangements can be made. ESA

N90-26057# Institut National Polytechnique, Grenoble (France). Unite Genie Materiel.
HEAVY ION TESTS ON PROGRAMMABLE VLSI Ph.D. Thesis [TEST AUX IONS LOURDS DE VLSI PROGRAMMABLES]
ANTOINE PROVOST-GRELLIER 1989 175 p IN FRENCH; ENGLISH summary
(ETN-90-97254) Avail: NTIS HC A08/MF A01

The natural radiative environment in space was shown to induce anomalies in satellite borne microelectronics. The qualification strategies which allow choice of the less vulnerable circuits are defined. The upset phenomenon is one of the most critical radiative effects on integrated circuits. Different test strategies are shown for programmable integrated circuits. An experimental test equipment was developed and a test methodology approach was validated by experiments using different heavy ion simulators. ESA

14

DATA & COMMUNICATION SYSTEMS

Communication and data storage or retrieval systems. Includes control systems and also computer networks and software.

A90-31957 TRW, Inc., Redondo Beach, CA.
OPTOMECHANICAL DESIGN OF LASER TRANSMITTERS AND RECEIVERS; PROCEEDINGS OF THE MEETING, LOS ANGELES, CA, JAN. 16, 17, 1989
BERNARD D. SEERY, ED. (TRW, Inc., Redondo Beach, CA) Meeting sponsored by SPIE, New Mexico State University, JPL, et al. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 1044), 1989, 285 p. For individual items see A90-31958 to A90-31985.
(SPIE-1044) Copyright

Various papers on optomechanical design of laser transmitters and receivers are presented. Individual topics addressed include: semiconductor lasers for space beacons and communications, optomechanical design of laser diode collimators for free space communications, hybrid current driver designed for a space-borne laser transmitter, space-qualified laser diode assembly for the NASA/DDLT program, optomechanical design of a grating power combiner for laser diodes, spectrally stable miniature external cavity laser oscillator, NASA direct detection laser diode driver, optomechanical design of a space-based diode laser transmitter assembly, transmitter and receiver technology for the NASA/DDLT, direct detection avalanche photodiode receiver design for the NASA/DDLT, laser-assisted remote temperature measurement, optical communications for a space station payload interface, diode laser spatial diversity transmitter, design of reflecting laser diode objective, diffractive microoptics for laser communications, phase-conjugated transmitter subsystem for laser communications, minimization of laser diode relative intensity noise. C.D.

A90-31972
OPTICAL COMMUNICATIONS FOR A SPACE STATION PAYLOAD INTERFACE
ANDREW SCHMIT, DENES KASSAI, GEORGE GELB, and JOEL GUGGENMOS (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) IN: Optomechanical design of laser transmitters and receivers; Proceedings of the Meeting, Los Angeles, CA, Jan. 16, 17, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 163-172.
Copyright

The Optical Data Subsystem (ODS) of the NASA Flat Plate Interface Prototype project was designed to transmit and receive data simultaneously across a contactless Space Station payload interface. The ODS uses optical fiber, GRIN lenses, and electronics to accomplish the project requirements. This paper describes the design rationale, analysis, and fabrication and assembly processes, as well as test and evaluation results for the ODS. C.D.

A90-32945#
DATA STORAGE SYSTEMS FOR SPACE MISSIONS IN THE 1990S
FRANZ J. ROMBECK and FRANZ PITTERMANN Dornier Post (ISSN 0012-5563), no. 4, 1989-no. 1, 1990, p. 20-22.
Copyright

Storage technologies applicable to future space missions are discussed. Proposed space missions require access to data in the range of several tens of gigabits. Technologies for permanent data storage are: (1) magnetic storage media, (2) optical storage media, and (3) semiconductor storage media. The storage capabilities of magnetic, optical, and semiconductor media, such as bubble memories, CD ROM, and PROMS, are examined in terms of data storage and retrieval requirements for the Columbus project. I.F.

A90-39577
PROBLEMS OF ANTENNA TECHNOLOGY [PROBLEMY ANTENNOI TEKHNIKI]
LEV D. BAKHRAKH, ED. and D. I. VOSKRESENSKII, ED. Moscow, Izdatel'stvo Radio i Sviaz', 1989, 368 p. In Russian. No individual items are abstracted in this volume.
Copyright

The current state of antenna development and various problems in developing antenna technology are examined. Consideration is given to the prediction of the parameters that determine electromagnetic compatibility, numerical modeling of phased-array networks, and methods for setting radiation patterns. Various types of antennas are discussed, including multifrequency scanning networks, multiray networks, adaptive networks, radiooptic networks, large mirror antennas, and antenna systems on automated space stations. Other topics include scanning antennas based on a refractive lens, statistical synthesis of antennas, the operation of antenna complexes, the electronic and spectral characteristics of antenna networks, and the economic aspects of antenna construction and operation. R.B.

A90-40994
PRINTED TECHNOLOGY FOR SELF-SUPPORTING PLANAR ARRAYS
J. BARBERO, C. MARTIN, and J. VASSAL'LO (IEC, Madrid, Spain) IN: International Conference on Radar 89, Paris, France, Apr. 24-28, 1989, Proceedings. Volume 1. Boulogne-Billancourt, France, RADAR 89, 1989, p. 293-297.
Copyright

Thermal and mechanical deformations in orbit represent one of the major constraints in the design of large antennas that are likely to be designed based on large printed arrays. Two alternatives to the classical patch that can improve either of these critical aspects of antenna behavior are presented. The results obtained with radiating circular slots compared to those obtained with patches are discussed. These show that they are very similar from the point of view of radiation pattern, gain, coverage and impedance, but they have the advantage of having an almost metallic radiating facet with a quasi-symmetric structure thus showing lower thermal deformations. R.E.P.

A90-43118* McDonnell-Douglas Space Systems Co., Houston, TX.
GENERAL UPPER BOUND ON SINGLE-EVENT UPSET RATE
DEAN CHLOUBER, PAT O'NEILL, and JIM POLLOCK (McDonnell Douglas Space Systems Co., Houston, TX) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 37, pt. 2, April 1990, p. 1065-1071. refs

(Contract NAS9-17650; NAS9-18200)
Copyright

A technique of predicting an upper bound on the rate at which single-event upsets due to ionizing radiation occur in semiconducting memory cells is described. The upper bound on the upset rate, which depends on the high-energy particle environment in earth orbit and accelerator cross-section data, is given by the product of an upper-bound linear energy-transfer spectrum and the mean cross section of the memory cell. Plots of the spectrum are given for low-inclination and polar orbits. An alternative expression for the exact upset rate is also presented. Both methods rely only on experimentally obtained cross-section data and are valid for sensitive bit regions having arbitrary shape. I.E.

A90-48542
MIR COMMUNICATIONS AND CONTROL
J. BRANEGAN British Interplanetary Society, Journal (ISSN 0007-084X), vol. 43, Sept. 1990, p. 411-416.
Copyright

Remote ground control of Soviet manned and unmanned spacecraft is discussed. It is pointed out that, while this equipment was originally applied to unmanned Progress supply craft, Star class space tugs, and test vehicles, these techniques are now being used to control both the flight envelope of the Mir/Kvant space complex and its internal equipment. Use of remote control to solve pointing problems aboard a manned craft is illustrated and details involved in recognizing the remote control signal are presented. The Mir spacecraft broadcasts a spread spectrum signal on or about 66.130 MHz and actual center frequency depends on Doppler shift and which ground control station or communications ship is involved. A 60-day calendar of remote control signals is presented for December 1987 to January 1988. L.K.S.

A90-50550* City Univ. of New York, Bronx.
USING ADA TASKS TO SIMULATE OPERATING EQUIPMENT
LOUIS A. DEACETIS (Bronx Community College, NY), ORON SCHMIDT, and KUMAR KRISHEN (NASA, Johnson Space Center, Houston, TX) Computers in Physics (ISSN 0894-1866), vol. 4, Sept.-Oct. 1990, p. 521-525. refs
Copyright

A method of simulating equipment using Ada tasks is discussed. Individual units of equipment are coded as concurrently running tasks that monitor and respond to input signals. This technique has been used in a simulation of the space-to-ground Communications and Tracking subsystem of Space Station Freedom. Author

A90-50646
ANNUAL COMPUTER SECURITY APPLICATIONS CONFERENCE, 5TH, TUCSON, AZ, DEC. 4-8, 1989, PROCEEDINGS
Conference sponsored by the American Society for Industrial Security, Aerospace Computer Security Associates, IEEE, and AIAA. Los Alamitos, CA, IEEE Computer Society Press, 1990, 374 p. For individual items see A90-50647 to A90-50649.
Copyright

Computer and data security issues are addressed in reviews and reports. Topics discussed include computer crime, CALS data security and integrity, human issues, OSI security standards, risk management, security standards for open systems, architectures for trusted systems, TCB subsets, issues affecting Gemini users, civil-sector security, and software development for security. Consideration is given to Space Station information security, database security, network security, cryptographic applications, integrity mechanisms, database design for MLS, security for command and control systems, and trusted distribution. T.K.

A90-51164
THE EUROPEAN DATA RELAY SYSTEM - PRESENT CONCEPT AND FUTURE EVOLUTION
GIULIANO BERRETTA, AGOSTINO DE AGOSTINI (ESA, Directorate of Telecommunications, Paris, France), and ANTONY DICKINSON (ESTEC, Noordwijk, Netherlands) IEEE, Proceedings (ISSN 0018-9219), vol. 78, July 1990, p. 1152-1164.
Copyright

After briefly reviewing the users' requirements and the results of traffic scenario simulations needed to size the system, the design of the European data relay system (DRS) (ground and space segment) is presented in detail. The interrelationship with the other data relay systems (NASA tracking and data relay satellite system (TDRSS) and the Japanese data relay and tracking satellite system (DRTSS)) is discussed together with the current status of systems interoperability. The evolution of DRS into a second generation, foreseen for operation at the beginning of next century, is outlined in terms of user scenario, improved spacecraft and system configurations, and technology developments needed. I.E.

A90-51177
MANAGEMENT AND CONTROL OF CCSDS CROSS-SUPPORT SERVICES
MICHAEL A. ALLEN (Mitre Corp., Greenbelt, MD) IEEE, Proceedings (ISSN 0018-9219), vol. 78, July 1990, p. 1304-1310. refs
Copyright

A candidate architecture for management and control of Consultative Committee for Space Data Systems (CCSDS) services is presented. An operations concept is presented. Candidate management procedures and a management information base for the resources to be managed are suggested. This architecture is based on concepts of network management of computer and telecommunication networks which are under study by other international standards bodies such as the International Organization for Standardization (ISO) and the International Telephone and Telegraph Consultative Committee (CCITT). I.E.

A90-51307
VIDEO COMPRESSION FOR MANNED SPACE MISSIONS
R. VIOLA (ESA, Noordwijk, Netherlands), L. CHIARIGLIONE (Centro Studi e Laboratori Telecomunicazioni S.p.A., Turin, Italy), and R. RUSSO (Selenia Spazio S.p.A., Misterbianco, Italy) IN: GLOBECOM '89 - IEEE Global Telecommunications Conference and Exhibition, Dallas, TX, Nov. 27-30, 1989, Conference Record. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 250-254. refs
Copyright

A complete design solution for transmitting video compressed images from orbiting spacecraft is presented. The design drives were maximum flexibility and minimization of equipment weight, power, and dimensions. The video multiplexing system is designed to maintain asynchronous access to the link while preserving an internally synchronous structure. Reed-Solomon codes are used to obtain a practically error-free system with low overhead. Coder and decoder are able to work asynchronously. The selected coding algorithm is DCT based and allows a variable bit rate from 64 to 2048 Kbit/s and also transmission of fixed images with full resolution. The presented design results show that only by developing ad hoc VLSI chips can the severe constraints for mass and power consumption of the flight hardware be met. I.E.

A90-51333* Lockheed Engineering and Sciences Co., Houston, TX.
KU-BAND INTERFERENCES FOR THE SPACE STATION MULTIPLE ACCESS LINK
Y. C. LOH, K. P. LAND (Lockheed Engineering and Sciences Co., Houston, TX), D. ARNDT, and S. W. NOVOSAD (NASA, Johnson Space Center, Houston, TX) IN: GLOBECOM '89 - IEEE Global Telecommunications Conference and Exhibition, Dallas, TX, Nov. 27-30, 1989, Conference Record. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 1382-1388.
Copyright

The multiple access (MA) system, an essential part of the United States Space Station, will be used to provide simultaneous communication services, voice and command, telemetry and video, between the Space Station and all the different coorbiting user vehicles. The system is designed to operate in the Ku-band

frequencies between 14 GHz and 14.89 GHz. Within this band, there are other users that could pose serious interference potential. The extent of the interference and its impact on the system operations are analyzed using a Monte Carlo simulation. Worst-case analysis indicated that certain links are very susceptible to interference. Mitigation techniques involving both hardware changes and operation constraints are presented. With the modification of some of the design and implementation of some of the mitigation techniques, the interference levels were found to be only a few percent and to occur in a burst manner. I.E.

A90-51362
SATELLITE APPLICATIONS OF SPREAD SPECTRUM FREQUENCY HOPPING TECHNIQUES
F. ANANASSO (Roma II, Universita, Rome, Italy), G. BJORNSTROM (ESA, Noordwijk, Netherlands), R. CRESCIMBENI, G. GALLINARO, and E. SAGGESE (Space Engineering, Rome, Italy) IN: GLOBECOM '89 - IEEE Global Telecommunications Conference and Exhibition, Dallas, TX, Nov. 27-30, 1989, Conference Record. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1989, p. 1738-1743. refs
(Contract ESA-7497/87-NL-JG)
Copyright

Some features of frequency-hopping (FH) code-division multiple-access (CDMA) techniques are discussed in connection with the mitigation of the effects of interferences in multiple-user satellite systems. The authors show how some specific satellite applications (data relay satellites, the Space Station, mobile satellite systems, and very small aperture terminals) may take advantage of CDMA features offered by spread-spectrum modulations. FH is briefly reviewed as a valid alternative to direct-sequence spread-spectrum methods, and FH techniques are analyzed in a specific scenario concerning Space Station communications. The design of spreading and forward error correction codes for FH systems is addressed. I.E.

N90-20112*# Harris Corp., Palm Bay, FL. Government Aerospace Systems Div.
PROXIMITY OPERATIONS CONCEPT DESIGN STUDY, TASK 6 Final Report
A. N. WILLIAMS Apr. 1990 294 p
(Contract NAS1-18225)
(NASA-CR-181971; JA-1264-6; NAS 1.26:181971) Avail: NTIS HC A13/MF A02 CSCL 17/2

The feasibility of using optical technology to perform the mission of the proximity operations communications subsystem on Space Station Freedom was determined. Proximity operations mission requirements are determined and the relationship to the overall operational environment of the space station is defined. From this information, the design requirements of the communication subsystem are derived. Based on these requirements, a preliminary design is developed and the feasibility of implementation determined. To support the Orbital Maneuvering Vehicle and National Space Transportation System, the optical system development is straightforward. The requirements on extra-vehicular activity are such as to allow large fields of uncertainty, thus exacerbating the acquisition problem; however, an approach is given that could mitigate this problem. In general, it is found that such a system could indeed perform the proximity operations mission requirement, with some development required to support extra-vehicular activity. Author

N90-20651*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
GRAPHICS TECHNOLOGY IN SPACE APPLICATIONS (GTSA 1989)
SANDY GRIFFIN, ed. Aug. 1989 247 p Workshop held in Houston, TX, 12-14 Apr. 1989; sponsored by NASA, Washington and Houston Univ., Clear Lake
(NASA-CP-3045; S-594; NAS 1.55:3045) Avail: NTIS HC A11/MF A02 CSCL 09/2

This document represents the proceedings of the Graphics Technology in Space Applications, which was held at NASA Lyndon B. Johnson Space Center on April 12 to 14, 1989 in Houston, Texas. The papers included in these proceedings were published in general as received from the authors with minimum modifications and editing. Information contained in the individual papers is not to be construed as being officially endorsed by NASA.

N90-20661*# McDonnell-Douglas Space Systems Co., Houston, TX.
APPLICATIONS OF GRAPHICS TO SUPPORT A TESTBED FOR AUTONOMOUS SPACE VEHICLE OPERATIONS
K. R. SCHMECKPEPER, J. P. ALDRIDGE, S. BENSON, S. HORNER, A. KULLMAN, T. MULDER, W. PARROTT, D. ROMAN, G. WATTS, and DANIEL C. BOCHSLER (LinCom Corp., Houston, TX.) *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 65-71 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 09/2

Researchers describe their experience using graphics tools and utilities while building an application, AUTOPS, that uses a graphical Machintosh (TM)-like interface for the input and display of data, and animation graphics to enhance the presentation of results of autonomous space vehicle operations simulations. AUTOPS is a test bed for evaluating decisions for intelligent control systems for autonomous vehicles. Decisions made by an intelligent control system, e.g., a revised mission plan, might be displayed to the user in textual format or he can witness the effects of those decisions via out of window graphics animations. Although a textual description conveys essentials, a graphics animation conveys the replanning results in a more convincing way. Similarily, iconic and menu-driven screen interfaces provide the user with more meaningful options and displays. Presented here are experiences with the SunView and TAE Plus graphics tools used for interface design, and the Johnson Space Center Interactive Graphics Laboratory animation graphics tools used for generating out of the window graphics. Author

N90-20673*# Lockheed Engineering and Sciences Co., Houston, TX.
SPACE STATION FREEDOM INTEGRATED FAULT MODEL
FRED J. BECKER *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 155-163 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 09/2

A demonstration of an integrated fault propagation model for Space Station Freedom is described. The demonstration uses a HyperCard graphical interface to show how failures can propagate from one component to another, both within a system and between systems. It also shows how hardware failures can impact certain defined functions like reboost, atmosphere maintenance or collision avoidance. The demonstration enables the user to view block diagrams for the various space station systems using an overview screen, and interactively choose a component and see what single or dual failure combinations can cause it to fail. It also allows the user to directly view the fault model, which is a collection of drawing and text listings accessible from a guide screen. Fault modeling provides a useful technique for analyzing individual systems and also interactions between systems in the presence of multiple failures so that a complete picture of failure tolerance and component criticality can be achieved. Author

N90-20679*# Lockheed Missiles and Space Co., Huntsville, AL.
SES CUPOLA INTERACTIVE DISPLAY DESIGN ENVIRONMENT
BANG Q. VU and KEVIN R. KIRKHOFF *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 205-214 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 09/2

The Systems Engineering Simulator, located at the Lyndon B. Johnson Space Center in Houston, Texas, is tasked with providing a real-time simulator for developing displays and controls targeted for the Space Station Freedom. These displays and controls will exist inside an enclosed workstation located on the space station. The simulation is currently providing the engineering analysis

environment for NASA and contractor personnel to design, prototype, and test alternatives for graphical presentation of data to an astronaut while he performs specified tasks. A highly desirable aspect of this environment is to have the capability to rapidly develop and bring on-line a number of different displays for use in determining the best utilization of graphics techniques in achieving maximum efficiency of the test subject fulfilling his task. The Systems Engineering Simulator now has available a tool which assists in the rapid development of displays for these graphic workstations. The Display Builder was developed in-house to provide an environment which allows easy construction and modification of displays within minutes of receiving requirements for specific tests. Author

N90-20680*# Lockheed Engineering and Sciences Co., Houston, TX.
ISSUES IN VISUAL SUPPORT TO REAL-TIME SPACE SYSTEM SIMULATION SOLVED IN THE SYSTEMS ENGINEERING SIMULATOR
VINCENT K. YUEN *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 215-218 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 09/2

The Systems Engineering Simulator has addressed the major issues in providing visual data to its real-time man-in-the-loop simulations. Out-the-window views and CCTV views are provided by three scene systems to give the astronauts their real-world views. To expand the window coverage for the Space Station Freedom workstation a rotating optics system is used to provide the widest field of view possible. To provide video signals to as many viewpoints as possible, windows and CCTVs, with a limited amount of hardware, a video distribution system has been developed to time-share the video channels among viewpoints at the selection of the simulation users. These solutions have provided the visual simulation facility for real-time man-in-the-loop simulations for the NASA space program. Author

N90-20683*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
REAL-TIME GRAPHICS FOR THE SPACE STATION FREEDOM CUPOLA, DEVELOPED IN THE SYSTEMS ENGINEERING SIMULATOR
MICHAEL T. RED and PHILIP W. HESS (Lockheed Missiles and Space Co., Huntsville, AL.) *In its* Graphics Technology in Space Applications (GTSA 1989) p 235-247 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 09/2

Among the Lyndon B. Johnson Space Center's responsibilities for Space Station Freedom is the cupola. Attached to the resource node, the cupola is a windowed structure that will serve as the space station's secondary control center. From the cupola, operations involving the mobile service center and orbital maneuvering vehicle will be conducted. The Systems Engineering Simulator (SES), located in building 16, activated a real-time man-in-the-loop cupola simulator in November 1987. The SES cupola is an engineering tool with the flexibility to evolve in both hardware and software as the final cupola design matures. Two workstations are simulated with closed-circuit television monitors, rotational and translational hand controllers, programmable display pushbuttons, and graphics display with trackball and keyboard. The displays and controls of the SES cupola are driven by a Silicon Graphics Integrated Raster Imaging System (IRIS) 4D/70 GT computer. Through the use of an interactive display builder program, SES, cupola display pages consisting of two dimensional and three dimensional graphics are constructed. These display pages interact with the SES via the IRIS real-time graphics interface. The focus is on the real-time graphics interface applications software developed on the IRIS. Author

N90-22307*# TRW, Inc., Redondo Beach, CA.
SPACECRAFT COMMAND VERIFICATION: THE AI SOLUTION
LORRAINE M. FESQ, AMY STEPHAN, and BRIAN K. SMITH (California Univ., Los Angeles.) *In* NASA, Goddard Space Flight Center, The 1990 Goddard Conference on Space Applications of Artificial Intelligence p 157-163 May 1990
Avail: NTIS HC A15/MF A02 CSCL 09/2

Recently, a knowledge-based approach was used to develop a system called the Command Constraint Checker (CCC) for TRW. CCC was created to automate the process of verifying spacecraft command sequences. To check command files by hand for timing and sequencing errors is a time-consuming and error-prone task. Conventional software solutions were rejected when it was estimated that it would require 36 man-months to build an automated tool to check constraints by conventional methods. Using rule-based representation to model the various timing and sequencing constraints of the spacecraft, CCC was developed and tested in only three months. By applying artificial intelligence techniques, CCC designers were able to demonstrate the viability of AI as a tool to transform difficult problems into easily managed tasks. The design considerations used in developing CCC are discussed and the potential impact of this system on future satellite programs is examined. Author

N90-22952*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
A COMPUTER GRAPHICS SYSTEM FOR VISUALIZING SPACECRAFT IN ORBIT
DON E. EYLES *In* NASA, Ames Research Center, Spatial Displays and Spatial Instruments 10 p Jul. 1989
Avail: NTIS HC A99/MF A04 CSCL 09/2

To carry out unanticipated operations with resources already in space is part of the rationale for a permanently manned space station in Earth orbit. The astronauts aboard a space station will require an on-board, spatial display tool to assist the planning and rehearsal of upcoming operations. Such a tool can also help astronauts to monitor and control such operations as they occur, especially in cases where first-hand visibility is not possible. A computer graphics visualization system designed for such an application and currently implemented as part of a ground-based simulation is described. The visualization system presents to the user the spatial information available in the spacecraft's computers by drawing a dynamic picture containing the planet Earth, the Sun, a star field, and up to two spacecraft. The point of view within the picture can be controlled by the user to obtain a number of specific visualization functions. The elements of the display, the methods used to control the display's point of view, and some of the ways in which the system can be used are described. Author

N90-22987*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PROCEEDINGS OF THE 3RD ANNUAL CONFERENCE ON AEROSPACE COMPUTATIONAL CONTROL, VOLUME 1
DOUGLAS E. BERNARD, ed. and GUY K. MAN, ed. 15 Dec. 1989 487 p Conference held in Oxnard, CA, Nov. 1989; sponsored in cooperation with NASA, NSF, and DOD
(Contract NAS7-198)
(NASA-CR-186446; JPL-PUBL-89-45-VOL-1; NAS 1.26:186446)
Avail: NTIS HC A21/MF A03 CSCL 09/2

Conference topics included definition of tool requirements, advanced multibody component representation descriptions, model reduction, parallel computation, real time simulation, control design and analysis software, user interface issues, testing and verification, and applications to spacecraft, robotics, and aircraft.

N90-23040*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PROCEEDINGS OF THE 3RD ANNUAL CONFERENCE ON AEROSPACE COMPUTATIONAL CONTROL, VOLUME 2
DOUGLAS E. BERNARD, ed. and GUY K. MAN, ed. 15 Dec. 1989 464 p Conference held in Oxnard, CA, Nov. 1989; sponsored in cooperation by NASA, NSF, and DOD
(Contract NAS7-918)
(NASA-CR-186447; JPL-PUBL-89-45-VOL-2; NAS 1.26:186447)
Avail: NTIS HC A20/MF A03 CSCL 09/2

This volume of the conference proceedings contain papers and discussions in the following topical areas: Parallel processing;

Emerging integrated capabilities; Low order controllers; Real time simulation; Multibody component representation; User environment; and Distributed parameter techniques.

N90-23457*# Research Inst. for Advanced Computer Science, Moffett Field, CA.
PERFORMANCE ANALYSIS OF CCSDS PATH SERVICE
MARJORY J. JOHNSON Apr. 1989 16 p
(Contract NCC2-387)
(NASA-CR-180699; NAS 1.26:180699; RIACS-TR-89.13) Avail: NTIS HC A03/MF A01 CSCL 09/6

A communications service, called Path Service, is currently being developed by the Consultative Committee for Space Data Systems (CCSDS) to provide a mechanism for the efficient transmission of telemetry data from space to ground for complex space missions of the future. This is an important service, due to the large volumes of telemetry data that will be generated during these missions. A preliminary analysis of performance of Path Service is presented with respect to protocol-processing requirements and channel utilization. Author

N90-24286# Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).
COLUMBUS ONBOARD FDIR CONCEPT
A. KELLNER, R. KUEKE, and J. SVED *In* ESA, Second European In-Orbit Operations Technology Symposium p 25-29 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

The Generic Element Management (GEM) software of Columbus will feature as one of its functions, a Failure Detection Isolation and Recovery (FDIR) system of high intelligence. The main underlying technological considerations comprise the capability to cope with locally erroneous data, incomplete data and tolerance to locally erroneous coding of the fault management database. These considerations have led to the novel concept of connection matrices which represent generalized decision tables in the sense that entries are implication strengths between zero and unity representing the degree of evidence a symptom bears to an anomaly. The methodology for the automatic computation and the processing of these implication strengths in the diagnostic process and the corresponding prototype, CONNEX, is described. Subsequent to the basic technology the operational embedding of the system into the overall fault management strategy is described. In particular, the interaction of CONNEX with REFLEX, the Automated Procedure implementation of exception handling during a reconfiguration sequence, within the hierarchical GEM concept is addressed. ESA

N90-24987*# Houston Univ., TX. Dept. of Psychology.
KNOWLEDGE-BASED CONTROL OF AN ADAPTIVE INTERFACE Final Report
ROY LACHMAN *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 2 12 p Dec. 1989
Avail: NTIS HC A08/MF A01 CSCL 05/8

The analysis, development strategy, and preliminary design for an intelligent, adaptive interface is reported. The design philosophy couples knowledge-based system technology with standard human factors approaches to interface development for computer workstations. An expert system has been designed to drive the interface for application software. The intelligent interface will be linked to application packages, one at a time, that are planned for multiple-application workstations aboard Space Station Freedom. Current requirements call for most Space Station activities to be conducted at the workstation consoles. One set of activities will consist of standard data management services (DMS). DMS software includes text processing, spreadsheets, data base management, etc. Text processing was selected for the first intelligent interface prototype because text-processing software can be developed initially as fully functional but limited with a small set of commands. The program's complexity then can be increased incrementally. The intelligent interface includes the operator's behavior and three types of instructions to the underlying application software are included in the rule base. A conventional expert-system inference engine searches the data base for antecedents to rules and sends the consequents of fired rules as commands to the underlying software. Plans for putting the expert system on top of a second application, a database management system, will be carried out following behavioral research on the first application. The intelligent interface design is suitable for use with ground-based workstations now common in government, industrial, and educational organizations. Author

N90-24988*# Stevens Inst. of Tech., Hoboken, NJ. Dept. of Electrical Engineering and Computer Science.
SOME ISSUES RELATED TO SIMULATION OF THE TRACKING AND COMMUNICATIONS COMPUTER NETWORK Final Report
ROBERT C. LACOVARA *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 2 11 p Dec. 1989
Avail: NTIS HC A08/MF A01 CSCL 17/2

The Communications Performance and Integration branch of the Tracking and Communications Division has an ongoing involvement in the simulation of its flight hardware for Space Station Freedom. Specifically, the communication process between central processor(s) and orbital replaceable units (ORU's) is simulated with varying degrees of fidelity. The results of investigations into three aspects of this simulation effort are given. The most general area involves the use of computer assisted software engineering (CASE) tools for this particular simulation. The second area of interest is simulation methods for systems of mixed hardware and software. The final area investigated is the application of simulation methods to one of the proposed computer network protocols for space station, specifically IEEE 802.4. Author

N90-25582# General Accounting Office, Washington, DC. Information Management and Technology Div.
SPACE OPERATIONS: NASA EFFORTS TO DEVELOP AND DEPLOY ADVANCED SPACECRAFT COMPUTERS. REPORT TO THE CHAIRMAN, SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS, COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY, HOUSE OF REPRESENTATIVES
SAMUEL W. BOWLIN et al. Mar. 1989 43 p
(GAO/IMTEC-89-17; B-234056) Avail: NTIS HC A03/MF A01; also available from GAO, Gaithersburg, MD HC first five copies free, additional copies $2.00

NASA faces great challenges in building and deploying computers for its spacecraft. The performance capabilities of existing NASA spacecraft computers are discussed as well as ongoing NASA and Department of Defense programs to develop and deploy advanced spacecraft computers, and NASA's plans for space station computers. The time lag between the availability of computer technology on the ground and the use of that technology in space in 8 to 20 years, outdating computers even before they are launched into space. NASA is aware of this problem, but needs to test computers for reliability in harsh environments and select a computer early in the design process. Time lags also occur with unavoidable launching delays - of sometimes as much as several years. Shortening the time lag could significantly increase spacecraft capabilities for collecting scientific data and possibly decrease future mission costs. The report recommends that NASA's Administrator consider further strengthening the agency's ongoing activities by establishing an independent expert panel to determine if additional might be taken to shorten the process. Case studies of five missions are appended. J.P.S.

N90-26048*# Alabama Univ., Huntsville.
LITERATURE CONCERNING CONTROL AND DISPLAY TECHNOLOGY APPLICABLE TO THE ORBITAL MANEUVERING VEHICLE (OMV)
24 Jul. 1990 168 p
(Contract NAG8-706)
(NASA-CR-186790; NAS 1.26:186790) Avail: NTIS HC A08/MF A01 CSCL 22/2

A review is presented of the literature concerning control and display technology that is applicable to the Orbital Maneuvering Vehicle (OMV), a system being developed by NASA that will enable

the user to remotely pilot it during a mission in space. In addition to the general review, special consideration is given to virtual image displays and their potential for use in the system, and a preliminary partial task analysis of the user's functions is also presented. Author

N90-27275*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
FIFTH CONFERENCE ON ARTIFICIAL INTELLIGENCE FOR SPACE APPLICATIONS
STEVE L. ODELL, comp. Washington May 1990 587 p Conference held in Huntsville, AL, 22-23 May 1990; sponsored in cooperation with Alabama Univ., Huntsville, IEEE, and AIAA
(NASA-CP-3073; M-627; NAS 1.55:3073) Avail: NTIS HC A25/MF A04 CSCL 09/2

The Fifth Conference on Artificial Intelligence for Space Applications brings together diverse technical and scientific work in order to help those who employ AI methods in space applications to identify common goals and to address issues of general interest in the AI community. Topics include the following: automation for Space Station; intelligent control, testing, and fault diagnosis; robotics and vision; planning and scheduling; simulation, modeling, and tutoring; development tools and automatic programming; knowledge representation and acquisition; and knowledge base/data base integration.

N90-27290*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
ATS DISPLAYS: A REASONING VISUALIZATION TOOL FOR EXPERT SYSTEMS
WILLIAM JOHN SELIG and JAMES D. JOHANNES (Alabama Univ., Huntsville.) *In its* Fifth Conference on Artificial Intelligence for Space Applications p 129-138 May 1990
Avail: NTIS HC A25/MF A04 CSCL 09/2

Reasoning visualization is a useful tool that can help users better understand the inherently non-sequential logic of an expert system. While this is desirable in most all expert system applications, it is especially so for such critical systems as those destined for space-based operations. A hierarchical view of the expert system reasoning process and some characteristics of these various levels is presented. Also presented are Abstract Time Slice (ATS) displays, a tool to visualize the plethora of interrelated information available at the host inferencing language level of reasoning. The usefulness of this tool is illustrated with some examples from a prototype potable water expert system for possible use aboard Space Station Freedom. Author

N90-27775# European Space Agency, Paris (France).
CUIS USER'S MANUAL
JOCELYNE LANDEAU, ed. Apr. 1990 119 p
(ESA-TM-03; ISBN-92-9092-009-2; ETN-90-97503) Copyright
Avail: NTIS HC A06/MF A01

A user guide for Columbus Utilization Information System (CUIS) is presented. A general introduction is given. The required equipment, the installation of CUIS onto a personal computer, and connection of CUIS to host computer are described. Communication tools are described: conferencing, electronic mail and the notice board. Tips on using the CUIS editor are given. The local information retrieval service, hypertext is described. The online information retrieval service is described. An aid to creating an automatic connection and an item on troubleshooting are included. ESA

N90-28047*# David Sarnoff Research Center, Princeton, NJ.
LINEAR LASER DIODE ARRAYS FOR IMPROVEMENT IN OPTICAL DISK RECORDING FOR SPACE STATIONS Final Report, Mar. 1988 - Sep. 1989
G. A. ALPHONSE, D. B. CARLIN, and J. C. CONNOLLY Washington, DC NASA Sep. 1990 88 p
(Contract NAS1-18226)
(NASA-CR-4322; NAS 1.26:4322; DSRC-CR-90-001) Avail: NTIS HC A05/MF A01 CSCL 14/5

The design and fabrication of individually addressable laser diode arrays for high performance magneto-optic recording systems are presented. Ten diode arrays with 30 mW cW light output, linear light vs. current characteristics and single longitudinal mode spectrum were fabricated using channel substrate planar (CSP) structures. Preliminary results on the inverse CSP structure, whose fabrication is less critically dependent on device parameters than the CSP, are also presented. The impact of systems parameters and requirements, in particular, the effect of feedback on laser design is assessed, and techniques to reduce feedback or minimize its effect on systems performance, including mode-stabilized structures, are evaluated. Author

N90-28365# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
APPLICATIONS OF X WINDOWS IN ASTRONAUTICS: STATUS AND PROSPECTS [X-WINDOWS ANWENDUNGEN IN DER RAUMFAHRT: STATUS UND AUSBLICK]
C. SIELAFF (Erno Raumfahrttechnik G.m.b.H. Bremen, Germany, F.R.) 1990 12 p In GERMAN
(MBB-UO-0082-90-PUB; ETN-90-97350) Avail: NTIS HC A03/MF A01

Applications of the X window system (software) and the requirements for a windowing system in a complex real time environment are investigated. Although the requirements are specific for astronautics, they can also, in the same or in similar form, be applied to the daily industrial practice. The complexity of the ESA program Columbus APM (Attached Pressurized Module) can be compared with that of e.g., the control and survey of a power supply and simultaneously performing complex scientific experiments. The presented studies and the further developments in astronautics have to show whether X windows and the tools based thereon can master such complex tasks, and whether the advanced workstation technology allows an easy operation of complex systems. ESA

15

LIFE SCIENCES/HUMAN FACTORS/SAFETY

Studies, models, planning, analyses and simulations of habitability issues. Includes the performance and well-being of the crew and crew rescue.

A90-32835* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NEAR-LIMIT FLAME SPREAD OVER A THIN SOLID FUEL IN MICROGRAVITY
SANDRA L. OLSON (NASA, Lewis Research Center, Cleveland, OH), PAUL V. FERKUL, and JAMES S. T'IEN (Case Western Reserve University, Cleveland, OH) IN: *Symposium (International)* on Combustion, 22nd, Seattle, WA, Aug. 14-19, 1988, Proceedings. Pittsburgh, PA, Combustion Institute, 1989, p. 1213-1219; Discussion, p. 1220-1222. refs
(Contract NGT-50088)
Copyright

Diffusion flame spread over a thin solid fuel in quiescent and slowly moving atmospheres is studied in microgravity. The flame behavior is observed to depend strongly on the magnitude of the relative velocity between the flame and the atmosphere. In particular, a low velocity quenching limit is found to exist in low oxgen environments. Using both the microgravity results and previously published data at high opposed-flow velocities, the flame spread behavior is examined over a wide velocity range. A flammability map using molar oxygen percentages and characteristic relative velocities as coordinates is constructed. Trends of flame spread rate are determined and mechanisms for flame extinction are discussed. Author

A90-34029
SOVIET SPACE FLIGHT - THE HUMAN ELEMENT

VICTORIA GARSHNEK (George Washington University, Washington, DC) ASGSB Bulletin (ISSN 0898-4697), vol. 1, May 1988, p. 67-80. refs
Copyright

After an overview of Soviet manned space missions of the period 1961-1988, and the description of the space station Mir, the paper concentrates on the methods of preparing cosmonauts for long-time missions at reduced-gravity conditions and on methods designed to counteract the absence of gravity. Particular attention is given to the psychological selection and preparation of cosmonauts, their medical training for medical emergencies that may arise in space, and the physiological and psychological countermeasures used to prevent complete adaptation to microgravity, such as exercises and antigravity suits, water and salt loading, nutrition, pharmacologic agents, and postflight recovery activities. I.S.

A90-34034* National Aeronautics and Space Administration, Washington, DC.
FUTURE PROSPECTS FOR SPACE LIFE SCIENCES FROM A NASA PERSPECTIVE
RONALD J. WHITE and BARBARA F. LUJAN (NASA, Life Sciences Div., Washington, DC) ASGSB Bulletin (ISSN 0898-4697), vol. 2, Aug. 1989, p. 93, 94.
Copyright

Plans for future NASA research programs in the life sciences are reviewed. Consideration is given to international cooperation in space life science research, the NASA approach to funding life science research, and research opportunities using the Space Shuttle, the Space Station, and Biological Satellites. Several specific programs are described, including the Centrifuge Project to provide a controlled acceleration environment for microgravity studies, the Rhesus Project to conduct biomedical research using rhesus monkeys, and the LifeSat international biosatellite project. Also, the Space Biology Initiative to design and develop life sciences laboratory facilities for the Space Shuttle and the Space Station and the Extended Duration Crew Operations program to study crew adaptation needs are discussed. R.B.

A90-36202*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
CONVERSION OF OMNIDIRECTIONAL PROTON FLUXES INTO A PITCH ANGLE DISTRIBUTION
GAUTAM D. BADHWAR and ANDREI KONRADI (NASA, Johnson Space Center, Houston, TX) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, May-June 1990, p. 350-352. refs
Copyright

The long-term radiation exposures anticipated for astronauts aboard oriented space stations entail consideration of spacecraft mass distribution and the direction of high-energy proton flux. A scheme has been developed for deriving pitch-angle distributions of energetic protons from the omnidirectional fluxes contained in the AP-8 MIN magnetospheric radiation model. A functional form is also presented for expressing the proton pitch-angle distributions at a given energy and L coordinate, as a function of only three parameters. O.C.

A90-38270*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
CREW EMERGENCY RETURN VEHICLE - ELECTRICAL POWER SYSTEM DESIGN STUDY
E. C. DARCY and T. P. BARRERA (NASA, Johnson Space Center, Houston, TX) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 6. New York, Institute of Electrical and Electronics Engineers, 1989, p. 2641-2645. refs

A crew emergency return vehicle (CERV) is proposed to perform the lifeboat function for the manned Space Station Freedom. This escape module will be permanently docked to Freedom and, on demand, will be capable of safely returning the crew to earth. The unique requirements that the CERV imposes on its power source are presented, power source options are examined, and a baseline system is selected. It consists of an active Li-BCX DD-cell modular battery system and was chosen for the maturity of its man-rated design and its low development costs. I.E.

A90-38388*# George Washington Univ., Washington, DC.
TRANSIENT ANALYSIS OF A CAPILLARY PUMPED LOOP HEAT PIPE
A. M. KIPER, G. FERIC, M. I. ANJUM (George Washington University, Washington, DC), and T. D. SWANSON (NASA, Goddard Space Flight Center, Greenbelt, MD) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 7 p.
(Contract NAG5-834)
(AIAA PAPER 90-1685) Copyright

A bench-top Capillary Pumped Loop (CPL) test system has been developed and tested to investigate the transient mode operation of this system by applying a step power input to the evaporators. Tests were conducted at several power input and evaporator inlet subcooling combinations. In addition, a lumped-heat-capacity model of the CPL test system has been presented which is used for predicting qualitatively the transient operation characteristics. Good agreement has been obtained between the predicted and the measured temperature variations. A simple evaporator inlet subcooler model has also been developed to study effects of inlet subcooling on the steady-state evaporator wall temperature. Results were compared with the test data collected. Author

A90-38439*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AEROTHERMODYNAMIC MEASUREMENTS ON A PROPOSED ASSURED CREW RETURN VEHICLE (ACRV) LIFTING-BODY CONFIGURATION AT MACH 6 AND 10 IN AIR
THOMAS J. HORVATH, MATTHEW N. RHODE, and GREGORY M. BUCK (NASA, Langley Research Center, Hampton, VA) AIAA and ASME, Joint Thermophysics and Heat Transfer Conference, 5th, Seattle, WA, June 18-20, 1990. 24 p. refs
(AIAA PAPER 90-1744) Copyright

A 0.02-scale model of a lifting-body concept for possible application to the Assured Crew Return Vehicle from Space Station Freedom was tested at Mach 6 and 10 in air. Thermal mappings and surface streamline patterns were obtained at angles of attack ranging from 0 to 30 deg and unit Reynolds numbers Re from 2 to 8 x 10 to the 6th/ft. Areas that experienced the highest heating were near the model nose and tip-fin leading edges. The effect of Re on windward centerline heating coefficients was negligible, whereas increases in angles of attack produced increases in heating. At Mach 6 and the highest unit Re, turbulent heat at the windward centerline was three to four times the laminar level. Leeward crossflow separation and vortex reattachment along the centerline are evident across the Re and angle-of-attack ranges tested, indicative of a complex flowfield. C.D.

A90-38498
SPACECRAFT CREW ESCAPE
BRIAN A. MILLER (Martin-Baker Aircraft Co., Ltd., Middlesex, England) SAFE Journal, vol. 20, Summer 1990, p. 10-14. Previously announced in STAR as N90-20066.
Copyright

The current preferred option from among the designs so far studied are described. Alternatives for seat design will still be studied to identify systems which offer the best possible approach with minimum design risk. Martin-Baker will continue to study the overall design and also initiate more detailed studies of the main elements, such as drogue stabilization, temperature extremes protection, and rocket motor thrust vectoring. The study of program management and the testing and qualification of such a system will also be initiated. It is already apparent that the test program would, at some point, require testing of the seat under actual conditions, if the required level of confidence is to be achieved. The Hermes Management Team are meeting the crew safety challenge by initiating and funding wide ranging feasibility studies. They are placing equal emphasis on the Crew Escape Module

concept and this study is also most promising. Hermes has the enormous advantage of hindsight which, we all know is perfect, and this valuable experience is being put to good use. This is believed to be pioneering work, whether by CEM or encapsulated ejection seats can provide an effective and efficient means of safe crew escape. Such a valuable prize will however not be obtained without continuing to commit the necessary resources and dedication. Author

A90-38870* New York Inst. of Tech., Dania, FL.
APPLICATION OF VISUAL PSYCHOPHYSICS TO THE DESIGN OF VIDEO SYSTEMS FOR USE IN SPACE
WILLIAM E. GLENN and KAREN G. GLENN (New York Institute of Technology, Dania, FL) IN: Human vision, visual processing, and digital display; Proceedings of the Meeting, Los Angeles, CA, Jan. 18-20, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 308-320. refs
(Contract NASW-4242)
Copyright

A series of two-alternative forced choice experiments was conducted to compare the sharpness of televised moving images sampled using cardinal or diagonal patterns with reference images of varying resolution. The results indicate that both image sampling and resolution orientation play an important role in determining apparent sharpness of the images. If an image has better cardinal than diagonal resolution, the apparent sharpness is significantly greater. Thus, if the polar distribution of resolution is limited by the sampling process, diagonal sampling can be expected to yield a sharper image than cardinal sampling with the same number of pixels. C.D.

A90-41117#
THE EUROPEAN ASTRONAUT TRAINING CONCEPT AND THE ROLE OF THE CREW TRAINING COMPLEX
FRED URBAN Dornier Post (ISSN 0012-5563), no. 2, 1990, p. 64-66.
Copyright

The capability and proficiency requirements for future European astronauts will range from payload and system specialists who will spend up to six months in the Space Station, to mission engineers whose principal task will be maintenance of the space laboratory, and pilots for the Hermes spaceplane. Basic training will include the knowledge and capabilities that are similar for all astronauts, regardless of their mission assignments, and which are required for eventual specialization. This will be followed by specialized training for those selected to individual tasks such as pilots, mission engineers, and system or payload specialists for the U.S. Space Station. The ESA will be organizing the various training complexes in Germany, France, Netherlands, and Belgium. R.E.P.

A90-42298* Case Western Reserve Univ., Cleveland, OH.
THE POSSIBILITY OF A REVERSAL OF MATERIAL FLAMMABILITY RANKING FROM NORMAL GRAVITY TO MICROGRAVITY
JAMES S. T'IEN (Case Western Reserve University, Cleveland, OH) Combustion and Flame (ISSN 0010-2180), vol. 80, June 1990, p. 355-357. refs
(Contract NAG3-1046)
Copyright

The purpose of the discussion is to show, by a theoretical model, that one of the material flammability indices, the flammability limit, can be reversed in proper circumstances. A stagnation-point diffusion flame adjacent to a spherical solid-fuel surface is considered. It is shown that a reversal of the limiting oxygen indices from normal gravity and microgravity is possible. Although the example is based on a particular theoretical model with a particular flame configuration and specifically for an oxygen limit, the flammability-limit reversal phenomenon is believed to be more general. V.T.

A90-43453*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN OVERVIEW OF THE SPACE MEDICINE PROGRAM AND DEVELOPMENT OF THE HEALTH MAINTENANCE FACILITY FOR SPACE STATION
SAM LEE POOL (NASA, Johnson Space Center, Houston, TX) Japanese Journal of Aerospace and Environmental Medicine (ISSN 0387-0723), vol. 25, March 1988, p. 1-12. refs

Because the prolonged stay on board the Space Station will increase the risk of possible inflight medical problems from that on Skylab missions, the Health Maintenance Facility (HMF) planned for the Space Station is much more sophisticated than the small clinics of the Skylab missions. The development of the HMF is directed by the consideration of three primary factors: prevention, diagnosis, and treatment of injuries and illnesses that may occur in flight. The major components of the HMF include the clinical laboratory, pharmacy, imaging system, critical-care system, patient-restraint system, data-management system, exercise system, surgical system, electrophysiologic-monitoring system, introvenous-fluid system, dental system, and hyperbaric-treatment-support system. I.S.

A90-43481
LIFE SCIENCES ROLE IN SYSTEMS ENGINEERING OF SPACE PROGRAMS
WILLIAM C. SCHNEIDER (Development Computer Sciences Corp., Silver Spring, MD) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 347-350.
(AAS PAPER 88-228) Copyright

The role of life science experimentation in determining the systems engineering of spacecraft is briefly addressed. The effect of life science findings on the design of life support systems is emphasized. The problem of acclimating living bodies to a long-term existence in a low-gravity environment is discussed. C.D.

A90-45781
SURVIVAL IN SPACE: MEDICAL PROBLEMS OF MANNED SPACEFLIGHT
RICHARD HARDING London and New York, Routledge, 1989, 249 p. refs
Copyright

The basic features of the space environment are reviewed, and the history and current status of efforts to protect humans from its immediate and long-term adverse effects are described, in an introduction for the general reader. Chapters are devoted to pressure and density; increased accelerations; radiation and micrometeoroids, temperature and humidity; nutrition, waste, and personal hygiene; dressing for space and mobility; health care; selection and training; microgravity; and the psychology of space flight, women in space, and spacecraft habitability. Diagrams, drawings, graphs, and photographs are provided. T.K.

A90-49037
IN OPEN SPACE [V OTKRYTOM KOSMOSE]
IURII N. GLAZKOV (Tsentr Podgotovki Kosmonavtov, USSR) and IURII V. KOLESNIKOV Moscow, Izdatel'stvo Pedagogika, 1990, 128 p.
Copyright

The performance of astronauts in space is discussed with reference to numerous first-hand accounts from the astronauts themselves. Particular attention is given to work involving the assembly of manufacturing installations, solar power facilities, radio telescopes, and other structures in space. B.J.

A90-49278* NASA Space Station Program Office, Reston, VA.
WORK/CONTROL STATIONS IN SPACE STATION WEIGHTLESSNESS
CHARLES WILLITS (NASA, Space Station Freedom Program Office, Reston, VA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 39 p.
(SAE PAPER 901203) Copyright

An ergonomic integration of controls, displays, and associated interfaces with an operator, whose body geometry and dynamics may be altered by the state of weightlessness, is noted to rank in importance with the optimal positioning of controls relative to the layout and architecture of 'body-ported' work/control stations applicable to the NASA Space Station Freedom. A long-term solution to this complex design problem is envisioned to encompass the following features: multiple imaging, virtual optics, screen displays controlled by a keyboard ergonomically designed for weightlessness, cursor control, a CCTV camera, and a hand-controller featuring 'no-grip' vernier/tactile positioning. This controller frees all fingers for multiple-switch actuations, while retaining index/register determination with the hand controller. A single architectural point attachment/restraint may be used which requires no residual muscle tension in either brief or prolonged operation. O.C.

A90-49279
DESIGNING SPACE HABITATS FOR HUMAN PRODUCTIVITY
MARC M. COHEN (Michigan, University, Ann Arbor) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 15 p. refs
(SAE PAPER 901204) Copyright

This summary paper addresses each of the key words in its title: Designing, Space Habitats and Productivity; from the perspective of a research architect. This approach looks at definitions of productivity in their specific economic, industrial, social and technical context. The discussion covers crew autonomy, democracy and teamwork as productivity values for space habitats. Author

A90-49283
WATER RECYCLING SYSTEM FOR CELSS ENVIRONMENT IN SPACE
AKIRA ASHIDA, KENJI MITANI, HIDEAKI KUROKAWA, TOSHIO SAWA (Hitachi, Ltd., Tokyo, Japan), and KEIJI NITTA (National Aerospace Laboratory, Chofu, Japan) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901208) Copyright

System configurations of water recycling for space use have been continued through theoretical and experimental studies. The water recycling system plays a central role in a Closed Ecological Life Support System which offers necessary environment and life styles in closed environment such as Space Stations, lunar bases, etc. Membrane technology is a possible candidate for purifying waste water produced by crew use facility, plant cultivation facility, etc. In consideration of the system compactness realizing energy saving, membrane distillation has been revealed to be a suitable purification process. Ground experiments have been performed using membrane filtration processes and membrane distillation process. Thermopervaporation technology with hydrophobic membrane is utilized in the distillation process. The energy saving is achieved by thermal return of condensation energy. Author

A90-49284
STATUS OF JEM ECLSS DESIGN
F. OTSUKI, T. SUZUKI, N. YAMAGUCHI (NASDA, Tokyo, Japan), A. HATTORI, Y. YOSHIDA (Kawasaki Heavy Industries, Ltd., Kobe, Japan) et al. SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 9 p. refs
(SAE PAPER 901209) Copyright

The preliminary design of the Japanese Experiment Module (JEM) was started in January 1990. As a result of the JEM configuration review activity, which was focused on the development cost and schedule prior to getting into the preliminary design, a part of the JEM environmental control and life support system (ECLSS) functions was changed. This paper presents the JEM ECLSS baseline and the subsystem configuration at the start of the Phase C/D. Also, the outline of the preliminary cabin air ventilation testing which started in March 1989 is described. Author

A90-49285* McDonnell-Douglas Space Systems Co., Huntsville, AL.
PAST AND PRESENT ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS ON MANNED SPACECRAFT
BRYCE L. DIAMANT (McDonnell Douglas Space Systems Co., Huntsville, AL) and W. R. HUMPHRIES (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 35 p. refs
(SAE PAPER 901210) Copyright

The spacecraft environmental control and life support systems (ECLSS) for Mercury, Gemini, Apollo, Skylab, Spacelab, the Space Shuttle Orbiter, and Space Station Freedom are reviewed, in addition to the ECLSS on Soviet spacecraft Vostok, Voskhod, Soyuz, Salyut Space Stations, the Buran Space Shuttle, and the Mir Space Station. Focus is placed on atmosphere control and supply, atmosphere revitalization, potable and supply water systems, waste-management systems, temperature and humidity control, water recovery and management, and fire detection and suppression. It is noted that the ECLSS evolution will continue during the lifetime of Space Station Freedom, leading to further simplifications and closure of the system which will become a controlled ecological life support system (CELSS). V.T.

A90-49286* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION FREEDOM ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM DESIGN - A STATUS REPORT
W. R. HUMPHRIES, J. L. REUTER, and R. G. SCHUNK (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 18 p. refs
(SAE PAPER 901211) Copyright

Space Station Freedom (S.S. Freedom) has entered into the Preliminary Design Review (PDR) phase of the program. This paper outlines the Environmental Control and Life Support System (ECLSS) design with emphasis on the systems aspects of the ECLSS. Interactions with other distributed systems, such as data management and electrical power are described. The integration of the ECLSS into the S.S. Freedom pressurized elements and truss are addressed. Author

A90-49287
OPTIMAL CONFIGURATION AND OPERATION FOR THE SPACE SHUTTLE FREEDOM ECLSS
WEN-HO CHU (Houston, University, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 20 p. refs
(SAE PAPER 901212) Copyright

The operations of the Space Station Freedom (SSF) Environmental Control and Life Support System (ECLSS) are determined by the configurations of the ECLSS subsystems. The configurations of the ECLSS subsystems are in turn determined by the NASA budget approved by Congress and the amount of money allocated to the SSF program. This paper uses the concepts of top-down techniques and the theory of optimization to present the mathematical formulations for determining the optimal configuration and optimal operation of the SSF ECLSS, based on different scenarios. The formulations can be used to determine the optimal number of units for the ECLSS processors to be configured, their recovery efficiencies, and the crew potable and hygiene water uses. Author

A90-49288
SYSTEM LEVEL WATER BALANCE FOR SPACE STATION FREEDOM
DONALD H. SARGENT (Grumman Corp., Space Station Program Support Div., Reston, VA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 6 p. refs
(SAE PAPER 901213) Copyright

As a result of a 1989 program rephasing, Space Station Freedom's system-level water balances have been materially

shifted. The average and the most likely values of the water balance, and the components of variability, were evaluated in this study. The Assembly Complete configuration has a large excess of ECLSS potable water but a deficit of ECLSS hygiene water. In contrast, there is a small ECLSS potable water deficit but an excess of ECLSS hygiene water for the 'Permanent Manned Capability' (PMC) configuration. Upon considering the Orbiter fuel cell water supply to the station and the combined demands for station water, the average and most likely values for the overall excess quantity are 6,800 and 9,000 pounds per year for the Assembly Complete configuration. Comparable values for the PMC configuration are 6,600 and 6,400 pounds per year. Author

A90-49289* McDonnell-Douglas Space Systems Co., Huntsville, AL.
WATER RECOVERY AND MANAGEMENT TEST SUPPORT MODELING FOR SPACE STATION FREEDOM
HABIB MOHAMADINEJAD (McDonnell Douglas Space Systems Co., Huntsville, AL) and ALLEN S. BACSKAY (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 21 p.
(SAE PAPER 901214) Copyright

The water-recovery and management (WRM) subsystem proposed for the Space Station Freedom program is outlined, and its computerized modeling and simulation based on a Computer Aided System Engineering and Analysis (CASE/A) program are discussed. A WRM test model consisting of a pretreated urine processing (TIMES), hygiene water processing (RO), RO brine processing using TIMES, and hygiene water storage is presented. Attention is drawn to such end-user equipment characteristics as the shower, dishwasher, clotheswasher, urine-collection facility, and handwash. The transient behavior of pretreated-urine, RO waste-hygiene, and RO brine tanks is assessed, as well as the total input/output to or from the system. The model is considered to be beneficial for pretest analytical predictions as a program cost-saving feature. V.T.

A90-49290
MICROGRAVITY FIRE DETECTION PROBLEMS - FACT OR FICTION
EMORY C. THOMAS (Brunswick Corp., Defense Div., Skokie, IL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901215) Copyright

The Fire Detection System for spacecraft has been designated as a subsystem of the ECLSS and is a little bit like a fish out of water, in that the main concern of the life support system designers does not lie in the field of fire protection and therefore draws little attention. Hazard detection and control does become of major concern, however, when it comes to the protection of the spacecraft and personnel from fire damage. The design of the Space Shuttle's early warning incipient Fire Detector is reviewed to explain the research that was conducted to establish its performance criteria. Comparisons are made to the Shuttle and Freedom fire detection specifications to illustrate the need for a better understanding of when is a hazard really a hazard and what defines early warning. A look is taken at the concern of detecting a fire hazard in microgravity. Is the lack of convective buoyancy forces that carry the products of combustion to the sensor location a problem or is the energy release and diffusion forces during the combustion phase sufficient? Finally, a description of a Fire Detection System concept for future spacecraft is given. Author

A90-49291
LIFE SUPPORT FUNCTION AND TECHNOLOGY ANALYSIS FOR FUTURE MISSIONS
SUSAN C. DOLL and CARL M. CASE (Boeing Aerospace and Electronics, Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p.
(SAE PAPER 901216) Copyright

A functional analysis was performed to identify life support functions and interrelationships required for manned space exploration. Methods were identified to provide each of these functions, ranging from resupply of consumables to totally regenerative processes. Specific mission characteristics and their effect on advanced life support requirements are outlined. A preliminary assessment is made as to which life support functions are critical for missions of various duration. Technologies which have been selected for Space Station Freedom and associated degrees of closure are discussed and areas for future work are suggested. Author

A90-49302
ENGINEERING TESTBED FOR BIOLOGICAL WATER/AIR RECLAMATION AND RECYCLING
DANIEL S. JANIK (Cetus Research, El Cerrito, CA) and JEFFERY J. DEMARCO (Pyraponic Industries, Inc., San Diego, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 9 p. refs
(SAE PAPER 901231) Copyright

Experience with reclaimed and recycled life support testbeds is necessary to identify problems unique to this new class of spacecraft systems. Current research and engineering testbeds necessary for advanced Space Station Freedom, moonbase, interplanetary travel and Mars/Phobos mission and base are large, complex, costly and rare. This paper reports on a small, simple, flexible and affordable experimental research and engineering testbed for biologically contaminated or enhanced physical chemical and biological water/air reclamation and recycling systems. Author

A90-49317
WATER RECYCLING IN SPACE
R. F. MADSEN, J. R. THOMASSEN, L. B. JORGENSEN (Danisco A/S, Denmark), J.-L. BERSILLON, D. VIAL (Lyonnaise des Eaux, France) et al. SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 19 p.
(SAE PAPER 901247) Copyright

The results of the preliminary studies of water recycling for ESA are presented. The main conclusion is that the treatments for all waste waters, except urine, should consist of (1) pretreatment (acidification, H2O2 addition, and filtration); (2) reverse osmosis; (3) oxidation (H2O2 + UV light); and (4) reverse osmosis (neutral pH). Together with reject from reverse osmosis, urine is treated by vapor compression distillation. Microbiological studies have been made, and practical experiments with RO on shower water are mentioned. It is shown that up to 98 percent recovery can be obtained with a power consumption of 45-60 Wh/liter. Author

A90-49318
LIFE SUPPORT - THOUGHTS ON THE DESIGN OF SAFETY SYSTEMS
ROBIN C. HUTTENBACH and STEPHEN D. ORAM (Nelson Space Services, Ltd., London, England) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 14 p. Research supported by ESA.
(SAE PAPER 901248) Copyright

This paper considers the design of safety systems as they might be applied to a manned habitat operating in space. Areas reviewed include the delineation, monitoring and suppression of hazards as well as the design of control systems. Examples of methods that could be used to suppress hazards are presented, including schematics for a shut-down hierarchy and a fire and hazardous gas control system. Author

A90-49319
PUMPING EQUIPMENT OF AUTONOMOUS INHABITED SYSTEMS
V. N. VASIL'EV, I. D. OSHMARIN, B. G. RITTENBERG, M. A. ROGUNOV, V. B. FILONENKO (Nauchno-Proizvodstvennoe Ob'edinenie VNIIGIDROMASH, Moscow, USSR) et al. SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 21 p. refs
(SAE PAPER 901250) Copyright

Practically any processes vital for autonomous inhabited systems require forced transfer of liquids. Therefore, such systems normally incorporate pumps of various types. The specific features of the autonomous inhabited systems result in the fact that the pumping equipment of these systems also has some specific features. The methods of selecting a particular type of pump and general estimate of its specific features are considered for one typical kind of autonomous inhabited system, i.e., for the life-support and survival systems of space vehicles. Author

A90-49320* Alabama Univ., Huntsville.
HUMAN SUBJECTS CONCERNS IN GROUND BASED ECLSS TESTING - MANAGING UNCERTAINTY IN CLOSELY RECYCLED SYSTEMS
WILLIAM J. CRUMP, DANIEL S. JANIK (Alabama, University, Huntsville), and L. DALE THOMAS (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p. refs
(SAE PAPER 901251) Copyright

U.S. space missions have to this point used water either made on board or carried from earth and discarded after use. For Space Station Freedom, long duration life support will include air and water recycling using a series of physical-chemical subsystems. The Environmental Control and Life Support System (ECLSS) designed for this application must be tested extensively at all stages of hardware maturity. Human test subjects are required to conduct some of these tests, and the risks associated with the use of development hardware must be addressed. Federal guidelines for protection of human subjects require careful consideration of risks and potential benefits by an Institutional Review Board (IRB) before and during testing. This paper reviews the ethical principles guiding this consideration, details the problems and uncertainties inherent in current hardware testing, and presents an incremental approach to risk assessment for ECLSS testing. Author

A90-49321* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PHASE III SIMPLIFIED INTEGRATED TEST (SIT) RESULTS - SPACE STATION ECLSS TESTING
BARRY C. ROBERTS, ROBYN L. CARRASQUILLO, MELISSA Y. DUBIEL, KATHRYN Y. OGLE, JAY L. PERRY, and KEN M. WHITLEY (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 8 p.
(SAE PAPER 901252) Copyright

During 1989, phase III testing of Space Station Freedom Environmental Control and Life Support Systems (ECLSS) began at Marshall Space Flight Center (MSFC) with the Simplified Integrated Test. This test, conducted at the MSFC Core Module Integration Facility (CMIF), was the first time the four baseline air revitalization subsystems were integrated together. This paper details the results and lessons learned from the phase III SIT. Future plans for testing at the MSFC CMIF are also discussed. Author

A90-49322* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
TEST BED DESIGN FOR EVALUATING THE SPACE STATION ECLSS WATER RECOVERY SYSTEM
TIMOTHY G. EZELL and DAVID A. LONG (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 23 p. refs
(SAE PAPER 901253) Copyright

The design of the Phase III Environmental Control and Life Support System (ECLSS) Water Recovery System (WRS) test bed is in progress at the Marshall Space Flight Center (MSFC), building 4755, in Huntsville, Alabama. The overall design for the ECLSS WRS test bed will be discussed. Described within this paper are the design, fabrication, placement, and testing of the supporting facility which will provide the test bed for the ECLSS subsystems. Topics to be included are sterilization system design, component selection, microbial design considerations, and verification of test bed design prior to initiating WRS testing. Author

A90-49323* Boeing Co., Seattle, WA.
FACILITY FOR GENERATING CREW WASTE WATER PRODUCT FOR ECLSS TESTING
ALAN BUITEKANT (Boeing Aerospace and Electronics, Seattle, WA) and BARRY C. ROBERTS (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p. refs
(SAE PAPER 901254) Copyright

An End-use Equipment Facility (EEF) has been constructed which is used to simulate water interfaces between the Space Station Freedom Environmental Control and Life Support Systems (ECLSS) and man systems. The EEF is used to generate waste water to be treated by ECLSS water recovery systems. The EEF will also be used to close the water recovery loop by allowing test subjects to use recovered hygiene and potable water during several phases of testing. This paper describes the design and basic operation of the EEF. Author

A90-49324
LIQUID CHROMATOGRAPHY/MASS SPECTROMETRY - A NEW TECHNIQUE FOR WATER RECOVERY SYSTEM TESTING
BRIAN L. BENSON, STUART A. OEHRLE, and MELVIN V. KILGORE, JR. (Alabama, University, Huntsville) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 8 p. refs
(SAE PAPER 901255) Copyright

Liquid Chromatography/Mass Spectrometry can improve Freedom water recovery systems testing by providing analytical information about nonvolatile organic contaminants not amenable to conventional analytic techniques. A preliminary liquid chromatography method has been developed for organic acids in human urine. Using this method, over twenty organic acids and related compounds can be resolved. Author

A90-49325
ATMOSPHERE COMPOSITION MONITOR FOR PREDEVELOPMENT OPERATIONAL SYSTEM TEST
RICHARD A. HEPPNER, DIEGO A. TORRES (Perkin-Elmer Corp., Applied Science Div., Pomona, CA), and JEFF HISS (Boeing Aerospace and Electronics, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 9 p.
(SAE PAPER 901256) Copyright

Perkin-Elmer is providing the Atmosphere Composition Monitor (ACM) for the Space Station Freedom Environmental Control and Life Support System (ECLSS) being developed by Boeing Aerospace and Electronics (BA&E). Prior to production of flight hardware the ECLSS system will be tested in the Predevelopment Operational System Test (POST). 'Predevelopment' or POST equipment must meet flight hardware functional requirements, but not size, weight, and power goals. The POST ACM consists of the following major modules: a Major Constituent Analyzer, a Trace Contaminant Monitor, a Carbon Monoxide Analyzer, a Particle Counter Monitor, a Sample Acquisition System and a Computer System. The Predevelopment ACM is designed for automated operation; operator intervention is required only for maintenance. Instrument performance is verified through periodic measurement of reference gas standards. Author

A90-49326
OPERATIONAL NINETY-DAY MANNED TEST OF REGENERATIVE LIFE SUPPORT SYSTEMS
TERRY C. SECORD and MARIO S. BONURA (McDonnell Douglas Space Systems Co., Huntington Beach, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901257) Copyright

A summary is presented of the results of the last known closed-door manned chamber test of an operational regenerative life-support system which took place in the Space Station Simulator in 1970. The 90-day test included the evaluation of a number of advanced life-support subsystems with backup provided by alternate subsystems that had undergone extensive manned testing during the middle 1960s. Data were collected on the performance of the equipment, the four-man crew, and the man/system interface. It was found that no psychological or physiological effects were experienced by the confined crew who used the recovered water and oxygen, and that there was time to troubleshoot and repair malfunctioning equipment. Test results aided in developing a strategy to improve equipment designs for Skylab and the Space Station, and to increase understanding of design impacts of closing the water and oxygen cycles. L.K.S.

A90-49327* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION FREEDOM CHECS OVERVIEW
JOEY B. BOYCE (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901258) Copyright

The current status, progress, and future plans for development of the Crew Health Care System (CHeCS) for the International Space Station Freedom are presented. Essential operational biomedical support requirements for the astronauts, including medical care, environmental habitat monitoring, and countermeasures for the potentially maladaptive physiological effects of space flight will be provided by the CHeCS. Three integral parts will make up the system: a health maintenance facility, an environmental health system, and the exercise countermeasures facility. Details of each of the major systems and their subsystems are presented. R.E.P.

A90-49328* Krug International, Houston, TX.
SPACE STATION REQUIREMENTS FOR IN-FLIGHT EXERCISE COUNTERMEASURES
JUDITH C. HAYES (Krug International, Houston, TX) and BERNARD A. HARRIS (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 7 p. refs
(SAE PAPER 901259) Copyright

In an effort to retard the deleterious effects of space adaptation, NASA has defined requirements for an Exercise Countermeasure Facility (ECF) within the Space Station Crew Health Care System (CHeCS). The application of exercise as a countermeasure to spaceflight-induced deconditioning has been utilized in the past by both the United States and the Soviet space programs. The ECF will provide exercise hardware, physiological monitoring capabilities, and an interactive motivational display system. ECF operations and data will be coupled through the Space Station Freedom Data Management System for monitoring of inflight training and testing from ground control, thus allowing for real-time evaluation of crewmember performance and modification of exercise prescriptions. Finally, the objective of the ECF is to monitor and control the exercise of crewmembers for the maintenance of an operational level of fitness to ensure mission success. Author

A90-49329* Krug International, Houston, TX.
DEVELOPMENT OF THE SPACE STATION FREEDOM ENVIRONMENTAL HEALTH SYSTEM
ELIZABETH E. RICHARD (Krug International, Technology Life Sciences Div., Houston, TX) and DANE RUSSO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 7 p. refs
(SAE PAPER 901260) Copyright

The Environmental Health System (EHS), a subsystem of the Space Station Freedom (SSF) Crew Health Care System, was established to ensure that crewmembers will have a safe and healthy environment in which to live and work. EHS is comprised of six subsystems: Microbiology, Toxicology, Water Quality, Radiological Health, Vibroacoustics, and Barothermal Physiology. Each subsystem contributes to the overall functions of the EHS including environmental planning, environmental monitoring, environmental monitoring, environmental health assessments, and operations support. The EHS will provide hardware for monitoring the air, water, and internal surfaces of Freedom, including capabilities for inflight sample collection, processing, and analysis. The closed environment of SSF, and its dependence on recycled air and water, will necessitate a reliable monitoring system to alert crewmembers if contamination levels exceed the maximum allowable limits established to ensure crew health and safety. This paper describes the functions and hardware design status of the EHS. Author

A90-49330* Krug International, Houston, TX.
MICROBIOLOGY FACILITIES ABOARD SPACE STATION FREEDOM (SSF)
L. A. CIOLETTI, S. K. MISHRA, ELIZABETH E. RICHARD (Krug International, Technology Life Sciences Div., Houston, TX), and R. TAYLOR (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 6 p. refs
(SAE PAPER 901262) Copyright

A comprehensive microbiological facility is being designed for use on board Space Station Freedom (SSF). Its purpose will be to conduct microbial surveillance of the SSF environment and to examine clinical specimens. Air, water, and internal surfaces will be periodically monitored to satisfy requirements for a safe environment. Crew health will remain a principle objective for every mission. This paper will review the Microbiology Subsystem capabilities planned for SSF application. Author

A90-49331
CLINICAL LABORATORY DIAGNOSIS FOR SPACE MEDICINE
BRUCE A. MCKINLEY (Krug International, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p. refs
(SAE PAPER 901263) Copyright

A clinical laboratory system, based on commercially available devices or technologies, is being designed for Space Station Freedom. This system will be used by the crew medical officer to provide analysis of discrete samples of blood and other biological fluids. Clinical chemistry, blood gas analysis, hematology, and microbiology are planned to be available at the Space Station as components of the Crew Health Care System. As with many space systems, ease of use, compact size, and reliability are primary guidelines. An experimental clinical chemistry analyzer was built for the Space Station Freedom medical care facility, and is being tested in selected clinical settings that may be similar to those that will be encountered at a space station, planetary outpost, or transfer vehicle. Author

A90-49333
APPLICATION OF A COMPREHENSIVE G189A ECLSS MODEL IN ASSESSING SPECIFIC SPACE STATION CONDITIONS
R. S. BARKER and R. G. VON JOUANNE (Boeing Aerospace and Electronics, Huntsville AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 17 p. refs
(SAE PAPER 901265) Copyright

A comprehensive environmental control and life support system model developed using the G189A environment control system simulation tool is described. The computational logic and input data for the atmosphere control and supply, atmosphere revitalization, water recovery and management, and temperature and humidity control have been verified while analyzing the performance under normal operating conditions and the effects during an orbiter docking maneuver accompanied by a changeout of crews. All ECLSS operating conditions during crew changeout were determined to be within limits, except possibly the levels of CO2. These CO2 levels were temporarily greater than the

established limits for normal operating conditions, but were well within the accepted emergency operating conditions. A series of modeling schematics is included. R.E.P.

A90-49336* McDonnell-Douglas Space Systems Co., Huntsville, AL.
COMPUTER AIDED SYSTEM ENGINEERING AND ANALYSIS (CASE/A) MODELING PACKAGE FOR ECLS SYSTEMS - AN OVERVIEW
ROBERT C. DALEE (McDonnell Douglas Space Systems Co., Huntsville, AL), ALLEN S. BACSKAY, and JAMES C. KNOX (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 18 p. refs
(SAE PAPER 901267) Copyright

An overview of the CASE/A-ECLSS series modeling package is presented. CASE/A is an analytical tool that has supplied engineering productivity accomplishments during ECLSS design activities. A components verification program was performed to assure component modeling validity based on test data from the Phase II comparative test program completed at the Marshall Space Flight Center. An integrated plotting feature has been added to the program which allows the operator to analyze on-screen data trends or get hard copy plots from within the CASE/A operating environment. New command features in the areas of schematic, output, and model management, and component data editing have been incorporated to enhance the engineer's productivity during a modeling program. R.E.P.

A90-49345
EVALUATION OF THE SUITABILITY OF CO MEASUREMENT FOR FIRE DETECTION IN SPACE
RAINER SONNENSCHEIN and KARL-OTTO HIENERWADEL (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 9 p. refs
(SAE PAPER 901285) Copyright

Methods of fire detection for space application are reviewed and compared. Arguments are given in favor of a decentralized, combined particulate and gas measurement system with highly sensitive, selective and miniaturized sensor elements. For the COLUMBUS pressurized modules, this leads to a new baseline concept which now includes an ionization chamber and light scattering smoke detectors in the return ducts as well as CO sensors on the rack level. Author

A90-49348
ATMOSPHERE TRACE GAS CONTAMINATION MANAGEMENT FOR THE COLUMBUS PRESSURIZED MODULES
HERMANN ABELE (Dornier GmbH, Friedrichshafen, Federal Republic of Germany), KLAUS AMMANN (Draegerwerk AG, Luebeck, Federal Republic of Germany), and JOCHEN FRANZEN (Bruker-Franzen Analytik GmbH, Bremen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 6 p. refs
(SAE PAPER 901288) Copyright

The COLUMBUS pressurized modules APM and PM2 are designed for a useful lifetime of 30 years. The APM, which forms part of the International Space Station, will be permanently manned with a three-man crew. The PM2, which is the pressurized module of the Men-Tended-Free-Flyer (MTFF) will be manned for the servicing period of 10 days followed by a 180-day unmanned period. In order to protect the crew from contamination by hazardous substances, which may be present in the cabin air, effective contamination management is required. This consists of a contamination monitoring system to detect and measure trace gases in the cabin atmosphere, and a contamination control system to be able to maintain the concentration of each potential contaminant below the maximum allowable concentration. Author

A90-49349
ECLS TECHNOLOGY DEVELOPMENT PROGRAMME - RESULTS AND FURTHER ACTIVITIES
WOLFRAM KNORR, HELMUT FUNKE, HELMUT PREISS (Dornier GmbH, Friedrichshafen, Federal Republic of Germany), and GIJSBERT TAN (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p. Research supported by DLR. refs
(SAE PAPER 901289) Copyright

A technological program was started in 1985 to support the Columbus environmental control and life support system (ECLSS) development. The program goal has been the development of an advanced breadboard for: (1) a regenerative CO2 removal system, (2) a trace gas contamination control system, (3) a trace gas contamination monitoring system, and (4) a low-noise variable speed fan. Results of the program indicate that the concept of the solid-amine-based regenerative CO2 removal could be largely advanced, and the trace gas contamination control assembly proved its feasibility. R.E.P.

A90-49350
CONSTRAINTS AND RATIONALE FOR SPACE STATION FREEDOM HABITATION AND LABORATORY MODULE TOPOLOGY
JOHN R. PALMER, WILLIAM P. LLOYD, and CANDACE CAMPBELL (Boeing Aerospace and Electronics, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 18 p.
(SAE PAPER 901297) Copyright

This paper addresses the constraints concerning the allocation of equipment to volume within two of the pressurized, habitable modules of Space Station Freedom. This problem of topology optimization must address multiple competing constraints at various stages of the design evolution. Consistent and logical balance of conflicting location constraints is the objective in design optimization. This study defines the physical, functional, and operational constraints affecting the optimization of the Space Station Freedom Habitation and U.S. Laboratory module configurations, and discusses the evolution of their current baseline. Author

A90-49351
DESIGN DEFINITION OF THE SPACE STATION FREEDOM GALLEY AND WARDROOM SUBSYSTEMS AND THEIR EFFECT ON SPACE STATION ENVIRONMENTAL SYSTEMS
MARTIN AGRELLA, AL KWAN, and JON ZELON (ILC Space Systems, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p.
(SAE PAPER 901299) Copyright

This paper describes the current Space Station Freedom (SSF) Galley and Wardroom system designs which enhance crew productivity and comfort, ensure crew safety, minimize technical impacts on the SSF Environmental Control and Life Support System (ECLSS) and allow for future SSF growth/modification. The discussion presented encompasses the design definition of the Galley and Wardroom integrated systems, identification of heat loads and contaminants that affect the SSF ECLSS, and the design approach taken to incorporate localized water and air treatment to minimize the impact on the SSF ECLSS. Author

A90-49352
DEVELOPMENT OF THE SPACE STATION FREEDOM REFRIGERATOR/FREEZER AND FREEZER
JON ZELON, JOHN SAIZ (ILC Space Systems, Houston, TX), and PETER GLASER (Arthur D. Little, Inc., Cambridge, MA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 14 p.
(SAE PAPER 901300) Copyright

This paper presents the current design configuration of the Space Station Freedom (SSF) Refrigerator/Freezer and Freezer (R/F and F) systems. In addition, this paper establishes the current

analyses/trade study activity related to refrigeration system design and defines Environmental Control and Life Support System (ECLSS) interfaces, anticipated heat loads, maintenance approaches and safety concerns. Author

A90-49353
SPACE STATION CREW QUARTERS AND PERSONAL HYGIENE FACILITY
LOUIS P. DIETZ and GARY L. DOERRE (Grumman Corp., Space Systems Div., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 14 p. refs
(SAE PAPER 901301) Copyright

The history of U.S. spacecraft Crew Quarters and Personal Hygiene Systems is traced from the time of the early space capsules through the present day Shuttle. Brief descriptions of these accommodations are provided. Design goals are defined for the Space Station Freedom Crew Quarters and Personal Hygiene so that the successes, or failures of each step of the space program can be compared and our progress thus measured. The Space Station Freedom requirements and preliminary design efforts for these facilities are described to considerable depth. Particular emphasis is given to sleeping arrangements and equipment of the Crew Quarters and the commode-urinal, zero gravity handwasher, and the zero gravity shower of the Space Station. Concerns and issues are discussed and an overview or summary is provided. Author

A90-49363
DESIGN AND EVALUATION OF AN ELECTRONIC STETHOSCOPE SYSTEM FOR THE SPACE STATION FREEDOM HMF
JOHN GOSBEE (Krug International Corp., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 6 p. refs
(SAE PAPER 901323) Copyright

With an electronic stethoscope system, the Space Station Freedom Health Maintenance Facility will have the capability to electronically acquire, store, and transmit lung, heart, and bowel sounds to earth. This electronic stethoscope system will aid in clinical diagnosis, treatment, and monitoring functions. To evaluate these clinically relevant performance requirements, both subjective and objective test plans have been conceived. These test plans as well as preliminary results are discussed. Author

A90-49364
STERILE WATER FOR INJECTION SYSTEM FOR ON-SITE PRODUCTION OF IV FLUIDS AT SPACE STATION FREEDOM HMF
BRUCE A. MCKINLEY (Krug International Corp., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 19 p. refs
(SAE PAPER 901324) Copyright

Space Station Freedom's Health Maintenance Facility (HMF) will have extremely limited storage space; the fluids for intravenous administration of drugs to crewmember must accordingly be prepared from potable water. The Sterile Water for Injection System (SWIS) Medical Development Unit devised to meet these requirements is based on passive disposable water purification cartridges, bacterial filters, and water containers. Solute or concentrate drugs are added to the sterile water to formulate the desired fluids. Preliminary test results from the SWIS prototype involving removal of ionic, organic, endotoxic, and microbial contaminants' removal have indicated considerable system reliability, despite the use of test solutions with contaminant contents far in excess of those envisioned in the HMF potable water supply. O.C.

A90-49365
FORMULATION, PREPARATION AND DELIVERY OF PARENTERAL FLUIDS FOR THE SPACE STATION FREEDOM HEALTH MAINTENANCE FACILITY
GERALD J. CREAGER (Krug International Corp., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p.
(SAE PAPER 901325) Copyright

Investigations were conducted to develop a system for preparation of solutions on-orbit for medical use. Fluid protection hardware was developed and evaluated to determine its suitability for producing sterile water for injection, and parenteral solutions as described in the United States Pharmacopia, vol. XXI. Testing was designed to determine the limits of the devices and laboratory evaluations of candidate intravenous infusion pumps were undertaken to characterize the devices. Fluid formulation in microgravity and delivery of the parental solutions are discussed. Design and testing procedures of the system are outlined and initial characterizations of the sterile water production hardware indicate its ability to function beyond the desired design limits. L.K.S.

A90-49366
MEDICAL CONCERNS FOR ASSURED CREW RETURN VEHICLE FROM SPACE STATION FREEDOM
DEBRA L. KRUPA (Krug International Corp., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901326) Copyright

The Assured Crew Return Vehicle (ACRV) system was created as a means of return or rescue of the crew from SSF in case the Space Shuttle becomes unavailable. Designed to perform as a lifeboat on a single mission, the vehicle has to be dependable while operated by a wide range of limited training personnel and to do the return safely. In case of illness or injury due to prolonged space exposure, the resulting inability of the crew to perform efficiently required an overall simplicity in operation. The development of suitable software and flight control systems, with few manual operations, help to achieve these goals. The vehicle has to be constantly available and the entire system reliable and affordable. Three emergency situations are singled out as most important for design purposes. The effects of acceleration on a deconditioned crewmember during the return flight, transport logistics and some related medical aspects are discussed in detail. B.P.

A90-49367
MEDICAL INFORMATION BUS - INTEGRATED MONITORING FOR THE HMF OF SPACE STATION FREEDOM
WELDON L. WHITE (Krug International Corp., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p.
(SAE PAPER 901328) Copyright

The features of a medical device (MD) communications standard, currently in development, are described and subsequent solutions to many of the MD data acquisition problems are illustrated. The P1073 Medical Information Bus (MIB) features a standardized MD data language which establishes a communication link between the host computer and any MIB medical device regardless of device type. It is projected that MIB will be able to provide the Space Station Freedom (SSF) health maintenance facility medical devices with standard hardware and software interfaces to connect to the medical decision support system (MDSS). A standardized interface on each of the medical devices located in the SSF crew health care system facilities will enable the MDSS to recognize and acquire data from each of these instruments regardless of the facility to which it is connected. L.K.S.

A90-49369
A GENERALIZED PHOTOSYNTHETIC MODEL FOR PLANT GROWTH WITHIN A CLOSED ARTIFICIAL ENVIRONMENT
ROBERT L. HEATH, MONICA A. MADORE (California, University, Riverside), and RACHEL M. S. HURD (McDonnell Douglas Space Systems Co., Huntington Beach, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 16 p. refs
(SAE PAPER 901331) Copyright

A generalized model of plant growth has been developed with a view to tests of the variations in mass flows and chemical/energy transformations that are possible within a closed artificial environment. Attention is given to mass transfers through the photosynthetic processes, leaf radiation/heat balances, and carbohydrate production/distribution; the generalization of a full plant's growth proceeds from the radiative loading and gas exchange capacities of a single leaf. The mathematical description of photosynthesis employed uses an exponential function for light dependence multiplied by a hyperbolic function for CO2/O2 levels: this keeps dependent variables to a minimum. The model is incorporated into a FORTRAN subroutine allowing its use in the CASE/A-CELSS version of NASA's ECLS system-simulation program. O.C.

A90-49384* McDonnell-Douglas Space Systems Co., Houston, TX.
SPACE STATION ENVIRONMENTAL HEALTH SYSTEM WATER QUALITY MONITORING
JOHANNA E. VINCZE (McDonnell Douglas Space Systems Co., Houston, TX) and RICHARD L. SAUER (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 8 p.
(SAE PAPER 901351) Copyright

One of the unique aspects of the Space Station is that it will be a totally encapsulated environment and the air and water supplies will be reclaimed for reuse. The Environmental Health System, a subsystem of CHeCS (Crew Health Care System), must monitor the air and water on board the Space Station Freedom to verify that the quality is adequate for crew safety. Specifically, the Water Quality Subsystem will analyze the potable and hygiene water supplies regularly for organic, inorganic, particulate, and microbial contamination. The equipment selected to perform these analyses will be commercially available instruments which will be converted for use on board the Space Station Freedom. Therefore, the commercial hardware will be analyzed to identify the gravity dependent functions and modified to eliminate them. The selection, analysis, and conversion of the off-the-shelf equipment for monitoring the Space Station reclaimed water creates a challenging project for the Water Quality engineers and scientists. Author

A90-49385* Little (Arthur D.), Inc., Cambridge, MA.
A VOLATILE ORGANICS CONCENTRATOR FOR USE IN MONITORING SPACE STATION WATER QUALITY
DANIEL J. EHNTHOLT, ITAMAR BODEK, JAMES R. VALENTINE (Arthur D. Little, Inc., Cambridge, MA), RUDY TRABANINO, JOHANNA E. VINCZE (McDonnell Douglas Space Systems Co., Houston, TX), and RICHARD L. SAUER (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 14 p.
(SAE PAPER 901352) Copyright

The process used to identify, select, and design an approach to the isolation and concentration of volatile organic compounds from a water sample prior to chemical analysis in a microgravity environment is discerned. The trade analysis leading to the recommended volatile organics concentrator (VOC) concept to be tested in a breadboard device is presented. The system covers the areas of gases, volatile separation from water, and water removal/gas chromatograph/mass spectrometer interface. Five options for potential use in the VOC and GC/MS system are identified and ranked, and also nine options are presented for separation of volatiles from the water phase. Seven options for use in the water removal/GC column and MS interface are also identified and included in the overall considerations. A final overall recommendation for breadboard VOC testing is given. L.K.S.

A90-49386
DETECTION OF GAS LOADING OF THE WATER ONBOARD SPACE STATION FREEDOM
D. C. SMITH, J. A. HOWARD, JR., and S. K. ROSE (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p.
(SAE PAPER 901353) Copyright

Because of gastrointestinal discomfort associated with the ingestion of gas-loaded water in microgravity, it is important to monitor the gas content of the potable water onboard Space Station Freedom. A major potential constituent of this gas is nitrogen, which cannot be detected in aqueous solution by electrodes or by spectrophotometric methods. This paper concerns Lockheed's work in behalf of McDonnell Douglas Space Systems Company for NASA's Space Station Work Package 2. As part of the environmental monitoring subsystem for the Crew Health Care System, Lockheed is developing an Optical Water Quality Analyzer. An important feature of this instrument is the ability to unload and measure the gas content of the water sample. Author

A90-49387
NEW TOTAL ORGANIC CARBON ANALYZER
RICHARD D. GODEC, PAUL P. KOSENKA, and RICHARD S. HUTTE (Sievers Research, Inc., Boulder, CO) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. Research supported by McDonnell Douglas Astronautics Co. refs
(SAE PAPER 901354) Copyright

The development of a high sensitivity, compact monitor for the measurement of total organic carbon (TOC) in water with no gravity-dependent components is discussed. The system is based on a combination of photo-catalzyed oxidation of organic compounds to form carbon dioxide, which is selectively measured using a gas permeable membrane and conductometric detection. This unique combination permits the development of a TOC analyzer with significant advantages over existing methods for TOC analysis including high sensitivity (i.e., detection limits at low parts per billion TOC concentrations), a linear response over a wide range of TOC concentrations (at least four orders of magnitude), long-term stable calibration, compact design, and performance with minimal maintenance for semi-continuous and continuous monitoring capabilities. The results from our preliminary investigations on the development of the TOC monitor are presented. Author

A90-49388* Houston Univ., TX.
INFLUENCE OF IODINE ON THE TREATMENT OF SPACECRAFT HUMIDITY CONDENSATE TO PRODUCE POTABLE WATER
JAMES M. SYMONS (Houston, University, TX) and SUSAN V. MUCKLE SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 25 p.
(Contract NAG9-284)
(SAE PAPER 901355) Copyright

Several compounds in the ersatz humidity condensate do react with iodine to form iodine-substituted organic compounds (TOI), most notably phenol, acetaldehyde, ethanol, and sodium formate. Iodination of the ersatz humidity condensate produced 3.0 to 3.5 mg/L of TOI within 24 hours. The TOI that was produced by the passage of the ersatz humidity condensate through the first iodinated resin (IR) in the adsorption system was removed by the granular activated carbon that followed. TOI detected in the final effluent was formed by the reaction of the non-adsorbable condensate compounds with the final IR in the treatment series. The activated carbon bed series in the adsorption system performed poorly in its removal of TOC. The rapid breakthrough of TOC was not surprising, as the ersatz humidity condensate contained several highly soluble organic compounds, alcohols and organic acids. Author

A90-49395
CREW SELECTION, PRODUCTIVITY AND WELL-BEING FOR HUMAN EXPLORATION MISSIONS
LAUREN B. LEVETON and LYDIA STONE (Lockheed Engineering and Sciences Co., Washington, DC) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990.

8 p. refs
(SAE PAPER 901362) Copyright

Available information from U.S. and Soviet spaceflight experiences is reviewed to aid in selecting crews and maintaining health and productivity for long-duration manned space exploration missions. Factors examined include group selection, cohesion, structure, and leadership. A brief historical review of the astronaut selection process is presented, and information from the Soviet space program is analyzed. NASA Life Sciences strategies and recommendations for addressing these concerns for future space exploration missions are also described. Recommendations include the development of a selection process with emphasis on the selection of groups and use of analogs such as the Antarctic and undersea habitats to enable researchers to investigate the effects of confinement and isolation on psychological health and group dynamics. It is noted that Antarctic bases provide a testbed for psychological countermeasures, crew selection and training, and performance. L.K.S.

A90-49408* Kansas State Univ., Manhattan.
APPLICATION OF THE PENTAIODIDE STRONG BASE RESIN DISINFECTANT TO THE U.S. SPACE PROGRAM
GEORGE L. MARCHIN (Kansas State University, Manhattan) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 7 p. Research supported by Hatch Fund. refs
(Contract NAGW-1197)
(SAE PAPER 901380) Copyright

A pentaiodide resin is described which has 70 percent of its weight composed of elemental iodine, has a relatively low iodine residual, and may offer superior disinfection capability for applications on long-duration space vehicles. Such a disinfectant is crucial for use on spacecraft for long periods of time where water would be recycled through various systems. The pentaiodide resin is capable of devitalizing 1 x 10 to the 9th bacteria per ml in aqueous suspension within 10 seconds of contact with the resin bed. A number of organisms have already been tested and the resin continues to prove effective. Resin properties and composition are discussed and a detailed account of the first investigation of the pentaiodide resin as a disinfectant against the intestinal parasite Giardia lamblia is provided. L.K.S.

A90-49409* Harvard Univ., Cambridge, MA.
SURVIVAL OF PATHOGENIC BACTERIA UNDER NUTRIENT STARVATION CONDITIONS
MICHAEL BOYLE, TIM FORD, RALPH MITCHELL, and JAMES MAKI (Harvard University, Cambridge, MA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p. Research supported by NASA. refs
(SAE PAPER 901381) Copyright

The survival of opportunistic pathogenic microorganisms in water, under nutrient-limiting conditions, has been investigated in order to ascertain whether human pathogens can survive within a water-distribution system of the kind proposed for the NASA Space Station. Cultures of a strain of pseudomonas aeruginosa and two strains of staphylococcus aureus were incubated at 10, 25, or 37 C, and samples at 1 day, 1 week, 1 month, and six weeks. While neither of the staphylococcus strains tested were detected after 1 week of starvation, the pseudomonas strain can survive in deionized water at all three temperatures. O.C.

A90-49410* Krug International, Houston, TX.
SPACE STATION FREEDOM VIEWED AS A 'TIGHT BUILDING'
THOMAS F. LIMERO, ROBERT D. TAYLOR (Krug International, Technology Life Sciences Div., Houston, TX), DUANE L. PIERSON, and JOHN T. JAMES (NASA, Johnson Space Center, Houston, Texas) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 19 p. refs
(SAE PAPER 901382) Copyright

The Space Station Freedom (SSF), with a 30-year projected lifetime and a completely closed-loop Environmental Control and Life Support System (ECLSS), is perhaps the ultimate 'tight building'. Recognizing the potential for the development of 'tight building syndrome' (TBS), and initiating actions to minimize possible TBS occurrences on SSF, requires a multidisciplinary approach that begins with appropriate design concerns and ends with detection and control measures on board SSF. This paper presents a brief summary of current experience with TBS on earth. Air contamination, including volatile organic compounds and microorganisms, is the focus of the discussion. Preventive steps to avoid TBS, control of environmental factors that may lead to TBS, and use of real-time instrumentation for the detection of potential causes of TBS are also outlined. Author

A90-49411* Houston Univ., Clear Lake, TX.
IDENTIFYING ATMOSPHERIC MONITORING NEEDS FOR SPACE STATION FREEDOM
DENNIS M. CASSERLY (Houston, University, TX) and DANE M. RUSSO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 14 p. refs
(Contract NGT-44-001-800)
(SAE PAPER 901383) Copyright

The monitoring needs for Space Station Freedom were identified by examining: the experiences of past missions; ground based tests of proposed life support systems; a contaminant load model; metabolic production from an 8-person crew; and a fire scenario. Continuous monitoring is recommended for components critical for life support, and that intermittent analysis be provided for all agents that may exceed one-half the spacecraft maximum allowable concentration. The minimum monitoring effort recommended includes continuous monitoring for: N2, O2, CO2, CO, H2O, H2, CH4, nonmethane hydrocarbons, aromatic hydrocarbons, refrigerants, and halons. Information on over 70 compounds is presented on the rationale for monitoring the frequency of analysis, and concentration ranges. Author

A90-49412
CRITICAL TECHNOLOGIES - SPACECRAFT HABITABILITY
R. A. J. DAMS (CJB Developments, Inc., Portsmouth, England) and C. SOULEZ-LARIVIERE (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p.
(SAE PAPER 901384) Copyright

A study for the European Space Agency (ESA) identifies critical technologies (CT) relating to spacecraft habitability, where CT are defined as technologies requiring a solution in order that the objectives of the European Manned Space Infrastructure (EMSI) can be met. The study lists 36 CTs and provides comparative timescales and costs for development programs to find solutions. Topics include food, clothing, hygiene and architecture and critical technologies for these topics include such things as a trash compactor, clothes washing procedures, oral hygiene, and body and foot restraints. It is noted that in order to implement these development programs, an overall habitability strategy will be required. L.K.S.

A90-49413
ALTERNATIVE HYGIENE CONCEPTS
JACQUELINE BAUNE (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 8 p. refs
(SAE PAPER 901385) Copyright

Hygiene alternatives that may be applicable to manned space flights are explored. It is proposed that overall body hygiene be based on exfoliation, which would be achieved through dry body brushing with 30 to 100 brush strokes deemed to be necessary. Focus is placed on development of the Environment and Life Support System capable of trapping and filtering the exfoliated debris and hair. As far as oral hygiene, a diet of sugar-free and nonrefined food rich in wholefoods, dairy products, and drinks containing polyphenols would reduce the need for current forms of oral hygiene practices. The use of a fecal bag made of rubber materials similar to condoms is suggested for collecting feces. The interrelationships of the various aspects of an alternative

diet/hygiene/waste-management system are illustrated, and an implementation process consisting of system design and development, preflight mission preparation, and activities performed during the mission is outlined with emphasis on crew acceptability. V.T.

A90-49414
HYGIENE AND WATER IN SPACE STATION
J. COLLET, A. BICHI (ESA, Paris, France), J. C. GERMAIN, J. M. BARREAU, E. KIHM (Matra Espace, Velizy-Villacoublay, France) et al. SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 15 p. refs
(SAE PAPER 901386) Copyright

A study on hygiene in long duration space missions was held between 1988-1989 for the ESA Long Term Programme Office. The impact of hygiene on station contamination and station layout was reviewed as well as psychological, social and cultural aspects, leading to the conclusion that hygiene is a key habitability issue. Among its main results, the study highlighted the importance of water in both environmental and personal hygiene. Due to the limited water availability in Space Stations, particular attention was paid to on board water management. Simulation software was developed to demonstrate the relation between hygiene subsystems concepts and water requirements. Author

A90-49415
EUROPEAN SPACE STATION HEALTH CARE SYSTEM CONCEPT
ROLF JESSL (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p.
(SAE PAPER 901387) Copyright

Results of a health risk analysis and the follow-on derivation of medical requirements for crews of the European Space Station are presented. Details are provided for health risk assessment, medical equipment definition, and health care system design. The health care system will consist of an onboard escape vehicle and ground based equipment to prevent accidents and sickness by maintaining and monitoring crew health, and providing a safety margin by stabilizing sick or injured crew before and during transfer to earth. R.E.P.

A90-49418* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION FREEDOM CONTAMINATION REQUIREMENTS AND PREDICTIONS
HORST K. F. EHLERS (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p.
(SAE PAPER 901408) Copyright

Space Station Freedom (SSF) requirements for the induced external gaseous and particulate environment have been defined. They include the Assembly Complete (AC) and the Permanently Manned Capability (PMC) phases which were established since the original configuration was developed. Requirements for both SSF configurations are discussed. Preliminary assessments of the impacts on SSF design and operation indicate that these requirements are both realistic and acceptable to the users with attached payloads. Author

A90-49423
IVA AND EVA WORK PLACE DESIGN FOR A MAN-TENDED SYSTEM
MANFRED BAUNE (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 17 p.
(SAE PAPER 901415) Copyright

This paper considers global and detailed design responses to the particular problems of a non-space adapted crew. It discusses crew disorientation problems and the space adaptation syndrome as they relate to certain design features of a prospective, man-tended vehicle. Both IVA and EVA scenarios and related design characteristics are addressed along with architectural and functional needs and implementation potentials. The paper notes some associated technological details such as, e.g., the need for matching the design of modern electronic units with the dimensional capabilities of module racks, or the use of a particular type of connectors to enhance EVA. An EVA and repair philosophy in response to crew capabilities and problems is also proposed. Author

A90-49424
HABEMSI STUDY - A STUDY ON HUMAN FACTORS FOR SPACE STATION DESIGN
L. BASILE (Aeritalia S.p.A., Naples, Italy), J. P. MAYER (AMDBA, S.A., Vaucresson, France), and A. LINDENTHAL (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 10 p.
(SAE PAPER 901416) Copyright

A preparatory program for the European Manned Space Infrastructure (EMSI) is presented. The EMSI system evolution, human factors analyses, habitation-module configuration evolution, and simulation programs and facilities are discussed. Four phases in the evolution process are identified from the initial step of the implementation of the European Space Station (ESS) in a man-tended mode to a permanently-manned facility. Human abilities, limitations, and performance affecting design considerations for systems, tasks, jobs, and environments for safe, comfortable, and effective human use are assessed. The habitation-module configuration selected on the basis of several trade-offs is described, and such crew functions as sleeping, eating, personal hygiene, waste management, clothing, communication, housekeeping, health management, exercise, and recreation are outlined. Attention is given to neutral buoyancy facilities on the ground, microgravity conditions on orbit, and the NASA program Health Radiation Initiative as a tool related to interplanetary space missions to Mars. V.T.

A90-49425
COMMON APPROACH FOR PLANETARY HABITATION SYSTEMS IMPLEMENTATION
FRANK STEINSIEK and UWE APEL (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 12 p. refs
(SAE PAPER 901417) Copyright

The European philosphy for the establishment of man's presence in space is defined by ESA's European Manned Space Infrastructure Programme (EMSI). The development toward a European manned space station is defined by discrete steps on manned capabilities and technology applications. Different, alternative evolutionary approaches toward a European space station and key elements have been studied by industry within the last years. Potential orbital scenarios, the habitation module, interconnecting element and escape vehicle were major themes of investigations. The purpose of this paper is to provide possible concepts for orbital, lunar and martian habitats, based on the recent study results and ESA's EMSI-philosophy. Advanced habitability conceptual designs concerning crew comfort and human factors, resources supply and different utilization aspects will be outlined, pending on the environmental characteristics of the operation sides: on moon, Mars or in low earth orbit. Key issues of these hab-system developments in terms of technology needs, operational characteristics and aspects of an international cooperation and European industrial potential are discussed. Author

A90-49774
HOME SWEET ORBITAL HOME
JOHN KROSS Ad Astra (ISSN 1041-102X), vol. 2, July-Aug. 1990, p. 23-26.
Copyright

Provisions for personal hygiene and nutrition aboard the Space

Station Freedom are discussed. It is maintained that amenities such as daily showers, private dressing areas, a washing machine, handwasher, and oven-prepared, interesting meals are an integral part of maintaining crew morale and efficiency. Resupply via logistics module carried by the Space Shuttle, rather than by robot resupply ships, will be scheduled every 90 days. Freedom's waste management compartment and its special provisions for dealing with human waste under closed-environment, zero-gravity conditions, are described. Other waste management will require a trash compactor to deal with garbage. L.K.S.

N90-20675*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
USING AN INSTRUMENTED MANIKIN FOR SPACE STATION FREEDOM ANALYSIS
LINDA ORR and RICHARD HILL (Lockheed Missiles and Space Co., Huntsville, AL.) *In its* Graphics Technology in Space Applications (GTSA 1989) p 171-175 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 09/2

One of the most intriguing and complex areas of current computer graphics research is animating human figures to behave in a realistic manner. Believable, accurate human models are desirable for many everyday uses including industrial and architectural design, medical applications, and human factors evaluations. For zero-gravity (0-g) spacecraft design and mission planning scenarios, they are particularly valuable since 0-g conditions are difficult to simulate in a one-gravity Earth environment. At NASA/JSC, an in-house human modeling package called PLAID is currently being used to produce animations for human factors evaluation of Space Station Freedom design issues. Presented here is an introductory background discussion of problems encountered in existing techniques for animating human models and how an instrumented manikin can help improve the realism of these models. Author

N90-21715*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SIMPLIFIED MODEL FOR SOLAR COSMIC RAY EXPOSURE IN MANNED EARTH ORBITAL FLIGHTS
JOHN W. WILSON, GOVIND S. KHANDELWAL, JUDY L. SHINN, JOHN E. NEALY, LAWRENCE W. TOWNSEND, and FRANCIS A. CUCINOTTA (Rockwell International Corp., Houston, TX.) Washington May 1990 15 p
(NASA-TM-4182; L-16738; NAS 1.15:4182) Avail: NTIS HC A03/MF A01 CSCL 03/2

A simple calculational model is derived for use in estimating solar cosmic ray exposure to critical body organs in low-Earth orbit at the center of a large spherical shield of fixed thickness. The effects of the Earth's geomagnetic field, including storm conditions and the astronauts' self-shielding, are evaluated explicitly. The magnetic storm model is keyed to the planetary index K(sub p). Author

N90-22593*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION FREEDOM ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM PHASE 3 SIMPLIFIED INTEGRATED TEST DETAILED REPORT
B. C. ROBERTS, R. L. CARRASQUILLO, M. Y. DUBIEL, K. Y. OGLE, J. L. PERRY, and K. M. WHITLEY Washington, DC May 1990 99 p
(NASA-TM-4204; NAS 1.15:4204) Avail: NTIS HC A05/MF A01 CSCL 22/2

A description of the phase 3 simplified integrated test (SIT) conducted at the Marshall Space Flight Center (MSFC) Core Module Integration Facility (CMIF) in 1989 is presented. This was the first test in the phase 3 series integrated environmental control and life support systems (ECLSS) tests. The basic goal of the SIT was to achieve full integration of the baseline air revitalization (AR) subsystems for Space Station Freedom. Included is a description of the SIT configuration, a performance analysis of each subsystem, results from air and water sampling, and a discussion of lessons learned from the test. Also included is a full description of the preprototype ECLSS hardware used in the test. Author

N90-24975*# Armstrong State Coll., Savannah, GA. Dept. of Biology.
EFFECT OF LOW AIR VELOCITIES ON THERMAL HOMEOSTASIS AND COMFORT DURING EXERCISE AT SPACE STATION OPERATIONAL TEMPERATURE AND HUMIDITY Final Report
RONALD J. BEUMER *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 1 15 p Dec. 1989
Avail: NTIS HC A09/MF A02 CSCL 05/8

The effectiveness of different low air velocities in maintaining thermal comfort and homeostasis during exercise at space station operational temperature and humidity was investigated. Five male subjects exercised on a treadmill for successive ten minute periods at 60, 71, and 83 percent of maximum oxygen consumption at each of four air velocities, 30, 50, 80, and 120 ft/min, at 22 C and 62 percent relative humidity. No consistent trends or statistically significant differences between air velocities were found in body weight loss, sweat accumulation, or changes in rectal, skin, and body temperatures. Occurrence of the smallest body weight loss at 120 ft/min, the largest sweat accumulation at 30 ft/min, and the smallest rise in rectal temperature and the greatest drop in skin temperature at 120 ft/min all suggested more efficient evaporative cooling at the highest velocity. Heat storage at all velocities was evidenced by increased rectal and body temperatures; skin temperatures declined or increased only slightly. Body and rectal temperature increases corresponded with increased perception of warmth and slight thermal discomfort as exercise progressed. At all air velocities, mean thermal perception never exceeded warm and mean discomfort, greatest at 30 ft/min, was categorized at worst as uncomfortable; sensation of thermal neutrality and comfort returned rapidly after cessation of exercise. Suggestions for further elucidation of the effects of low air velocities on thermal comfort and homeostasis include larger numbers of subjects, more extensive skin temperature measurements and more rigorous analysis of the data from this study. Author

N90-24977*# Houston Univ., Clear Lake, TX. School of Natural and Applied Sciences.
IDENTIFYING ATMOSPHERIC MONITORING NEEDS FOR SPACE STATION FREEDOM Final Report
DENNIS M. CASSERLY *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 1 15 p Dec. 1989
Avail: NTIS HC A09/MF A02 CSCL 06/11

The atmospheric monitoring needs for Space Station Freedom were identified by examining the following from an industrial hygiene perspective: the experiences of past missions; ground based tests of proposed life support systems; the unique experimental and manufacturing facilities; the contaminant load model; metabolic production; and a fire. A target list of compounds to be monitored is presented and information is provided relative to the frequency of analysis, concentration ranges, and locations for monitoring probes. Author

N90-24981*# Montana State Univ., Bozeman. Dept. of Chemistry.
ELECTROCHEMICAL CONTROL OF IODINE DISINFECTANT FOR SPACE TRANSPORTATION SYSTEM AND SPACE STATION POTABLE WATER Final Report
RICHARD D. GEER *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 1 15 p Dec. 1989
Avail: NTIS HC A09/MF A02 CSCL 06/11

An electrochemical microbial check valve method (EC-MCV) for controlling the iodine disinfectant in potable water (PW) for NASA's space operations was proposed. The factors affecting the design and performance of the unit were analyzed. This showed that it would be feasible to construct a recyclable unit in a small volume that will operate in either an iodine removal or addition mode. The EC-MCV should remove active iodine species rapidly

from PW, but the rapid delivery rates at end-use may make complete removal of excess I(-) difficult under some conditions. Its performace change with AgI buildup needs to be investigated, as this controls the time for recycling the unit. The EC-MCV has advantages over the passive microbial check valve (MCV) method currently in use, as it would allow precise control of the I2 level and would not introduce excess I(-) to the water. The presence of oxygen in the EC-MCV needs to be investigated as it could affect the efficiency of I2 addition and excess I(-) removal. Author

N90-24982*# North Carolina Univ., Chapel Hill. Dept. of Physical Education, Exercise and Sport Sciences.
OVERTRAINING AND EXERCISE MOTIVATION: A RESEARCH PROSPECTUS Final Report
ANTHONY C. HACKNEY *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 1 16 p Dec. 1989
Avail: NTIS HC A09/MF A02 CSCL 05/9

The problems of exercise overtraining has recently become one of great interest to professionals in the field of human performance assessment. Quite obviously, the ultimate goal of the training process is to improve physical performance. However, excessive training can result in the opposite effect, that is, a performance decline and an impairment in the functional work capacity of the body. Research indicates that both psychological as well as physiological disturbances are quite common in overtrained individuals. For example, psychological changes include increased levels of depression, fatigue, and a lack of motivation. Similarly, impairment of the physiological function of the cardiovascular, metabolic, and endocrine systems also have been found. Some similarities may be found in the psychological and physiological states of crew members exposed to extended space flight and overtrained individuals. Therefore, the possibility exists that the crew members subjected to extended missions in space may develop overstressed or overtrained or both states during their flights. If such states do develop within the crew members, mission performance may be impaired. With these points as a background, the intent is to address potential research directions that NASA may consider viable and of a mutual interest to the researcher. A clear framework by which to begin discussion of research topics is needed; therefore, working definitions of overtraining and exercise motivation are presented. Subsequently, a proposed conceptional model of how exercise overtraining and motivation interact is presented. In support of the proposed model is a brief literature review of relevant areas. Potential research projects are presented and discussed. Author

N90-24983*# Texas Univ., Galveston. Dept. of Physical Therapy.
RESEARCH IN HUMAN PERFORMANCE RELATED TO SPACE: A COMPILATION OF THREE PROJECTS/PROPOSALS Final Report
SCOTT M. HASSON *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 1 13 p Dec. 1989
Avail: NTIS HC A09/MF A02 CSCL 05/8

Scientific projects were developed in order to maximize performance in space and assure physiological homeostatis upon return. Three projects that are related to this common goal were either initiated or formulated during the Faculty Fellowship Summer Program. The projects were entitled: (1) Effect of simulated weightlessness (bed rest) on muscle performance and morphology; (2) Effect of submaximal eccentric muscle contractions on muscle injury, soreness and performance: A grant proposal; and (3) Correlation between isolated joint dynamic muscle strength to end-effector strength of the push and pull extravehicular activity (EVA) ratchet maneuver. The purpose is to describe each of these studies in greater detail. Author

N90-25162*# Michigan Univ., Ann Arbor.
PROJECT EGRESS: EARTHBOUND GUARANTEED REENTRY FROM SPACE STATION. THE DESIGN OF AN ASSURED CREW RECOVERY VEHICLE FOR THE SPACE STATION
Apr. 1990 195 p
(Contract NASW-4435)
(NASA-CR-186657; NAS 1.26:186657) Avail: NTIS HC A09/MF A02 CSCL 22/2

Unlike previously designed space-based working environments, the shuttle orbiter servicing the space station will not remain docked the entire time the station is occupied. While an Apollo capsule was permanently available on Skylab, plans for Space Station Freedom call for a shuttle orbiter to be docked at the space station for no more than two weeks four times each year. Consideration of crew safety inspired the design of an Assured Crew Recovery Vehicle (ACRV). A conceptual design of an ACRV was developed. The system allows the escape of one or more crew members from Space Station Freedom in case of emergency. The design of the vehicle addresses propulsion, orbital operations, reentry, landing and recovery, power and communication, and life support. In light of recent modifications in space station design, Project EGRESS (Earthbound Guaranteed ReEntry from Space Station) pays particular attention to its impact on space station operations, interfaces and docking facilities, and maintenance needs. A water-landing medium-lift vehicle was found to best satisfy project goals of simplicity and cost efficiency without sacrificing safety and reliability requirements. One or more seriously injured crew members could be returned to an earth-based health facility with minimal pilot involvement. Since the craft is capable of returning up to five crew members, two such permanently docked vehicles would allow a full evacuation of the space station. The craft could be constructed entirely with available 1990 technology, and launched aboard a shuttle orbiter. Author

N90-25497*# Florida Technological Univ., Orlando. Dept. of Aerospace Engineering.
DESIGN AND IMPLEMENTATION OF SENSOR SYSTEMS FOR CONTROL OF A CLOSED-LOOP LIFE SUPPORT SYSTEM
LESLIE ALNWICK, AMY CLARK, PATRICIA DEBS, CHRIS FRANCZEK, TOM GOOD, and PEDRO RODRIGUES Dec. 1989 121 p
(Contract NASW-4435)
(NASA-CR-186675; NAS 1.26:186675) Avail: NTIS HC A06/MF A01 CSCL 06/11

The sensing and controlling needs for a Closed-Loop Life Support System (CLLSS) were investigated. The sensing needs were identified in five particular areas and the requirements were defined for workable sensors. The specific areas of interest were atmosphere and temperature, nutrient delivery, plant health, plant propagation and support, and solids processing. The investigation of atmosphere and temperature control focused on the temperature distribution within the growth chamber as well as the possibility for sensing other parameters such as gas concentration, pressure, and humidity. The sensing needs were studied for monitoring the solution level in a porous membrane material along with the requirements for measuring the mass flow rate in the delivery system. The causes and symptoms of plant disease were examined and the various techniques for sensing these health indicators were explored. The study of sensing needs for plant propagation and support focused on monitoring seed viability and measuring seed moisture content as well as defining the requirements for drying and storing the seeds. The areas of harvesting, food processing, and resource recycling, were covered with a main focus on the sensing possibilities for regulating the recycling process. Author

N90-25500*# Alabama A & M Univ., Normal. Dept. of Plant and Soil Sciences.
A PROPOSAL TO DEMONSTRATE PRODUCTION OF SALAD CROPS IN THE SPACE STATION MOCKUP FACILITY WITH PARTICULAR ATTENTION TO SPACE, ENERGY, AND LABOR CONSTRAINTS Annual Progress Report, 1 Jul. - 30 Jun. 1990
CAROLYN A. BROOKS, GOVIND C. SHARMA, and CAULA A. BEYL 25 Jul. 1990 30 p
(Contract NCC2-607)
(NASA-CR-186811; NAS 1.26:186811) Avail: NTIS HC A03/MF A01 CSCL 06/11

A desire for fresh vegetables for consumption during long

term space missions has been foreseen. To meet this need in a microgravity environment within the limited space and energy available on Space Station requires highly productive vegetable cultivars of short stature to optimize vegetable production per volume available. Special water and nutrient delivery systems must also be utilized. As a first step towards fresh vegetable production in the microgravity of Space Station, several soil-less capillary action media were evaluated for the ability to support growth of two root crops (radish and carrot) which are under consideration for inclusion in a semi-automated system for production of salad vegetables in a microgravity environment (Salad Machine). In addition, productivity of different cultivars of radish was evaluated as well as the effect of planting density and cultivar on carrot production and size. Red Prince radish was more productive than Cherry Belle and grew best on Jiffy Mix Plus. During greenhouse studies, vermiculite and rock wool supported radish growth to a lesser degree than Jiffy Mix Plus but more than Cellular Rooting Sponge. Comparison of three carrot cultivars (Planet, Short n Sweet, and Goldinhart) and three planting densities revealed that Short n Sweet planted at 25.6 sq cm/plant had the greatest root fresh weight per pot, the shortest mean top length, and intermediate values of root length and top fresh weight per pot. Red Prince radish and Short n Sweet carrot showed potential as productive cultivars for use in a Salad Machine. Results of experiments with solid capillary action media were disappointing. Further research must be done to identify a solid style capillary action media which can productively support growth of root crops such as carrot and radish. Author

N90-25523*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM ADVANCED AUTOMATION PROJECT. PHASE 1: APPLICATION EVALUATION
BRANDON S. DEWBERRY *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 195-208 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 06/11

The Environmental Control and Life Support System (ECLSS) is a Freedom Station distributed system with inherent applicability to advanced automation primarily due to the comparatively large reaction times of its subsystem processes. This allows longer contemplation times in which to form a more intelligent control strategy and to detect or prevent faults. The objective of the ECLSS Advanced Automation Project is to reduce the flight and ground manpower needed to support the initial and evolutionary ECLS system. The approach is to search out and make apparent those processes in the baseline system which are in need of more automatic control and fault detection strategies, to influence the ECLSS design by suggesting software hooks and hardware scars which will allow easy adaptation to advanced algorithms, and to develop complex software prototypes which fit into the ECLSS software architecture and will be shown in an ECLSS hardware testbed to increase the autonomy of the system. Covered here are the preliminary investigation and evaluation process, aimed at searching the ECLSS for candidate functions for automation and providing a software hooks and hardware scars analysis. This analysis shows changes needed in the baselined system for easy accommodation of knowledge-based or other complex implementations which, when integrated in flight or ground sustaining engineering architectures, will produce a more autonomous and fault tolerant Environmental Control and Life Support System. Author

N90-26032*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ORBITER UTILIZATION AS AN ACRV
JONATHAN N. CRUZ, MICHAEL L. HECK, RENJITH R. KUMAR, DANIEL D. MAZANEK (Analytical Mechanics Associates, Inc., Hampton, VA.), and PATRICK A. TROUTMAN Jun. 1990 101 p
(NASA-TM-102700; NAS 1.15:102700) Avail: NTIS HC A06/MF A01 CSCL 22/2

Assuming that a Shuttle Orbiter could be qualified to serve long duration missions attached to Space Station Freedom in the capacity as an Assured Crew Return Vehicle (ACRV), a study was conducted to identify and examine candidate attach locations. Baseline, modified hardware, and new hardware design configurations were considered. Dual simultaneous Orbiter docking accommodation were required. Resulting flight characteristics analyzed included torque equilibrium attitude (TEA), microgravity environment, attitude controllability, and reboost fuel requirements. The baseline Station could not accommodate two Orbiters. Modified hardware configurations analyzed had large TEA's. The utilization of an oblique docking mechanism best accommodated an Orbiter as an ACRV. Author

N90-26039*# Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.
PRELIMINARY SUBSYSTEM DESIGNS FOR THE ASSURED CREW RETURN VEHICLE (ACRV), VOLUME 1 Final Report
Jun. 1990 589 p Presented at the 1990 Annual Summer Conference, Cleveland, OH, 11-15 Jun. 1990
(Contract NASW-4435)
(NASA-CR-186677-VOL-1; NAS 1.26:186677-VOL-1) Avail: NTIS HC A25/MF A04 CSCL 22/2

A series of design studies is presented concerning the Assured Crew Return Vehicle (ACRV) for Space Station Freedom. Four alternate designs are presented for the ACRV braking and landing system. Options presented include: ballistic and lifting body reentries; the use of high-lift, high-payload aerodynamic decelerators, as well as conventional parachutes; landing systems designed for water landings, land landings, or both; and an aerial recovery system. All four design options presented combine some or all of the above attributes, and all meet performance requirements established by the ACRV Program Office. Two studies of ACRV growth options are also presented. Use of the ACRV or a similarly designed vehicle in several roles for possible future space missions is discussed, along with the required changes to a basic ACRV to allow it to perform these missions optimally. The outcome of these studies is a set of recommendations to the ACRV Program Office describing the vehicle characteristics of the basic ACRV which lend themselves most readily to be adapted for use in other missions. Finally, the impacts on the design of the ACRV due to its role as a medical emergency vehicle were studied and are presented. The use of the ACRV in this manner will impact its shape, internal configuration, and equipment.
Author

N90-26463*# Medical Coll. of Wisconsin, Milwaukee. Dept. of Anatomy and Cellular Biology.
EXPERIMENT K-6-09. MORPHOLOGICAL AND BIOCHEMICAL INVESTIGATION OF MICROGRAVITY-INDUCED NERVE AND MUSCLE BREAKDOWN. PART 1: INVESTIGATION OF NERVE AND MUSCLE BREAKDOWN DURING SPACEFLIGHT; PART 2: BIOCHEMICAL ANALYSIS OF EDL AND PLT MUSCLES
D. A. RILEY, S. ELLIS, J. BAIN, F. SEDLAK, G. SLOCUM, and V. OGANOV (Institute of Biomedical Problems, Moscow, USSR) *In* NASA, Ames Research Center, The US Experiments Flown on the Soviet Biosatellite Cosmos 1887 p 215-261 Feb. 1990
Avail: NTIS HC A22/MF A03 CSCL 06/3

The present findings on rat hindlimb muscles suggest that skeletal muscle weakness induced by prolonged spaceflight can result from a combination of muscle fiber atrophy, muscle fiber segmental necrosis, degeneration of motor nerve terminals and destruction of microcirculatory vessels. Damage was confined to the red adductor longus (AL) and soleus muscles. The midbelly region of the AL muscle had more segmental necrosis and edema than the ends. Macrophages and neutrophils were the major mononucleated cells infiltrating and phagocytosing the cellular debris. Toluidine blue-positive mast cells were significantly decreased in Flight AL muscles compared to controls; this indicated that degranulation of mast cells contributed to tissue edema. Increased ubiquitination of disrupted myofibrils may have promoted myofilament degradation. Overall, mitochondria content and SDH activity were normal, except for a decrease in the subsarcolemmal

region. The myofibrillar ATPase activity shifted toward the fast type in the Flight AL muscles. Some of the pathological changes may have occurred or been exacerbated during the 2 day postflight period of readaptation to terrestrial gravity. While simple atrophy should be reversible by exercise, restoration of pathological changes depends upon complex processes of regeneration by stem cells. Initial signs of muscle and nerve fiber regeneration were detected. Even though regeneration proceeds on Earth, the space environment may inhibit repair and cause progressive irreversible deterioration during long term missions. Muscles obtained from Flight rats sacrificed immediately (within a few hours) after landing are needed to distinguish inflight changes from postflight readaptation. Author

N90-26500*# Kansas State Univ., Manhattan. Dept. of Mechanical Engineering.
AUTOMATION OF CLOSED ENVIRONMENTS IN SPACE FOR HUMAN COMFORT AND SAFETY Report, 1989-1990
1990 121 p
(Contract NGT-21-002-800)
(NASA-CR-186834; NAS 1.26:186834) Avail: NTIS HC A06/MF A01 CSCL 05/8

The results are presented of the first year of a three year project on the automation of the Environmental Control and Life Support System (ECLSS) of the Space Station Freedom (SSF). The results are applicable to other future space mission. The work was done by the Kansas State University NASA/USRA interdisciplinary student design team. The six ECLSS subsystems and how they interact are discussed. Proposed control schemes and their rationale are discussed for the Atmosphere Revitalization (AR) subsystem. Finally, a description of the mathematical models for many components of the ECLSS control system is given. Author

N90-26855*# Illinois Univ., Urbana-Champaign. Dept. of Engineering.
NASA/USRA UNIVERSITY ADVANCED DESIGN PROGRAM. Final Report, 1988-1989
MICHAEL F. LEMBECK and JOHN PRUSSING 15 Jun. 1989 23 p
(Contract NASW-4435)
(NASA-CR-186050; NAS 1.26:186050) Avail: NTIS HC A03/MF A01 CSCL 22/2

The participation of the University of Illinois at Urbana-Champaign in the NASA/USRA University Advanced Design Program for the 1988 to 1989 academic year is reviewed. The University's design project was the Logistics Resupply and Emergency Crew Return System for Space Station Freedom. Sixty-one students divided into eight groups, participated in the spring 1989 semester. A presentation prepared by three students and a graduate teaching assistant for the program's summer conference summarized the project results. Teamed with the NASA Marshall Space Flight Center (MSFC), the University received support in the form of remote telecon lectures, reference material, and previously acquired applications software. In addition, a graduate teaching assistant was awarded a summer 1989 internship at MSFC. Author

N90-27294*# Vanderbilt Univ., Nashville, TN.
A STUDY ON DIAGNOSABILITY OF SPACE STATION ECLSS
S. PADALKAR, W. BLOKLAND, and J. SZTIPANOVITS *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 165-174 May 1990
Sponsored in part by Boeing Aerospace Co., Huntsville, AL
Avail: NTIS HC A25/MF A04 CSCL 06/11

The use is demonstrated of the Multigraph Architecture (MGA) for studies on the Environment Control and Life Support System (ECLSS). The objective was the following: (1) to create an updated set of models of the Potable Water Subsystem (PWS) by using the graphical model building tools of the Multigraph Programming Environment (MPE); (2) to derive a real time alarm simulator from the models; and (3) to demonstrate the effects of sensor allocation on the diagnosability of the PWS. This work may serve as a preliminary study for the detailed analysis of the sensor allocation and diagnosability problems in the ECLSS. Author

N90-27297*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION FREEDOM ECLSS: A STEP TOWARD AUTONOMOUS REGENERATIVE LIFE SUPPORT SYSTEMS
BRANDON S. DEWBERRY *In its* Fifth Conference on Artificial Intelligence for Space Applications p 193-201 May 1990
Avail: NTIS HC A25/MF A04 CSCL 06/11

The Environmental Control and Life Support System (ECLSS) is a Freedom Station distributed system with inherent applicability to extensive automation primarily due to its comparatively long control system latencies. These allow longer contemplation times in which to form a more intelligent control strategy and to prevent and diagnose faults. The regenerative nature of the Space Station Freedom ECLSS will contribute closed loop complexities never before encountered in life support systems. A study to determine ECLSS automation approaches has been completed. The ECLSS baseline software and system processes could be augmented with more advanced fault management and regenerative control systems for a more autonomous evolutionary system, as well as serving as a firm foundation for future regenerative life support systems. Emerging advanced software technology and tools can be successfully applied to fault management, but a fully automated life support system will require research and development of regenerative control systems and models. The baseline Environmental Control and Life Support System utilizes ground tests in development of batch chemical and microbial control processes. Long duration regenerative life support systems will require more active chemical and microbial feedback control systems which, in turn, will require advancements in regenerative life support models and tools. These models can be verified using ground and on orbit life support test and operational data, and used in the engineering analysis of proposed intelligent instrumentation feedback and flexible process control technologies for future autonomous regenerative life support systems, including the evolutionary Space Station Freedom ECLSS. Author

N90-28597*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION FREEDOM PRESSURIZED ELEMENT INTERIOR DESIGN PROCESS
GEORGE D. HOPSON, JOHN AARON, and RICHARD L. GRANT (Boeing Aerospace Co., Huntsville, AL.) 1990 29 p
(Contract NAS8-50000)
(NASA-CR-181297; NAS 1.26:181297) Avail: NTIS HC A03/MF A01 CSCL 22/2

The process used to develop the on-orbit working and living environment of the Space Station Freedom has some very unique constraints and conditions to satisfy. The goal is to provide maximum efficiency and utilization of the available space, in on-orbit, zero G conditions that establishes a comfortable, productive, and safe working environment for the crew. The Space Station Freedom on-orbit living and working space can be divided into support for three major functions: (1) operations, maintenance, and management of the station; (2) conduct of experiments, both directly in the laboratories and remotely for experiments outside the pressurized environment; and (3) crew related functions for food preparation, housekeeping, storage, personal hygiene, health maintenance, zero G environment conditioning, and individual privacy, and rest. The process used to implement these functions, the major requirements driving the design, unique considerations and constraints that influence the design, and summaries of the analysis performed to establish the current configurations are described. Sketches and pictures showing the layout and internal arrangement of the Nodes, U.S. Laboratory and Habitation modules identify the current design relationships of the common and unique station housekeeping subsystems. The crew facilities, work stations, food preparation and eating areas (galley and wardroom), and exercise/health maintenance configurations, waste management and personal hygiene area configuration are shown. U.S. Laboratory

experiment facilities and maintenance work areas planned to support the wide variety and mixtures of life science and materials processing payloads are described. Author

N90-28753*# Texas A&M Univ., College Station. Surface Electrochemistry Lab.
ELECTROCHEMICAL INCINERATION OF WASTES Final Report, Feb. - Aug. 1990
R. C. BHARDWAJ, D. K. SHARMA, and J. OM. BOCKRIS Aug. 1990 95 p
(Contract NAGW-1779)
(NASA-CR-187033; NAS 1.26:187033) Avail: NTIS HC A05/MF A01 CSCL 13/2

The novel technology of waste removal in space vehicles by electrochemical methods is presented to convert wastes into chemicals that can be eventually recycled. The important consideration for waste oxidation is to select a right kind of electrode (anode) material that should be stable under anodic conditions and also a poor electrocatalyst for oxygen and chlorine evolution. On the basis of long term electrolysis experiments on seven different electrodes and on the basis of total organic carbon reduced, two best electrodes were identified. The effect of redox ions on the electrolyte was studied. Though most of the experiments were done in mixtures of urine and waste, the experiments with redox couples involved 2.5 M sulfuric acid in order to avoid the precipitation of redox ions by urea. Two methods for long term electrolysis of waste were investigated: (1) the oxidation on Pt and lead dioxide electrodes using the galvanostatic methods; and (2) potentiostatic method on other electrodes. The advantage of the first method is the faster rate of oxidation. The chlorine evolution in the second method is ten times less then in the first. The accomplished research has shown that urine/feces mixtures can be oxidized to carbon dioxide and water, but current densities are low and must be improved. The perovskite and Ti4O7 coated with RuO2 are the best electrode materials found. Recent experiment with the redox agent improves the current density, however, sulphuric acid is required to keep the redox agent in solution to enhance oxidation effectively. It is desirable to reduce the use of acid and/or find substitutes. Author

N90-29084*# Perkin-Elmer Corp., Pomona, CA. Applied Science Operation.
ATMOSPHERE AND WATER QUALITY MONITORING ON SPACE STATION FREEDOM
WILLIAM NIU 1990 22 p Presented at the Space Conference, Long Beach, CA, 22 Sep. 1990
(Contract NAS8-50000)
(NASA-CR-186707; NAS 1.26:186707) Avail: NTIS HC A03/MF A01 CSCL 06/11

In Space Station Freedom air and water will be supplied in closed loop systems. The monitoring of air and water qualities will ensure the crew health for the long mission duration. The Atmosphere Composition Monitor consists of the following major instruments: (1) a single focusing mass spectrometer to monitor major air constituents and control the oxygen/nitrogen addition for the Space Station; (2) a gas chromatograph/mass spectrometer to detect trace contaminants; (3) a non-dispersive infrared spectrometer to determine carbon monoxide concentration; and (4) a laser particle counter for measuring particulates in the air. An overview of the design and development concepts for the air and water quality monitors is presented. Author

N90-29430*# Alabama Univ., Huntsville. Dept. of Biological Sciences.
DEFINITION OF A NEAR REAL TIME MICROBIOLOGICAL MONITOR FOR SPACE VEHICLES Final Report
MELVIN V. KILGORE, JR., ROBERT J. ZAHORCHAK, and WILLIAM F. ARENDALE Sep. 1989 302 p Original contains color illustrations
(Contract NAS9-17973)
(NASA-CR-185599; NAS 1.26:185599; UAH-812) Avail: NTIS HC A14/MF A02; 3 functional color pages CSCL 22/2

Efforts to identify the ideal candidate to serve as the biological monitor on the space station Freedom are discussed. The literature review, the evaluation scheme, descriptions of candidate monitors, experimental studies, test beds, and culture techniques are discussed. Particular attention is given to descriptions of five candidate monitors or monitoring techniques: laser light scattering, primary fluorescence, secondary fluorescence, the volatile product detector, and the surface acoustic wave detector. Author

16

ORBITS & ORBITAL TRANSFER

Maintenance of space station or other large structures in their orbits, as well as transfer between orbits. Includes docking with servicing or transfer vehicles.

A90-32102* Carnegie-Mellon Univ., Pittsburgh, PA.
ESTIMATING SATELLITE POSE AND MOTION PARAMETERS USING A NOVELTY FILTER AND NEURAL NET TRACKER
ANDREW J. LEE, DAVID CASASENT, PIETER VERMEULEN, and ETIENNE BARNARD (Carnegie-Mellon University, Pittsburgh, PA) IN: Optical pattern recognition; Proceedings of the Meeting, Los Angeles, CA, Jan. 17, 18, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 2-16. Research supported by JPL. refs
Copyright

A system for determining the position, orientation and motion of a satellite with respect to a robotic spacecraft using video data is advanced. This system utilizes two levels of pose and motion estimation: an initial system which provides coarse estimates of pose and motion, and a second system which uses the coarse estimates and further processing to provide finer pose and motion estimates. The present paper emphasizes the initial coarse pose and motion estimation sybsystem. This subsystem utilizes novelty detection and filtering for locating novel parts and a neural net tracker to track these parts over time. Results of using this system on a sequence of images of a spin stabilized satellite are presented. Author

A90-36923#
ATTITUDE ESTIMATION USING GPS
J. RATH and P. WARD (Texas Instruments, Inc., Defense Systems and Electronics Group, Plano) IN: Institute of Navigation, National Technical Meeting, San Mateo, CA, Jan. 23-26, 1989, Proceedings. Washington, DC, Institute of Navigation, 1989, p. 169-178.

The validity of an algorithm using GPS carrier Doppler phase measurements for determining the attitude in three dimensions (heading, pitch, and roll) of a space platform that also is undergoing attitude variation is assessed via a simulation. The space platform is taken to revolve in a circular orbit appropriate for the Space Station and Shuttle. It is shown that the multipath effects are potentially the dominant source of error in carrier Doppler phase measurements. A model for the multipath phase errors is presented, and ways to reduce the effects are studied. Preliminary 1-sigma error in heading, pitch, and roll using a 5-meter antenna separation is indicated to be 0.015 deg, which compares favorably with the performance of earth sensors currently used for spacecraft attitude measurements. V.T.

A90-37681
THE SEMI-ANNUAL VARIATION IN UPPER-ATMOSPHERE DENSITY DEDUCED FROM THE ORBITAL DECAY OF COSMOS 482
LLYR C. JONES and GRAHAM G. SWINERD (Southampton, University, England) Planetary and Space Science (ISSN 0032-0633), vol. 38, May 1990, p. 637-646. Research supported by SERC and Ministry of Defence of England. refs
Copyright

Cosmos 482 (1972-23A) was launched on March 31, 1972. Although an escape trajectory to Venus was intended, the escape

maneuver failed and the vehicle remained in a high-drag elliptical orbit about the earth. The orbit has been determined previously by King-Hele and Winterbottom (1985) at 77 epochs, and a subset of 46 of these orbits is used in this paper to determine thermospheric density values at heights near 220 km. One hundred and twenty-six such density values are obtained for the period August 1979-February 1981. Standardized to a fixed height of 222 km, and corrected for variations in exospheric temperature, these values reveal the semiannual variation in density which is discussed and compared with standard atmospheric models.
Author

A90-38197
A CONCEPTUAL STUDY OF THE USE OF A PARTICLE BED REACTOR NUCLEAR PROPULSION MODULE FOR THE ORBITAL MANEUVERING VEHICLE
JOHN MALLOY and DICK POTEKHEN (Babcock and Wilcox Co., Lynchburg, VA) IN: IECEC-89; Proceedings of the Twenty-fourth Intersociety Energy Conversion Engineering Conference, Washington, DC, Aug. 6-11, 1989. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1989, p. 1209-1213. refs
Copyright

The use of a particle-bed-reactor nuclear engine for direct thrust in a spacecraft based on the NASA/TRW orbital maneuvering vehicle (OMV) is discussed. The conceptual design of a 500-lb-thrust engine that matches critical design features of the existing OMV bipropellant propulsion system is presented. This application contrasts with the usual tendency to consider a nuclear heat source either for high-thrust direct propulsion or as a power source for electric propulsion. A nuclear propulsion module adapted to the OMV could potentially accomplish several US Department of Defense missions, such as multiple round trips from a space-based support platform at 280 nmi to service a constellation of satellites orbiting at 1800 nmi. I.E.

A90-43486* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ORBITAL MECHANICS AND MISSION DESIGN; PROCEEDINGS OF THE AAS/NASA INTERNATIONAL SYMPOSIUM, GREENBELT, MD, APR. 24-27, 1989
JEROME TELES, ED. (NASA, Goddard Space Flight Center, Greenbelt, MD) Symposium sponsored by NASA and AAS. San Diego, CA, Univelt, Inc., 1989, 860 p. For individual items see A90-43487 to A90-43539.
Copyright

The present conference discusses topics in LEO mechanics, the earth-sun-moon orbital regime, space navigation, and lunar and planetary missions. Attention is given to an improved technique for passive eccentricity control, H-I launch vehicle mission planning, glideslope approaches, the control of Space Station-based tethered systems, rendezvous operations in GEO, launch-window expansion and trajectory correction for the First Lunar Swingby, the nature of lunar gravity assists, and the numerical determination of libration-point trajectories with solar exclusion zone-avoiding out-of-plane maneuvers. Also discussed are the interferometric tracking of multiple spacecraft, an improved determination of Martian satellite orbits, the Magellan Venus Mapping Mission, the Mars Rover Sample Return Mission, round-trip trajectories for manned Mars exploration, advanced missions using fusion propulsion, Vesta trajectories and navigation, and Voyager interstellar mission design. O.C.

A90-43493
A SURVEY OF RENDEZVOUS AND DOCKING ISSUES AND DEVELOPMENTS
CAROLINA L. LEONARD (Aerospace Corp., Los Angeles, CA) and EDWARD V. BERGMANN (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 85-101. refs
(AAS PAPER 89-158) Copyright

This is a survey paper on rendezvous and docking issues; it is based on papers that have been published in the open literature over the past fifteen years, including NASA reports, industry contracted and in-house studies, and foreign documents. Specific topics addressed are: rendezvous and docking approach techniques, man-in-the-loop versus autonomous docking, communications constraints such as lack of coverage and time delays, control implications, plume impingement, targeting aids such as light or reflector patterns on the target vehicle, problems associated with controlling the coupled vehicle, and the effect on the docking process of sensor and human operator induced errors. Author

A90-43494* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEFINING OPTIMAL POINT-TO-POINT TRANSFER SURFACES FOR ORBITAL PATH-CONSTRAINED RENDEZVOUS
KERRY M. SOILEAU (NASA, Johnson Space Center, Houston, TX) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 103-107.
(AAS PAPER 89-161) Copyright

Many scenarios for future orbital operations involve maneuvering in proximity to such large space structures as the Space Station Freedom; in most cases, the accidental contact of a vehicle with such a structure will be dangerous and must be avoided. Classical rendezvous targeting is inadequate for this purpose, because it recognizes no restraint on the path between the point of departure and the desired point of arrival. A computer program has been devised to minimize this susceptibility. Surfaces are found to exist whose penalty is less than that of a sphere, though not markedly less. O.C.

A90-43495* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE GLIDESLOPE APPROACH
DON J. PEARSON (NASA, Johnson Space Center, Houston, TX) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 109-123. refs
(AAS PAPER 89-162) Copyright

The problems associated with optimum approaches to an orbiting spacecraft at the completion of rendezvous are exacerbated when the maneuvering spacecraft is to dock with such large and extended structures as the NASA Space Station, which also has a torque equilibrium attitude due to which the docking port does not point directly into the orbital track. Attention is presently given to a candidate 'operationally optimum' approach to a local vertical-local horizontal stabilized target; this glideslope approach is derived on the basis of Hill's relative-motion equations, which have been expanded to encompass constant relative accelerations in a closed form solution. The motion is described in polar coordinates. O.C.

A90-43499
SERVICING OF MULTIPLE SATELLITES USING AN OMV-DERIVED TRANSFER VEHICLE
CARL D. GRAVES, HANS F. MEISSINGER, and ALAN ROSEN (TRW Space and Technology Group, Redondo Beach, CA) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 171-190.
(AAS PAPER 89-183) Copyright

Servicing vehicles and supplies to be used for extending the mission life of polar orbiting satellites will be launched into orbit by expendable launch vehicles, since the Space Shuttle currently is not expected to operate in this orbital regime. The Orbital Maneuvering Vehicle or a smaller version being designed for this purpose, and its performance potential as a permanently space-based satellite servicing vehicle, are the subject of this paper. A single servicing vehicle of this class can maneuver, as required, to visit multiple user satellites in their respective orbits. Cost-effective orbit transfer techniques are essential for a viable

multi-satellite servicing scenario. Such transfer modes and servicing scenarios, and the usable payload delivery performance achievable are analyzed and compared. Author

A90-43503
RENDEZVOUS IN GEOSTATIONARY ORBIT
E. MATTIAS SOOP (ESA, European Space Operations Centre, Darmstadt, Federal Republic of Germany) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 237-251.
(AAS PAPER 89-187) Copyright

The intensive exploitation of the geostationary orbit as the site for communications satellites prompts the frequent replacement of an older spacecraft with a new one, requiring a rendezvous to be performed within the stationkeeping latitude/longitude control box. This maneuver entails the finding of a safe drift orbit for the approaching spacecraft, followed by a safe drift/stop maneuver which takes uncertainties in thruster performance prediction into account. A specified minimum spacecraft separation is maintained in order to preclude collisions. Two such rendezvous were conducted during October and September, 1988 among three satellites of the ESA European Communications Satellite system. O.C.

A90-43504
POTENTIALS OF SATELLITE SERVICING IN THE GEOSTATIONARY ORBIT
A. HACKEL (Muenchen Technische Universitaet, Munich, Federal Republic of Germany), E.-L. KLINGELHOEFER, and J. PULS (DLR, Wessling, Federal Republic of Germany) (Zeitschrift fuer Flugwissenschaften und Weltraumforschung, vol. 13, May-June 1989, p. 145-151) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 253-266. Previously cited in issue 22, p. 3457, Accession no. A89-50369. refs
(AAS PAPER 89-188) Copyright

A90-43676
INSTITUTE OF NAVIGATION SATELLITE DIVISION, INTERNATIONAL TECHNICAL MEETING, 2ND, COLORADO SPRINGS, CO, SEPT. 27-29, 1989, PROCEEDINGS
Washington, DC, Institute of Navigation, 1989, 518 p. For individual items see A90-43677 to A90-43725.

Various papers on navigation satellites are presented. The general topics considered include: overview and status of GPS, kinematic positioning, international developments and perspective on satellite positioning, test range applications, civil applications, and receiver developments and equipment. Consideration is given to multisensor integration, military applications, differential operation, integrity, propagation phenomena and measurement networks, and precise time and time transfer. C.D.

A90-46754* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ASTRODYNAMICS 1989; PROCEEDINGS OF THE AAS/AIAA ASTRODYNAMICS CONFERENCE, STOWE, VT, AUG. 7-10, 1989. PARTS 1 & 2
CATHERINE L. THORNTON, ED. (JPL, Pasadena, CA), RONALD J. PROULX, ED. (Charles Stark Draper Laboratory, Inc., Cambridge, MA), JOHN E. PRUSSING, ED. (Illinois, University, Urbana), and FELIX R. HOOTS, ED. (General Research Corp., Colorado Springs, CO) Conference sponsored by AAS and AIAA. San Diego, CA, Univelt, Inc., 1990, p. Pt. 1, 740 p.; pt. 2, 753 p. For individual items see A90-46755 to A90-46835.
Copyright

The conference focuses of analytical and numerical aspects of astrodynamics and celestial mechanics with emphasis on planetary mission design, trajectory analysis and design, orbit determination, attitude determination and control, guidance systems, and dynamics and control of large flexible space structures. Trajectory computation techniques, satellite dynamics, and geocentric satellite orbit analysis are presented, along with earth orbiter mission analysis, trajectory optimization applications, planetary spacecraft orbit determination, and orbiting debris considerations. Neutral upper-atmosphere density is addressed, and guidance analysis, planetary mission design and analysis, trajectory analysis, estimation/identification techniques are discussed in addition to the dynamics and control of space structures or multi-body systems. V.T.

A90-47615*# Lockheed Engineering and Sciences Co., Houston, TX.
AUTOMATED TERMINAL GUIDANCE FOR A SHUTTLE RENDEZVOUS TO SPACE STATION FREEDOM
OSCAR W. OLSZEWSKI (Lockheed Engineering and Sciences Co., Houston, TX) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 377-387. refs
(Contract NAS9-17900)
(AIAA PAPER 90-3356) Copyright

An automated terminal guidance for a Shuttle rendezvous based on the Clohessy-Wiltshire (CW) linear equations of relative motion is described. The algorithm guides the Shuttle from the last rendezvous midcourse maneuver (MC4) through docking with Space Station Freedom (SSF). The uniqueness of this algorithm is that it makes it possible to use the CW equations to fly a line-of-sight (LOS) Vbar or Rbar in the final-approach docking phase. The algorithm is made of two parts, in and out-of-plane, and can also be used for station keeping during final approaches. Simulation results of the guidance integrated with the Shuttle's flight control system in the Systems Engineering Simulator (SES) at NASA Johnson are discussed. Plans to add a laser radar docking sensor to the SES and integrate it with the Shuttle's rendezvous navigation are examined. Author

A90-47644#
GNC ARCHITECTURE FOR THE COLUMBUS FREE-FLYING LABORATORY
D. ULRICH and H. BAUER (Dornier GmbH, Friedrichshafen, Federal Republic of Germany) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 667-676.
(AIAA PAPER 90-3389) Copyright

The Columbus Free Flying Laboratory presents a significant challenge for the design of the guidance, navigation, and control (GNC) subsystem. The paper gives an overview on the requirements put on the GNC and a description of the GNC subsystem architecture as defined within the Columbus program. The subsystem comprises a GNC computer assembly including a real-time data bus, an inertial and optical measurement assembly, and a navigation and control assembly. The paper describes the implementation aspects of the subsystem hardware and the breakdown and implementation concept of the subsystem application software. The GNC performance during the microgravity phase is demonstrated by simulations. Author

A90-47645#
RENDEZVOUS AND BERTHING BETWEEN COLUMBUS FREE FLYER AND SPACE STATION FREEDOM
WOLFGANG SCHNETZER (MBB Space Systems Group, Bremen, Federal Republic of Germany) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 677-685. Sponsorship: Research supported by ESA.
(AIAA PAPER 90-3390) Copyright

The rendezvous and proximity operations of the European Columbus Free Flyer with the International Space Station Freedom (SSF) are safety-critical, as a collision of the two spacecraft would endanger the crew. According to the Columbus System Requirements Document, any possibility of collision must be avoided. In addition, a Safe Abort Function must be implemented

which provides a supplementary two-failure-tolerant capability to safely abort rendezvous operations, and a special Red Button capability enables the SSF crew to abort the rendezvous at their discretion. This paper describes the rendezvous safety concept and how it will be implemented in the guidance, navigation and control subsystem of the Columbus Free Flyer. The safe trajectory principle benefits from the orbit dynamics. All flight operations in the vicinity of the SSF are performed such that, at any time, propulsion can be shut off resulting in a free drift trajectory which does not intercept the SSF flight path. Author

A90-47646#
ATTITUDE AND RELATIVE POSITION MEASUREMENT ASSEMBLY AND GNC COMPUTER ASSEMBLY ON BOARD THE COLUMBUS FREE FLYING LABORATORY
A. VAISSIERE and G. GRISERI (Matra Espace, Velizy-Villacoublay, France) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 686-689.
(AIAA PAPER 90-3391) Copyright

The design and operation of the Attitude and Rendezvous Measurement Assembly (ARMA) and the guidance, navigation, and control (GNC) Computer Assembly (GCA) for the ESA Columbus Free-Flying Laboratory spacecraft are briefly reviewed. ARMA is designed to provide attitude estimates with accuracy 0.2 deg during microgravity operations and during transfer and rendezvous. The ARMA hardware includes a coarse sun sensor, an optical reference assembly, and an inertial reference assembly; the ARMA software package performs software, hardware, and parameters management; attitude determination; rendezvous measurement; and fault detection, identification, and reconfiguration (FDIR). The GCA comprises three identical fail-stop 80386-based microcomputers with analog I/O and interfaces to the real-time bus and data-management system. This GCA design provides reliable computations for the FDIR subsystem. T.K.

A90-47710#
SIX DIMENSIONAL TRAJECTORY SOLVER FOR AUTONOMOUS PROXIMITY OPERATIONS
RONALD J. SIMMONS, EDWARD V. BERGMANN, BRUCE A. PERSSON (Charles Stark Draper Laboratory, Inc., Cambridge, MA), and WALTER M. HOLLISTER (MIT, Cambridge, MA) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1291-1303. Research supported by Charles Stark Draper Laboratory, Inc. refs
(AIAA PAPER 90-3459) Copyright

This paper describes the development of one component of an autonomous proximity operations controller, the trajectory planner. The trajectory planner uses a modified gradient search to find a locally optimal trajectory from the initial state to the target state that does not violate any of the mission constraints (defined as the maximum time of flight for the operation, the maximum closing velocity allowed, and the obstacles in close proximity to the chase and target craft). The Clohessy-Wiltshire (1980) equations for relative position and quaternions for relative attitude are used to define a state-space relationship between the initial state and the final state as a function of time. The trajectory solver uses these equations to find the minimum fuel required to maneuver to a target position and attitude while evading moving obstacles. Example results and simulations are included for various initial conditions and maneuvering constraints. Author

A90-47712#
A SPACECRAFT DOCKING PROBLEM - POSITION ESTIMATION USING A COMPUTER VISION APPROACH
CHI-CHANG J. HO and N. HARRIS MCCLAMROCH (Michigan, University, Ann Arbor) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1313-1318. refs
(AIAA PAPER 90-3461) Copyright

A new computer vision based method for estimating the position of a spacecraft relative to a space station in three-dimensions is developed. A noisy image of four feature points on a single standard mark on the space station is obtained by a TV camera mounted on the spacecraft. Simple geometric relations are determined which form the basis for a nonlinear least squares approach to obtain a position estimate of the spacecraft based on the noisy measurements of the four image parameters. Author

A90-48303
SPACECRAFT RENDEZVOUS CONTROL USING THE FREE TRAJECTORY METHOD BASED ON AN ALGORITHM WITH A PREDICTION MODEL [SINTEZ UPRAVLENIIA SBLIZHENIEM KA PO METODU SVOBODNYKH TRAEKTORII NA OSNOVE ALGORITMA S PROGNOZIRUIUSHCHEI MODEL'IU]
N. E. ZUBOV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, July-Aug. 1990, p. 506-512. In Russian. refs
Copyright

An approach to the problem of free-trajectory spacecraft rendezvous is proposed whereby the problem is treated as an optimal control problem using an algorithm with a prediction model. Simple analytical formulas for control calculations are obtained. The region of initial conditions for which the algorithm is valid is determined. A method is proposed for relating the generalized work functionals to the initial conditions. V.L.

A90-48304
APPLICATION OF THE RECURSIVE METHOD OF PARABOLIC EXTREMUM APPROXIMATION TO THE PROBLEM OF OPTIMUM SPACECRAFT BEHAVIOR [PRIMENENIE REKURRENTNOGO METODA PARABOLICHESKOI APPROKSIMATSII EKSTREMALEI V ZADACHE OPTIMAL'NOGO POVEDENIIA KA]
A. L. VOROB'EV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, July-Aug. 1990, p. 513-520. In Russian. refs
Copyright

A recursive extremum approximation method has been developed which describes the behavior of a dynamic system during a rapid transition from the initial phase state to a final state with allowance for the limits of the system motion characteristics. A solution to the problem of a rendezvous between a spacecraft and a satellite is obtained by modifying the one-dimensional Pontriagin regulator for use with a two-dimensional system. V.L.

A90-49277* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
MANUAL CONTROL ASPECTS OF SPACE STATION DOCKING MANEUVERS
ADAM R. BRODY (NASA, Ames Research Center; Sterling Software, Inc., Moffett Field, CA) and STEPHEN R. ELLIS (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 8 p. refs
(SAE PAPER 901202) Copyright

Due to an increase in spacecraft traffic forecasted for the Space Station era, researchers are investigating manual control and other aspects of docking operations with hopes of increasing safety, productivity, and likelihood of success while decreasing cost. Experiments have been performed which revealed the effect of approach velocity, in-flight anomalies, and control mode. Displays have been designed to enable flight planners to more easily overcome the difficulties presented by orbital mechanics. Improved understanding of human factors in the docking mission and other orbital maneuvers will play a significant role in design tradeoffs concerning thruster size, docking fixture style and mass, and on-board trajectory planning displays. Incorporating both empirical and analytic results into current and future planning of missions occurring not only in earth orbit, but also for missions in lunar and Mars orbit, will expand the performance envelopes of the astronauts who participate in these missions. Author

A90-50616#
AUTONOMOUS MAGNETIC NAVIGATION FOR EARTH ORBITING SPACECRAFT
MARK PSIAKI (Cornell University, Ithaca, NY) and FRANCOIS MARTEL (Ithaco, Inc., Ithaca, NY) IN: Annual AIAA/Utah State University Conference on Small Satellites, 3rd, Logan, UT, Sept. 26-28, 1989, Proceedings. Logan, UT, Utah State University, 1989, 25 p. Research supported by Ithaco, Inc. refs

The feasibility and potential performance of two approaches to spacecraft magnetometer-based navigation were investigated. In one configuration, the magnetic field orientation was assumed to be complemented by measurements of the nadir direction provided by an earth horizon sensor on board; the two vectors formed the basis of a 'space sextant.' In the second configuration, the magnetic field magnitude was the sole source of external information. The preliminary results show that a magnetometer-based system can perform navigation for an earth-orbiting spacecraft. Three-axis position can be estimated to within a 1-sigma accuracy of 2.5 km or better based on 24 hrs worth of magnetometer data. Even without a horizon sensor, 1-sigma accuracy of 4 km or better can be achieved. C.D.

A90-52957
AIAA/AAS ASTRODYNAMICS CONFERENCE, PORTLAND, OR, AUG. 20-22, 1990, TECHNICAL PAPERS. PARTS 1 & 2
Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. Pt. 1, 528 p.; pt. 2, 516 p. For individual items see A90-52958 to A90-53060.
Copyright

Topics presented include the universal Lambert and Kepler algorithms for autonomous rendezvous, a launch window analysis for the CRRES mission, Voyager 2 Neptune navigation results, and the performance of three-way data types during Voyager's encounter with Neptune. Also presented are the perturbation of ground tracks of periodic orbits, the design of good partial coverage satellite constellations, the Mars parking orbit selection, a comparison of earth-based radiometric data strategies for deep space navigation, and near minimum time control of a flexible manipulator. Also addressed are autonomous spacecraft navigation and control for comet observation and landing, abort strategies for Mars missions, launching lunar missions from Space Station Freedom, a station-keeping method for libration point trajectories, and the Newtonian derivation of the equations of motion for a tethered satellite system. R.E.P.

A90-53051*# Chung Shan Inst. of Science and Technology, Lung Tan (China).
OPTIMAL IMPULSIVE TIME-FIXED ORBITAL RENDEZVOUS AND INTERCEPTION WITH PATH CONSTRAINTS
D.-R. TAUR (Chung Shan Institute of Science and Technology, Lung-Tan, Republic of China), J. E. PRUSSING (Illinois, University, Urbana), and V. COVERSTONE-CARROLL IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 899-906. refs
(Contract NAG3-1138)
(AIAA PAPER 90-2972) Copyright

Minimum-fuel, impulsive, time-fixed solutions are obtained for the problem of orbital rendezvous and interception with interior path constraints. Transfers between coplanar circular orbits in an inverse-square gravitational field are considered, subject to a circular path constraint representing a minimum or maximum permissible orbital radius. Primer vector theory is extended to incorporate path constraints. The optimal number of impulses, their times and positions, and the presence of initial or final coasting arcs are determined. The existence of constraint boundary arcs and boundary points is investigated as well as the optimality of a class of singular arc solutions. To illustrate the complexities introduced by path constraints, an analysis is made of optimal rendezvous in field-free space subject to a minimum radius constraint. Author

A90-53059#
THE ELECTRIC VEHICLE ANALYZER (EVA) - AN ELECTRIC ORBIT TRANSFER VEHICLE MISSION PLANNING TOOL
M. R. DICKEY, R. S. KLUCZ, and L. W. MATUSZAK (USAF, Astronautics Laboratory, Edwards AFB, CA) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1001-1010. refs
(AIAA PAPER 90-2984)

Technology developments and the assured access to space philosophy has increased the interest in developing low thrust, electric propulsion based orbit transfer vehicles. The move towards such a vehicle requires a solid understanding of system level payoffs and interactions. Existing mission analysis software represented two ends of the analysis spectrum and was not conducive to parametric evaluation of a full variety of vehicles. The Electric Vehicle Analyzer was designed as a user-friendly, preliminary mission planning tool that would be able to model the effects of a low thrust trajectory accurately, while keeping run times on the order of seconds on a mainframe computer and minutes on a personal computer. It was also designed to have the ability to model a variety of missions and types of electric propulsion systems. The mathematical model is presented here along with the mission analysis and example initial vehicle design for one possible reference mission. The usefulness and flexibility of the software is demonstrated as well as the performance benefits realized by the adoption of an electric orbit transfer vehicle architecture. Author

N90-20126* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DOCKING MECHANISM FOR SPACECRAFT Patent
GREGORY A. LANGE, inventor (to NASA), JOHN P. MCMANAMEN, inventor (to NASA), and JOHN A. SCHLIESING, inventor (to NASA) 22 Aug. 1989 14 p Filed 30 Dec. 1988
(NASA-CASE-MSC-21386-1; US-PATENT-4,858,857; US-PATENT-APPL-SN-292123; US-PATENT-CLASS-244-161; US-PATENT-CLASS-244-159; US-PATENT-CLASS-405-188; US-PATENT-CLASS-166-343) Avail: US Patent and Trademark Office CSCL 22/2

A system is presented for docking a space vehicle to a space station where a connecting tunnel for in-flight transfer of personnel is required. Cooperable coupling mechanisms include docking rings on the space vehicle and space station. The space station is provided with a tunnel structure, a retraction mechanism, and a docking ring. The vehicle coupling mechanism is designed to capture the station coupling mechanism, arrest relative spacecraft motions while limiting loads to acceptable levels, and then realign the spacecraft for final docking and tunnel interconnection. The docking ring of the space vehicle coupling mechanism is supported by linear attentuator actuator devices, each of which is controlled by a control system which receives loading information signals and attenuator stroke information signals from each device and supplies output signals for controlling its linear actuation to attenuate impact loading or to realign the spacecraft for final docking and tunnel interconnection. The retraction mechanism is used to draw the spacecraft together after initial contact and coupling. Tunnel trunnions, cooperative with the latches on the space vehicle constitute the primary structural tie between the spacecraft in final docked configuration.
Official Gazette of the U.S. Patent and Trademark Office

N90-20669*# TRW Defense Systems Group, Redondo Beach, CA.
OMV MISSION SIMULATOR
KEITH E. COK *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 129-134 Aug. 1989
Avail: NTIS HC A11/MF A02 CSCL 09/2

The Orbital Maneuvering Vehicle (OMV) will be remotely piloted during rendezvous, docking, or proximity operations with target spacecraft from a ground control console (GCC). The real-time mission simulator and graphics being used to design a console

pilot-machine interface are discussed. A real-time orbital dynamics simulator drives the visual displays. The dynamics simulator includes a J2 oblate earth gravity model and a generalized 1962 rotating atmospheric and drag model. The simulator also provides a variable-length communication delay to represent use of the Tracking and Data Relay Satellite System (TDRSS) and NASA Communications (NASCOM). Input parameter files determine the graphics display. This feature allows rapid prototyping since displays can be easily modified from pilot recommendations. A series of pilot reviews are being held to determine an effective pilot-machine interface. Pilots fly missions with nominal to 3-sigma dispersions in translational or rotational axes. Console dimensions, switch type and layout, hand controllers, and graphic interfaces are evaluated by the pilots and the GCC simulator is modified for subsequent runs. Initial results indicate a pilot preference for analog versus digital displays and for two 3-degree-of-freedom hand controllers. Author

N90-20684*# CAE-Link Corp., Houston, TX. Link Flight Simulation Div.

THE ORBITAL MANEUVERING VEHICLE TRAINING FACILITY VISUAL SYSTEM CONCEPT

KEITH WILLIAMS *In* NASA, Lyndon B. Johnson Space Center, Graphics Technology in Space Applications (GTSA 1989) p 249-254 Aug. 1989

Avail: NTIS HC A11/MF A02 CSCL 09/2

The purpose of the Orbital Maneuvering Vehicle (OMV) Training Facility (OTF) is to provide effective training for OMV pilots. A critical part of the training environment is the Visual System, which will simulate the video scenes produced by the OMV Closed-Circuit Television (CCTV) system. The simulation will include camera models, dynamic target models, moving appendages, and scene degradation due to the compression/decompression of video signal. Video system malfunctions will also be provided to ensure that the pilot is ready to meet all challenges the real-world might provide. One possible visual system configuration for the training facility that will meet existing requirements is described. Author

N90-20969*# Mayflower Communications Co., Inc., Reading, MA.

AUTONOMOUS INTEGRATED GPS/INS NAVIGATION EXPERIMENT FOR OMV. PHASE 1: FEASIBILITY STUDY

TRIVENI N. UPADHYAY, GEORGE J. PRIOVOLOS, and HARLEY RHODEHAMEL Washington NASA Jan. 1990 93 p (Contract NAS8-38031)

(NASA-CR-4267; NAS 1.26:4267) Avail: NTIS HC A05/MF A01 CSCL 17/7

The phase 1 research focused on the experiment definition. A tightly integrated Global Positioning System/Inertial Navigation System (GPS/INS) navigation filter design was analyzed and was shown, via detailed computer simulation, to provide precise position, velocity, and attitude (alignment) data to support navigation and attitude control requirements of future NASA missions. The application of the integrated filter was also shown to provide the opportunity to calibrate inertial instrument errors which is particularly useful in reducing INS error growth during times of GPS outages. While the Orbital Maneuvering Vehicle (OMV) provides a good target platform for demonstration and for possible flight implementation to provide improved capability, a successful proof-of-concept ground demonstration can be obtained using any simulated mission scenario data, such as Space Transfer Vehicle, Shuttle-C, Space Station. Author

N90-22085*# Centre National d'Etudes Spatiales, Toulouse (France).

A DYNAMIC MOTION SIMULATOR FOR FUTURE EUROPEAN DOCKING SYSTEMS

G. BRONDINO, PH. MARCHAL, D. GRIMBERT, and P. NOIRAULT (MATRA Espace, Paris-Velizy, France) *In* NASA, John F. Kennedy Space Center, The 24th Aerospace Mechanisms Symposium p 75-87 Apr. 1990

Avail: NTIS HC A16/MF A03 CSCL 14/2

Europe's first confrontation with docking in space will require extensive testing to verify design and performance and to qualify hardware. For this purpose, a Docking Dynamics Test Facility (DDTF) was developed. It allows reproduction on the ground of the same impact loads and relative motion dynamics which would occur in space during docking. It uses a 9 degree of freedom, servo-motion system, controlled by a real time computer, which simulates the docking spacecraft in a zero-g environment. The test technique involves and active loop based on six axis force and torque detection, a mathematical simulation of individual spacecraft dynamics, and a 9 degree of freedom servomotion of which 3 DOFs allow extension of the kinematic range to 5 m. The configuration was checked out by closed loop tests involving spacecraft control models and real sensor hardware. The test facility at present has an extensive configuration that allows evaluation of both proximity control and docking systems. It provides a versatile tool to verify system design, hardware items and performance capabilities in the ongoing HERMES and COLUMBUS programs. The test system is described and its capabilities are summarized. Author

N90-22953*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

INTERACTIVE ORBITAL PROXIMITY OPERATIONS PLANNING SYSTEM

ARTHUR J. GRUNWALD and STEPHEN R. ELLIS *In its* Spatial Displays and Spatial Instruments 21 p Jul. 1989

Avail: NTIS HC A99/MF A04 CSCL 22/1

An interactive, graphical proximity operations planning system was developed which allows on-site design of efficient, complex, multiburn maneuvers in the dynamic multispacecraft environment about the space station. Maneuvering takes place in, as well as out of, the orbital plane. The difficulty in planning such missions results from the unusual and counterintuitive character of relative orbital motion trajectories and complex operational constraints, which are both time varying and highly dependent on the mission scenario. This difficulty is greatly overcome by visualizing the relative trajectories and the relative 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 the space station and co-orbiting spacecraft on the background of the station's orbital plane. The operator has control over two modes of operation: (1) a viewing system mode, which enables him or her to explore the spatial situation about the space station and thus choose and frame in on areas of interest; and (2) a trajectory design mode, which allows the interactive editing of a series of way-points and maneuvering burns to obtain a trajectory which complies with all operational constraints. Through a graphical interactive process, the operator will continue to modify the trajectory design until all operational constraints are met. The effectiveness of this display format in complex trajectory design is presently being evaluated in an ongoing experimental program. Author

N90-23029*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

SPACE STATION DYNAMICS, ATTITUDE CONTROL AND MOMENTUM MANAGEMENT Abstract Only

JOHN W. SUNKEL, RAMEN P. SINGH, and RAVI VENGOPAL (DYNACS Engineering Co., Inc., Clearwater, FL.) *In* JPL, Proceedings of the 3rd Annual Conference on Aerospace Computational Control, Volume 1 p 370 15 Dec. 1989

Avail: NTIS HC A21/MF A03 CSCL 22/2

The Space Station Attitude Control System software test-bed provides a rigorous environment for the design, development and functional verification of GN and C algorithms and software. The approach taken for the simulation of the vehicle dynamics and environmental models using a computationally efficient algorithm is discussed. The simulation includes capabilities for docking/berthing dynamics, prescribed motion dynamics associated with the Mobile Remote Manipulator System (MRMS) and microgravity disturbances. The vehicle dynamics module interfaces with the test-bed through the central Communicator facility which is in turn driven by the Station Control Simulator (SCS) Executive.

The Communicator addresses issues such as the interface between the discrete flight software and the continuous vehicle dynamics, and multi-programming aspects such as the complex flow of control in real-time programs. Combined with the flight software and redundancy management modules, the facility provides a flexible, user-oriented simulation platform. Author

N90-23461 Southampton Univ. (England).
THE INFLUENCE OF THE GAS SURFACE INTERACTION ON SPACECRAFT ORBITAL MOTION Ph.D. Thesis
RICHARD CROWTHER 1989 232 p
Avail: Univ. Microfilms Order No. BRDX87353

Characterization of the interaction between the neutral atmosphere in low earth orbit and spacecraft surfaces is required for a broad range of applications to system and mission definition. For the prediction of spacecraft trajectories in this free molecular regime, the nature of the interaction must be accurately modeled. Accurate definition of the interaction is also required for the design of the attitude control system for vehicles such as Space Station which will generate large aerodynamic moments. The methods available to determine this interaction indirectly from observation of the motion of a satellite are reviewed. The orbital analysis technique is chosen. Two methods of modeling complex spacecraft configurations are developed. The first, a Monte Carlo Test Particle approach, is able to account for all the phenomena characteristic of Free Molecular Flow. The second, adopting a panel method approach, accounts only for the possible shielding of surfaces from the flow. Discrepancies between the two modeling programs are identified but for the limited flow range relevant to the ANS-1 mission, good agreement is found and the computationally more efficient panel method program adopted. A new set of momentum accommodation coefficients are introduced to characterize the interaction. The theory required to represent the relationship between the changes in the spacecraft trajectory and the gas-surface interaction is then developed. The sensitivity of the derived momentum accommodation to the parameters used in the modeling process is then determined. This theory is then applied to the orbital data derived for ANS-1 (1970-70A) by ESOC. The results suggest that the nature of the interaction is close to the classical diffuse case but the accuracy of the results are limited by uncertainties in the measured changes in orbital inclination. Dissert. Abstr.

N90-24282*# National Aeronautics and Space Administration, Washington, DC.
A PROPOSED CHANGE TO THE NASA STRATEGY FOR SERVICING SPACE ASSETS
GEORGE C. LEVIN *In* ESA, Second European In-Orbit Operations Technology Symposium p xxix-xxxi Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 22/2

Given the limitations of the present Shuttle manifest, it is necessary for NASA to consider revision of its previous strategy for servicing satellites. This is particularly important in a period of tight budgets, when space assets will be difficult to replace. Therefore on-orbit assets take on additional value and keeping these assets operational will take on added importance. The key to maintaining these assets will be the long term strategy of developing a remote servicing capability which is space based and has a minimum reliance on the Shuttle. Such a strategy will require that the users of this servicing system design serviceable spacecraft at a high level and that these assets be located in or be capable of reaching orbits that are accessible to or compatible with the proposed servicing infrastructure. The infrastructure required to support this type of remote servicing architecture and the development of the necessary systems, tools, and procedures required to support a remote servicing architecture of this type are addressed. ESA

N90-24310# Polytechnical Univ. of Madrid (Spain).
GPS NAVIGATIONAL PERFORMANCE IN SPACE RENDEZVOUS OPERATIONS
M. A. MARTINEZOLAGUE, M. PEREZCORTES, and R. LUCASRODRIGUEZ (European Space Agency. European Space Research and Technoogy Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Second European In-Orbit Operations Technology Symposium p 227-235 Dec. 1989
(Contract ESA-7617/88/NL)
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

During a typical rendezvous operation (RVD) between Hermes and the Man Tended Free Flyer (MTFF) the relative state vector between the two space vehicles will be updated by GPS (Global Positioning System) operating in relative mode from a distance of 40 km to 100 m approximately. A method for processing GPS differential raw measurements is presented and the performance results based on a complete simulation of a separation maneuver are given. The model for the real-world dynamics is based in a Chohessy-Wiltshire solution for relative motion between target and chaser including aerodynamic and gravitational perturbations and the consideration of a perturbated elliptic orbit for the target. The navigation filter process integrated Doppler measurements (accumulated carrier cycle count) and the achieved results are very satisfactory: 0.8 m and 9 mm/s (1 sigma) for relative position and velocity respectively. ESA

N90-24322*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SATELLITE SERVICER SYSTEM FLIGHT DEMONSTRATION PROGRAM
JAMES S. MOORE *In* ESA, Second European In-Orbit Operations Technology Symposium p 337-340 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 22/2

A program to develop the capability of servicing satellites in remote locations, where a series of flight that will demonstrate autonomous rendezvous and docking, supervised autonomous Orbital Replacement Unit (ORU) exchange, supervised autonomous fluid transfer and, proximity operations for Space Station Freedom were planned, is described. The flight demonstrations are the results of several mission scenarios with complex technical objectives. Three Shuttle flights are planned to complete the multi-objective program. The major hardware elements of the program are described and discussed. Demonstration objectives and technical approaches to the flight demonstrations are discussed. Existing and developing technologies are assessed for applicability to the Satellite Servicer System (SSSFD) program. ESA

N90-24980*# Military Academy, West Point, NY. Dept. of Physics.
UTILIZATION OF MOIRE PATTERNS AS AN ORBITAL DOCKING AID TO SPACE SHUTTLE/SPACE STATION FREEDOM Final Report
EDWIN L. DOTTERY *In* Texas A&M Univ., NASA/ASEE Summer Faculty Fellowship Program-1989, Volume 1 16 p Dec. 1989
Avail: NTIS HC A09/MF A02 CSCL 22/2

Moire patterns are investigated as possible docking aids for use between the National Space Transportations System (Space Shuttle Orbiter) and the Space Station Freedom. A sight reticle placed in optical conjunction with a docking target can generate moire fringes from which position and alignment can be inferred. Design specifications and a mathematical development to meet those specifications are discussed. A motion based simulator and experimental hardware have been constructed. Author

N90-25554*# Sterling Software, Moffett Field, CA.
REMOTE OPERATION OF AN ORBITAL MANEUVERING VEHICLE IN SIMULATED DOCKING MANEUVERS
ADAM R. BRODY *In* NASA, Lyndon B. Johnson Space Center, Third Annual Workshop on Space Operations Automation and Robotics (SOAR 1989) p 471-475 Mar. 1990
Avail: NTIS HC A99/MF A04 CSCL 22/2

Simulated docking maneuvers were performed to assess the effect of initial velocity on docking failure rate, mission duration, and delta v (fuel consumption). Subjects performed simulated

docking maneuvers of an orbital maneuvering vehicle (OMV) to a space station. The effect of the removal of the range and rate displays (simulating a ranging instrumentation failure) was also examined. Naive subjects were capable of achieving a high success rate in performing simulated docking maneuvers without extensive training. Failure rate was a function of individual differences; there was no treatment effect on failure rate. The amount of time subjects 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. Radial impulse was significant both by subject and by treatment. NASA's 0.1 percent rule, dictating an approach rate no greater than 0.1 percent of the range, is seen to be overly conservative for nominal docking missions. Author

N90-26041# General Accounting Office, Washington, DC. National Security and International Affairs Div.
SPACE TRANSPORTATION: NASA HAS NO FIRM NEED FOR INCREASINGLY COSTLY ORBITAL MANEUVERING VEHICLE
CHARLES REY and JAMES MORRISON Jul. 1990 32 p
(GAO/NSIAD-90-192; B-239570) Avail: NTIS HC A03/MF A01; also available from GAO, Gaithersburg, MD HC first five copies free, additional copies $2.00

The General Accounting Office's (GAO) findings on the Orbital Maneuvering Vehicle (OMV) are described. It was to be a multipurpose space tug used to transport satellites from the space shuttle to other orbits, reboost them when their orbits decayed; retrieve and return them to the shuttle when they malfunctioned, and control their reentry into the atmosphere when their useful lives expired. Subsequent OMV enhancements would enable it to refuel satellites in orbit, perform in-orbit satellite repairs, and rescue out-of-control satellites. The OMV was to operate initially from the shuttle's cargo bay but would ultimately operate from the Space Station Freedom. OMV was designed to be a free-flying, remotely controlled propulsion stage about 15 feet in diameter and 6 feet thick, that would be carried into orbit inside the shuttle's cargo bay. Once separated from the shuttle, the OMV would be remotely controlled by astronauts working at consoles on earth. GAO found that a firm requirement for the OMV to accomplish the scheduled missions does not exist. Also the estimated cost has greatly increased while the OMV's capabilities have significantly decreased. GAO recommended that the OMV program be terminated, which NASA did following the receipt of GAO's draft report. J.P.S.

N90-26051*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace Engineering.
PROJECT SPARC: SPACE-BASED AEROASSISTED REUSABLE CRAFT
May 1990 155 p
(Contract NGT-21-002-800)
(NASA-CR-186816; NAS 1.26:186816) Avail: NTIS HC A08/MF A01 CSCL 22/2

Future United States' space facilities include a Space Station in low Earth orbit (LEO) and a Geosynchronous Operations Support Center, or GeoShack, in geosynchronous orbit (GEO). One possible mode of transfer between the two orbits is an aerobraking vehicle. When traveling from GEO to LEO, the Earth's atmosphere can be used to aerodynamically reduce the velocity of the vehicle, which reduces the amount of propulsive change in velocity required for the mission. An aerobrake is added to the vehicle for this purpose, but the additional mass increases propellant requirements. This increase must not exceed the amount of propellant saved during the aeropass. The design and development of an aerobraking vehicle that will transfer crew and cargo between the Space Station and GeoShack is examined. The vehicle is referred to as Project SPARC, a SPace-based Aeroassisted Reusable Craft. SPARC consists of a removable 45 ft diameter aerobrake, two modified Pratt and Whitney Advanced Expander Engines with a liquid oxygen/liquid hydrogen propellant, a removable crew module with a maximum capacity of five, and standard sized payload bays providing a maximum payload capacity of 28,000 lbm. The aerobrake, a rigid, ellipsoidally blunted elliptical cone, provides lift at zero angle-of-attack due to a 73 deg rake angle, and is covered with a flexible multi-layer thermal protection system. Maximum dry mass of the vehicle without payload is 20,535 lbm, and the maximum propellant requirement is 79,753 lbm at an oxidizer to fuel ratio of 6/1. Key advantages of SPARC include its capability to meet mission changes, and its removable aerobrake and crew module. Author

N90-26053*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Aerospace Senior Design Team.
THE AEROBRAKING SPACE TRANSFER VEHICLE
GLEN ANDREWS, BRIAN CARPENTER, STEVE CORNS, ROBERT HARRIS, BRIAN JUN, BRUCE MUNRO, ERIC PULLING, AMRIT SEKHON, WALT WELTON, and A. JAKUBOWSKI Apr. 1990 116 p
(Contract NGT-21-002-800)
(NASA-CR-186819; NAS 1.26:186819) Avail: NTIS HC A06/MF A01 CSCL 22/2

With the advent of the Space Station and the proposed Geosynchronous Operation Support Center (GeoShack) in the early 21st century, the need for a cost effective, reusable orbital transport vehicle has arisen. This transport vehicle will be used in conjunction with the Space Shuttle, the Space Station, and GeoShack. The vehicle will transfer mission crew and payloads between low earth and geosynchronous orbits with minimal cost. Recent technological advances in thermal protection systems such as those employed in the Space Shuttle have made it possible to incorporate and aerobrake on the transfer vehicle to further reduce transport costs. The research and final design configuration of the aerospace senior design team from VPISU, working in conjunction with NASA, are presented. The topic of aerobraking and focuses on the evolution of an Aerobraking Space Transfer Vehicle (ASTV), is addressed. Author

N90-26861*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
CLOSED-LOOP AUTONOMOUS DOCKING SYSTEM Patent Application
RICHARD DABNEY, inventor (to NASA) and RICHARD HOWARD, inventor (to NASA) 20 Feb. 1990 29 p
(NASA-CASE-MFS-28421-1; NAS 1.71:MFS-28421-1; US-PATENT-APPL-SN-481537) Avail: NTIS HC A03/MF A01 CSCL 22/2

An autonomous docking system is provided which produces commands for the steering and propulsion system of a chase vehicle used in the docking of that chase vehicle with a target vehicle. The docking system comprises a passive optical target affixed to the target vehicle and comprising three reflective areas including a central area mounted on a short post, and tracking sensor and process controller apparatus carried by the chase vehicle. The latter apparatus comprises a laser diode array for illuminating the target so as to cause light to be reflected from the reflective areas of the target; a sensor for detecting the light reflected from the target and for producing an electrical output signal in accordance with an image of the reflected light; a signal processor for processing the electrical output signal in accordance with an image of the reflected light; a signal processor for processing the electrical output signal and for producing, based thereon, output signals relating to the relative range, roll, pitch, yaw, azimuth and elevation of the chase and target vehicles; and a docking process controller, responsive to the output signals produced by the signal processor, for producing command signals for controlling the steering and propulsion system of the chase vehicle. NASA

N90-27281*# Bureau of Mines, Tuscaloosa, AL. Research Center.
GENETIC ALGORITHM BASED FUZZY CONTROL OF SPACECRAFT AUTONOMOUS RENDEZVOUS
C. L. KARR, L. M. FREEMAN, and D. L. MEREDITH (Alabama Univ., Tuscaloosa.) *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 43-51 May 1990
Avail: NTIS HC A25/MF A04 CSCL 09/2

The U.S. Bureau of Mines is currently investigating ways to combine the control capabilities of fuzzy logic with the learning capabilities of genetic algorithms. Fuzzy logic allows for the uncertainty inherent in most control problems to be incorporated into conventional expert systems. Although fuzzy logic based expert systems have been used successfully for controlling a number of physical systems, the selection of acceptable fuzzy membership functions has generally been a subjective decision. High performance fuzzy membership functions for a fuzzy logic controller that manipulates a mathematical model simulating the autonomous rendezvous of spacecraft are learned using a genetic algorithm, a search technique based on the mechanics of natural genetics. The membership functions learned by the genetic algorithm provide for a more efficient fuzzy logic controller than membership functions selected by the authors for the rendezvous problem. Thus, genetic algorithms are potentially an effective and structured approach for learning fuzzy membership functions. Author

N90-27295*# Honeywell, Inc., Minneapolis, MN. Systems and Research Center.
ATTITUDE DETERMINATION AND CONTROL SYSTEM (ADCS) AND MAINTENANCE AND DIAGNOSTIC SYSTEM (MDS): A MAINTENANCE AND DIAGNOSTIC SYSTEM FOR SPACE STATION FREEDOM
DAVID TOMS, GEORGE D. HADDEN, and JIM HARRINGTON (Honeywell, Inc., Clearwater, FL.) *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for Space Applications p 175-183 May 1990 Sponsored in part by McDonnell-Douglas Space Systems Co.
(Contract NAS9-18200)
Avail: NTIS HC A25/MF A04 CSCL 22/2

The Maintenance and Diagnostic System (MDS) that is being developed at Honeywell to enhance the Fault Detection Isolation and Recovery system (FDIR) for the Attitude Determination and Control System on Space Station Freedom is described. The MDS demonstrates ways that AI-based techniques can be used to improve the maintainability and safety of the Station by helping to resolve fault anomalies that cannot be fully determined by built-in-test, by providing predictive maintenance capabilities, and by providing expert maintenance assistance. The MDS will address the problems associated with reasoning about dynamic, continuous information versus only about static data, the concerns of porting software based on AI techniques to embedded targets, and the difficulties associated with real-time response. An initial prototype was built of the MDS. The prototype executes on Sun and IBM PS/2 hardware and is implemented in the Common Lisp; further work will evaluate its functionality and develop mechanisms to port the code to Ada. Author

N90-27753# MATRA Espace, Toulouse (France). Dept. of Dynamics and Control.
HERMES RENDEZVOUS WITH THE SPACE STATION
MICHEL CALDICHOURY, CALIXTE CHAMPETIER, and ERIC DESPLATS *In* AGARD, Space Vehicle Flight Mechanics 21 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

An overview of the requirements and concepts for the Hermes rendezvous system is presented. A review of the mission requirements and constraints, mainly dictated by safety rules and man involvement, is first performed to highlight the impact of the vehicle configurations and environment on the definition of the Guidance, Navigation and Control (GNC) subsystem. The whole Rendezvous (RV) scenario from the end of the transfer phase up to the docking is described. A particular attention is devoted to the elaboration of guidance and control strategies for the homing and the final approach phases. The navigation system selected and designed for Hermes is presented, with some emphasis on the GPS navigation dedicated to the homing and closing phases and the optical navigation during the final approach. The redundant philosophy for the RV system and the crew involvement in the GNC and management process are also discussed. Author

N90-27767*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE DYNAMICS OF ORBITAL MANEUVERING: DESIGN AND EVALUATION OF A VISUAL DISPLAY AID FOR HUMAN CONTROLLERS
STEPHEN R. ELLIS (California Univ., Berkeley.) and ARTHUR J. GRUNWALD *In* AGARD, Space Vehicle Flight Mechanics 13 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 05/8

An interactive proximity operations planning system, which allows on-site planning of fuel-efficient, multi-burn maneuvers in a potential multi-spacecraft environment was developed and tested. Though this display system most directly assists planning by providing visual feedback to aid visualization of the trajectories and constraints, its most significant features include an inverse dynamics algorithm that removes control nonlinearities facing the operator and a trajectory planning technique that reduces the order of control and creates, through a geometric spread-sheet the illusion of an inertially stable environment. This synthetic environment provides the user with control of relevant static and dynamic properties of way-points during small orbital changes allowing independent solutions to the normally coupled problems of orbital maneuvering. An experiment was carried out in which experienced operators were required to plan a trajectory to retrieve an object accidently separated from a dual-keel space station. The time required to plan these maneuvers was found to be predicted by the direction of the insertion thrust and did not depend on the point of separation from the space station. Author

N90-29026*# Georgia Inst. of Tech., Atlanta. School of Information and Computer Science.
THREE-DIMENSIONAL MOTOR SCHEMA BASED NAVIGATION
RONALD C. ARKIN *In* JPL, California Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 1 p 291-299 31 Jan. 1989
Avail: NTIS HC A21/MF A03 CSCL 09/2

Reactive schema-based navigation is possible in space domains by extending the methods developed for ground-based navigation found within the Autonomous Robot Architecture (AuRA). Reformulation of two dimensional motor schemas for three dimensional applications is a straightforward process. The manifold advantages of schema-based control persist, including modular development, amenability to distributed processing, and responsiveness to environmental sensing. Simulation results show the feasibility of this methodology for space docking operations in a cluttered work area. Author

17

PROPULSION SYSTEMS/FLUID MANAGEMENT

Descriptions, analyses, and subsystem requirements of propellant/fluid management, and propulsion systems for attitude control, orbital maintenance and transfer maneuvers for the station and supporting vehicles.

A90-33386#
HYDROELASTIC PROBLEMS IN SPACE FLIGHT VEHICLES
H. F. BAUER (Muenchen, Universitaet der Bundeswehr, Munich, Federal Republic of Germany) IN: European Forum on Aeroelasticity and Structural Dynamics, Aachen, Federal Republic of Germany, Apr. 17-19, 1989, Proceedings. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1989, p. 359-367. refs

The hydroelastic behavior of an incompressible and frictionless liquid with a free surface has been presented for a cylindrical container. Coupled frequencies are presented for nonrotating and rotating containers. Through the coupling of liquid and structure

the frequency may be removed from areas dangerous to the overall stability of the space vehicle. The instability of a rotating container may be removed by the inclusion of liquid. Author

A90-33637
FLUID SCIENCE LABORATORY SCIENTIFIC STUDY FOR COLUMBUS
R. MONTI (Napoli, Universita, Naples, Italy) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 93-96.
Copyright

The objectives of fluid science research in microgravity conditions are presented, and experiments are categorized according to their objectives. The goals of basic and support experiments are described, and criteria for the selection of experiments are presented. Main features of the Fluid Science Laboratory (FSL) are described, and design considerations as to regards to technology, life time, scientific return and the type of operations are discussed. The utilization of the FSL facilities is discussed. They will incorporate an AFPM-like facility for the study of liquid specimens surrounded by large surfaces, and a BDPU-like facility for the study of fully contained liquid specimens. They should be optically accessible for the accommodation of ad hoc facilities, that carry out mostly short-time, support experiments. N.B.

A90-35601*
SPACE CRYOGENIC WORKSHOP, 8TH, CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, JULY 31, AUG. 1, 1989, PROCEEDINGS
Workshop sponsored by NASA. Cryogenics (ISSN 0011-2275), vol. 30, March 1990, 144 p. For individual items see A90-35602 to A90-35624.
Copyright

Recent advances in cryogenic technology for space applications are examined in reviews and reports. Topics addressed include very-low-force cooling contacts for the ISO cryostat cover, convective heat flow in space cryogenics plugs, liquid-acquisition devices for superfluid He transfer, and pressure drop in the SHOOT superfluid-He acquisition system. Consideration is given to a liquid-He vibration cryostat for space qualification tests, closed-cycle coolers for temperatures below 30 K, stress analysis down to liquid-He temperature, a cryogenic valve actuator, and a spaceborne He-3 refrigerator. Also discussed are an adiabatic-demagnetization refrigerator for SIRTF, rejection of waste heat from O liquefaction operations at a lunar O production plant, SHOOT flowmeter and pressure transducers, and space qualification of the ISO cryogenic rupture disks. T.K.

A90-35606* Ball Corp., Boulder, CO.
CO-OPERATIVE OSCILLATIONS OF BUBBLES
H. A. SNYDER and A. J. MORD (Ball Corp., Electro-Optics/Cryogenics Div., Boulder, CO; Colorado, University, Boulder) (NASA, Space Cryogenic Workshop, 8th, Pasadena, CA, July 31, Aug. 1, 1989) Cryogenics (ISSN 0011-2275), vol. 30, March 1990, p. 187-192.
(Contract NAGW-1388)
Copyright

A closed cryogenic storage tank in space may contain several bubbles. It is shown that these bubbles can oscillate in volume with n-1 resonant frequencies for n bubbles. The resonances can be excited by a sudden change in pressure, such as withdrawing fluid or venting, or by motion of the vehicle. In situations in which the ac accelerations dominate, such as in large space structures, the potential for harmful coupling of these oscillations to the spacecraft structure must be examined. Experimental data are presented which support the theoretical predictions. Author

A90-40546# Fairchild Technical Support Center, Greenbelt, MD.
AUTOMATED FLUID INTERFACE SYSTEM (AFIS) FOR REMOTE SATELLITE REFUELING
RICHARD M. STUDENICK (Fairchild Space/Washington Technical Support Center, Greenbelt, MD) and LEON B. ALLEN (Fairchild Space/Huntsville Technical Support Center, AL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. Research supported by NASA and Fairchild Space Co. refs
(AIAA PAPER 90-1884) Copyright

The AFIS design and operation in terms of its structural, thermal, and electrical systems is presented. It is designed to be a flexible, completely redundant, reconfigurable system, capable of handling either cryogens, bipropellants, or monopropellants. It can accommodate up to 8 fluid couplers, 4 gas couplers, and 8 electrical connectors on a single mission. The number and location of the couplers can be arranged as dictated by mission requirements. It is designed to be compatible with the OMV Three Point Docking Mechanism and the Remote Grapple Docking Mechanism. The AFIS is torus shaped, with an outer diameter of 61 inches and a 36 inch annular opening. The height of the mechanism is 17.5 inches and weighs between 320 and 450 pounds, depending on the number of fluid couplers and electrical connectors required. R.E.P.

A90-40564#
AN AUTOMATED FLUID INTERFACE SYSTEM FOR ON-ORBIT SERVICING
JOSEPH M. CARDIN (Moog, Inc., Space Products Div., East Aurora, NY) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p.
(AIAA PAPER 90-1938) Copyright

The Automated Fluid Interface System (AFIS) is an umbilical connector carrier designed to facilitate the fully automated transfer of propellants, pressurants, cryogens, electrical power and data between docked spacecraft. The AFIS is capable of connecting up to twenty fluid couplings and/or connectors simultaneously. It is compatible with all known docking mechanisms and is reusable for a minimum of forty missions to any orbit. Potential applications include on-orbit spacecraft assembly or satellite servicing via fluid transfer or tank module exchange. Author

A90-42171#
DESIGN, DEVELOPMENT AND VERIFICATION OF THE EURECA A ORBIT TRANSFER ASSEMBLY (OTA)
H. D. SCHMITZ and R. BRANDT (MBB-ERNO Raumfahrttechnik GmbH; ESA, Bremen, Federal Republic of Germany) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p.
(AIAA PAPER 90-2423) Copyright

The design and development of the Eureca A monopropellant hydrazine OTA are described. The functional requirements for the OTA are: an on-board propellant mass of up to 670 kg of N2He; total thrust during orbit transfer of 80 N, total impulse/thruster 1.2 x 10 to the 6th Ns; minimum impulse bit of 0.5 Ns; and off-modulation quantity of 50,000. The OTA consists of propellant tanks and pressurant tank; the propellant and pressurant loading and control assembly; the thruster assembly; and the tubing and manifold system. Particular consideration is given to the development of the diaphragm tank and the 20 N thruster. The verification of the OTA subsystem is discussed. I.F.

A90-42532#
TEST RESULTS OF A 15 KWE WATER COOLED ARCJET AT BPD AND IRS
E. TOSTI (BPD Difesa e Spazio, Colleferro, Italy), H. O. SCHRADE (Stuttgart, Universitaet, Federal Republic of Germany), and C. PETAGNA (ESTEC, Noordwijk, Netherlands) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 21st, Orlando, FL, July 18-20, 1990. 16 p. refs
(Contract ESTEC-6966/86/NL/PH)
(AIAA PAPER 90-2535) Copyright

This paper describes the results of 15 kWe water-cooled arcjet testing activities. Test results are presented with particular emphasis on the electric characteristics (voltage-current curves) and on the heat flux data gathered during the tests. Values of the main parameters measured using different test facilities are

compared and discussed. The paper also gives a brief description of the experimental set-up and test procedures. Moderate power arcjets, nominally 15 kWe, will be used mainly for the orbit maneuvering and maintenance of large platforms in low earth orbits. Author

A90-42533#
DEVELOPMENT OF A 1N, RADIATIVELY COOLED ARCJET
G. CRUCIANI, W. D. DEININGER (BPD Difesa e Spazio, Colleferro, Italy), and C. PETAGNA (ESTEC, Noordwijk, Netherlands) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 21st, Orlando, FL, July 18-20, 1990. 7 p. refs
(Contract ESTEC-6966/86/NL/PH; ESTEC-7632/88/NL/PH)
(AIAA PAPER 90-2536) Copyright

Large space platforms, such as those needed for Man-Tended Free Flyer Missions, might benefit significantly from 1 N class arcjets, particularly for orbit change missions. This paper describes the preliminary results of the first year development activities in a 1 N class radiatively-cooled arcjet technology program. A constricted-arc arcjet has been designed and manufactured. The engine has been characterized in terms of electrical behavior and performance over the power range from 5 to 10 kW at a number of nitrogen mass flow rates. Temperatures on the outer surface of the anode have been measured and ranged from 1200 to 1600 C. Author

A90-42591#
EARTH ORBIT MISSIONS AND APPLICATIONS USING ELECTRIC PROPULSION
A. R. MARTIN, A. J. PEARCE (Atomic Energy Research Establishment, Culham Laboratory, Abingdon, England), W. KOKOTT, and H. BASSNER (MBB GmbH, Munich, Federal Republic of Germany) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 21st, Orlando, FL, July 18-20, 1990. 7 p. refs
(AIAA PAPER 90-2619) Copyright

Some of the more important papers dealing with missions in near-earth space (up to geosynchronous altitude) are reviewed in order to establish the trends in electric propulsion. The mission budget parameters for the most important mission types are summarized. Potential applications are examined for propulsion systems with the general characteristics of a thrust level range of 0.2 - 1.0 newtons, and a specific impulse range of 3,000 - 4,000 sec. Discussion of propulsion system is limited to the ion thruster, and covers such earth-orbit applications as orbit raising missions, electrically propelled tugs, and free-flying platforms. It is noted that certain spacecraft mission requirements for the next generation of vehicles could be extremely propellant intensive, and the use of electric rather than chemical propulsion could prove to be mission enabling. V.T.

A90-42700*# McDonnell-Douglas Space Systems Co., Huntington Beach, CA.
U.S. SPACE STATION FREEDOM WASTE FLUID DISPOSAL SYSTEM WITH CONSIDERATION OF HYDRAZINE WASTE GAS INJECTION THRUSTERS
BRIAN A. WINTERS (McDonnell Douglas Space Systems Co., Space Station Div., Huntington, Beach, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. Research supported by NASA.
(AIAA PAPER 90-1944) Copyright

The results are reported of a study of various methods for propulsively disposing of waste gases. The options considered include hydrazine waste gas injection, resistojets, and eutectic salt phase change heat beds. An overview is given of the waste gas disposal system and how hydrozine waste gas injector thruster is implemented within it. Thruster performance for various gases are given and comparisons with currently available thruster models are made. The impact of disposal on station propellant requirements and electrical power usage are addressed. Contamination effects, reliability and maintainability assessments, safety issues, and operational scenarios of the waste gas thruster and disposal system are considered. C.D.

A90-42789*# Boeing Aerospace Co., Seattle, WA.
CONCEPTUAL DESIGN OF THE SUBSCALE ORBITAL FLUID TRANSFER EXPERIMENT (SOFTE)
O. S. JONES, J. S. MESEROLE, D. E. HEDGES (Boeing Aerospace and Electronics, Seattle, WA), and G. R. SCHMIDT (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 10 p. refs
(AIAA PAPER 90-2378) Copyright

The Subscale Orbital Fluid Transfer Experiment is a planned space experiment with the objective of obtaining video and numerical data on fluid dynamics and thermal physics pertinent to on-orbit liquid acquisition and tank filling operations, particularly with cryogens. These data have significant application to space-based transportation systems, Space Station Freedom, and space defense systems. This paper presents the rationale for the experiment and a description of its design. The experiment will mount in two Get Away Special canisters that are connected to each other by an electrical umbilical. It involves transferring Freon 113 between two transparent plexiglass tanks. Axial and tangential no-vent fills will be done over a range of flow rates. The apparatus includes a screened-channel liquid acquisition device with plexiglass channels for examining vapor breakthrough and channel refill processes. Video cameras will monitor the transfer operations. Author

A90-42790#
LOW-G VENTING TESTS TO SUPPORT ON-ORBIT FLUID RESUPPLY SYSTEMS
B. A. BICKNELL and P. M. CZYSZ (Martin Marietta Corp., Denver, CO) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 12 p. refs
(AIAA PAPER 90-2379) Copyright

Fluid behavior during low-g venting and methods of on-orbit resupply are investigated, with emphasis on aircraft tests. Tests performed with 12.5-in- and 4.0-in-diameter spherical vaned tanks are presented, and bulk boiling and pressurant evolution phenomena are analyzed. Tank venting is achieved without liquid expulsion in both types of tanks aboard the aircraft and in drop-tower facilities. Preliminary results indicate that tank venting can be achieved without bubble formation occurring at approximately 2.7 percent ullage volume per second with the specified vaned tank configuration, and that tank resupply while simultaneously venting can be achieved at fill rates corresponding to a Weber number of ten. V.T.

A90-42822*# McDonnell-Douglas Space Systems Co., Huntington Beach, CA.
EXAMINATION OF THE EVOLUTIONARY GROWTH REQUIREMENT OF THE U.S. SPACE STATION FREEDOM PROPULSION SYSTEM
JOSEPH S. MORANO (McDonnell Douglas Space Systems Co., Space Station Div., Huntington Beach, CA) and JOHN B. HENDERSON (NASA, Johnson Space Center, Houston, TX) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p.
(AIAA PAPER 90-2734)

A trade study, performed to examine different propulsion systems into which the modular hydrazine system may evolve after the completion of the assembly phase, is discussed and results of this study are presented. Propulsion system options include: the modular hydrazine system, a modified hydrazine system, hypergolic bipropellant systems, an oxygen-hydrogen system, hypergolic bipropellant/hydrazine hybrid systems, and the oxygen-hydrogen/hydrazine hybrid system. Trade study criteria and methodology are reviewed. Water availability and growth and nongrowth configurations are discussed. Recommendations are made on the type of Space Station propulsion system that should be developed for long-term operations at minimal life cycle cost. It is suggested that, due to growth of the station shown in the assembly complete configuration, the oxygen-hydrogen propulsion system should be further developed so that related technology will be mature by assembly complete. L.K.S.

A90-47224*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CALCULATIONS OF GASEOUS H2/O2 THRUSTER
S. C. KIM (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) and T. J. VANOVERBEKE (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 26th, Orlando, FL, July 16-18, 1990. 9 p. refs
(Contract NAS3-25266)
(AIAA PAPER 90-2490)

Calculations were made for the gaseous H2/O2 thruster for the Space Station by using the RPLUS code which employs an implicit finite volume, LUSSOR scheme to solve the Navier-Stokes equations and the species equations. The combustion processes of hydrogen and oxygen are modeled by a 9 species and 18 step reaction mechanism and the turbulence is simulated by the Baldwin-Lomax turbulence model for the thruster wall boundary layer and the modified Prandtl's mixing length model for the reacting shear layer. Results are presented for different mixture ratios and fuel film cooling percents and compared with the experimental data. The calculated performance predictions for the thruster agree well with the experimental data and the results demonstrate that the RPLUS code can be used for design and analysis of thrusters and rockets. Author

A90-47647#
PROPULSION S/S DESIGN OF THE COLUMBUS FREE FLYING LABORATORY - STATE OF THE ART AND DRIVING CONCEPTS
M. ATTILI and F. CECCARELLI (BPD Difesa e Spazio, Colleferro, Italy) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 690-697. refs
(AIAA PAPER 90-3392) Copyright

The aim of this paper is to describe the baseline design presently available for the propulsion subsystem of the Columbus Free Flying Laboratory (CFFL). It mainly consists of a bipropellant section and a cold gas system using nitrogen gas as pressurant agent. The specific function of the subsystem is to enable the CFFL to perform orbit transfer and attitude control functions as well as rendezvous maneuvers to the Space Station Freedom. As an auxiliary function, the propulsion subsystem also supplies nitrogen and oxygen gases to the pressurized module for leakage compensation, via the environmental control and life support subsystem. This paper focuses on particular driving concepts such as the two-failure-tolerance design approach and dedicated devices such as the residual-propellant measurement device and the main-engine gimbal actuator. Author

A90-48305
EXPERIMENTAL VERIFICATION OF A MATHEMATICAL MODEL OF A SPACECRAFT WITH IN-TANK DAMPERS ALLOWING FOR FLUID VORTICITY [EKSPERIMENTAL'NAIA PROVERKA MATEMATICHESKOI MODELI KA S VNUTRIBAKOVYMI DEMPFIRUIUSHCHIMI USTROISTVAMI, UCHITYVAIUSHCHEI ZAVIKHRENNOST' ZHIDKOSTI]
V. G. LEBEDEV, A. I. MYTAREV, B. I. RABINOVICH, and G. A. CHURILOV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, July-Aug. 1990, p. 521-530. In Russian. refs
Copyright

Consideration is given to mathematical models of varying degrees of sophistication describing the rotation of a spacecraft with in-tank dampers about a longitudinal axis of symmetry with allowance for fluid vorticity. An analysis of the results of a full-scale experiment confirms the validity of the mathematical models proposed here; applicability regions are defined for each of the models. The effect of vorticity on the dynamics and stability of the controlled motion of the spacecraft is analyzed. V.L.

A90-50618#
AMSAT PHASE IV PROPULSION AND ATTITUDE CONTROL SYSTEMS CONCEPTUAL DESIGN
DOUG MAY (Thiokol Corp., Ogden, UT) IN: Annual AIAA/Utah State University Conference on Small Satellites, 3rd, Logan, UT, Sept. 26-28, 1989, Proceedings. Logan, UT, Utah State University, 1989, 9 p. refs

Preliminary design considerations and interactions between the primary propulsion, station keeping, and attitude control services for the Phase IV Amsat satellite are discussed. The relationships that lead to criteria and boundary conditions for selecting system hardware are presented. Methods for sizing momentum system components, thrusters, and propellant tanks are given, and preliminary mass property data are provided in examples to demonstrate how the system parameters are interrelated. C.D.

A90-52420
THE MENISCUS AND SLOSHING OF A LIQUID IN AN AXISYMMETRIC CONTAINER AT LOW-GRAVITY
MASAHIKO UTSUMI (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) JSME International Journal, Series III (ISSN 0914-8825), vol. 33, Sept. 1990, p. 346-356. refs
Copyright

The meniscus shape and the free oscillation of a liquid in an axisymmeric container in low gravity environments were investigated theoretically using partial spherical coordinates. A variational principle is used to formulate the equilibrium and dynamic behavior of the liquid. Basic equations are derived by relating the virtual work done by the surface tension to the normal vector of the liquid surface. The results obtained are found to be in good agreement with experimental data. V.L.

A90-52562*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
XENON ION PROPULSION FOR ORBIT TRANSFER
V. K. RAWLIN, M. J. PATTERSON, and R. P. GRUBER (NASA, Lewis Research Center, Cleveland, OH) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 21st, Orlando, FL, July 18-20, 1990. 29 p. refs
(AIAA PAPER 90-2527) Copyright

The status of critical ion propulsion system elements is reviewed. Electron bombardment ion thrusters for primary propulsion have evolved to operate on xenon in the 5-10 kW power range. Thruster efficiencies of 0.7 and specific impulse values of 4000 s have been documented. The baseline thruster currently under development by NASA LeRC includes ring-cusp magnetic field plasma containment and dished two-grid ion optics. Based on past experience and demonstrated simplifications, power processors for these thrusters should have approximately 500 parts, a mass of 40 kg, and an efficiency near 0.94. Thrust vector control, via individual thruster gimbals, is a mature technology. High pressure, gaseous xenon propellant storage and control schemes, using flight qualified hardware, result in propellant tankage fractions between 0.1 and 0.2. In-space and ground integration testing has demonstrated that ion propulsion systems can be successfully integrated with their host spacecraft. Author

A90-52565*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCED PROPULSION FOR LEO AND GEO PLATFORMS
JAMES S. SOVEY (NASA, Lewis Research Center, Cleveland, OH) and DAVID J. PIDGEON (NASA, Langley Research Center; George Washington University, Hampton, VA) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 21st, Orlando, FL, July 18-20, 1990. 25 p. Previously announced in STAR as N90-27785. refs
(AIAA PAPER 90-2551) Copyright

Mission requirements and mass savings applicable to specific low earth orbit and geostationary earth orbit platforms using three highly developed propulsion systems are described. Advanced hypergolic bipropellant thrusters and hydrazine arcjets can provide about 11 percent additional instrument payload to 14,000 kg LEO platforms. By using electric propulsion on a 8,000 kg class GEO platform, mass savings in excess of 15 percent of the beginning-of-life platform mass are obtained. Effects of large,

advanced technology solar arrays and antennas on platform propulsion requirements are also discussed. Author

N90-20236* *National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.*
VORTEX MOTION PHASE SEPARATOR FOR ZERO GRAVITY LIQUID TRANSFER Patent
FRANK S. HOWARD, inventor (to NASA) and WILSON M. FRASER, JR., inventor (to NASA) 18 Jul. 1989 8 p Filed 16 Aug. 1988
(NASA-CASE-KSC-11387-1; US-PATENT-4,848,987; US-PATENT-APPL-SN-232734; US-PATENT-CLASS-55-160; US-PATENT-CLASS-55-182; US-PATENT-CLASS-55-205; US-PATENT-CLASS-141-45) Avail: US Patent and Trademark Office CSCL 22/1

A vortex motion phase separator is disclosed for transferring a liquid in a zero gravity environment while at the same time separating the liquid from vapors found within either the sender or the receiving tanks. The separator comprises a rigid sender tank having a circular cross-section and rigid receiver tank having a circular cross-section. A plurality of ducts connects the sender tank and the receiver tank. Disposed within the ducts connecting the receiver tank and the sender tank is a pump and a plurality of valves. The pump is powered by an electric motor and is adapted to draw either the liquid or a mixture of the liquid and the vapor from the sender tank. Initially, the mixture drawn from the sender tank is directed through a portion of the ductwork and back into the sender tank at a tangent to the inside surface of the sender tank, thereby creating a swirling vortex of the mixture within the sender tank. As the pumping action increases, the speed of the swirling action within the sender tank increases creating an increase in the centrifugal force operating on the mixture. The effect of the centrifugal force is to cause the heavier liquid to migrate to the inside surface of the sender tank and to separate from the vapor. When this separation reaches a predetermined degree, control means is activated to direct the liquid conveyed by the pump directly into the receiver tank. At the same time, the vapor within the receiver tank is directed from the receiver tank back into the sender tank. This flow continues until substantially all of the liquid is transferred from the sender tank to the receiver tank.
Official Gazette of the U.S. Patent and Trademark Office

N90-21097*# Ball Aerospace Systems Div., Boulder, CO.
BASG THERMOMECHANICAL PUMP HELIUM 2 TRANSFER TESTS
G. L. MILLS, D. A. NEWELL, and A. R. URBACH Mar. 1990 72 p
(Contract NAS2-11979)
(NASA-CR-177541; A-90127; NAS 1.26:177541) Avail: NTIS HC A04/MF A01 CSCL 22/2

The purpose of the effort described was to perform experiments and calculations related to using a thermomechanical pump in the space-based resupply of the Space Infrared Telescope Facility (SIRTF) with Helium 2. Thermomechanical (fountain effect) pumps have long been suggested as a means for pumping large quantities of Helium 2. The unique properties of Helium 2 have made it useful for cooling space instruments. Several space science missions, including SIRTF, are now being planned which would benefit greatly from on-orbit resupply of Helium 2. A series of experiments were performed to demonstrate that large volumes of Helium 2 can be transferred with a thermomechanical pump at high flow rates and at high efficiency from one dewar to another through valves and lines that are similar to the plumbing arrangement that would be necessary to accomplish such a transfer on-orbit. In addition, temperature, pressure, and flow rate data taken during the tests were used to verify and refine a computer model which was developed. Author

N90-23473# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
ANALYSIS OF THE USE OF A METHANE PROPELLANT IN A BIOWASTE RESISTOJET M.S. Thesis
JOHN A. VISE Mar. 1990 119 p
(AD-A220475; AFIT/GA/ENY/90M-2) Avail: NTIS HC A06/MF A01 CSCL 21/3

An engineering model resistojet has been developed by NASA for possible space station applications that will operate on a variety of waste gases, including methane. This investigation develops a computer program using the principles of laminar flow heat transfer to simulate operation of the resistojet heat exchanger. The principles of chemical kinetics are used to determine how carbon deposits from methane decomposition in the heat exchanger. The results of the program show a wide variation in deposition versus operational pressure, power, and methane mass flow rate. GRA

N90-24324*# *National Aeronautics and Space Administration.* Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT OF A FULLY AUTOMATED FLUID RESUPPLY INTERFACE SYSTEM
J. M. CARDIN (Moog, Inc., East Aurora, NY.), WILLIAM C. BOYD, and MARK S. FALLS *In* ESA, Second European In-Orbit Operations Technology Symposium p 351-358 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders CSCL 22/2

The results of a cooperative effort to develop fluid components and systems that facilitate on-orbit servicing are discussed. The evolution from manual couplings to semi-automatic dual line interfaces to fully automatic multi-line resupply interfaces is traced. Hardware designs are presented in the context of solutions to requirements. Test data and user evaluations are reviewed. ESA

N90-24465# Societe Anonyme Belge de Constructions Aeronautiques, Brussels.
FLUID CONNECTORS FOR OPERATION IN SPACE
G. BEKAERT and NEIL CABLE (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 19-23 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Two different mechanisms carrying fluid connectors are described. Fluid connectors and subassemblies used for refilling/refueling in docking/berthing systems are discussed. Fluid connectors and subassemblies for active thermal control in orbital replacement units are outlined. The guidelines and verification tests used in the selection of the concepts are described. Breadboard test results, confirming the suitability of the design concept are presented. The need to further minimize the mass and size of the connectors is stressed. Tests of leakage and ageing in a thermal vacuum environment are called for. ESA

N90-24478# ETEL S.A., Motiers (Switzerland).
DESIGN AND USE OF HIGH SPEED SYNCHRONOUS MOTOR RUNNING IN AGGRESSIVE LIQUIDS
N. WAVRE *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 109-115 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Two applications of synchronous motors used to drive high speed pumps are presented. The first is developed for an Electric Propellant Pump System (EPPS). The system consists of a centrifugal pump assembled on the motor shaft. A nominal power of 2.5KW is obtained at 2500 rpm and a peak power of 3.5kW at 35000 rpm. A second motor developed for a Water Freon Wet Rotor Pump (WFPP) is described. The system consists of a centrifugal pump directly assembled on the shaft. The shaft is identified as the most critical part because it has to run in microgravity. Ways in which theses motors have been designed to run in aggressive liquids are described. ESA

N90-24506# Polytechnical Univ. of Madrid (Spain). Dept. of Aerospace Materials and Production.
DESIGN AND MANUFACTURING OF AN APTF TO TEST FLUID BEHAVIOUR IN MICROGRAVITY ENVIRONMENT
P. RODRIGUEZ, A. SANZ, J. M. PERALES, and A. P. SANZ *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 299-304 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The design and manufacture of an Advanced Plateau Tank Facility (APTF) are described. The APTF is to be used for carrying out Earth experiments, previous to space experiments, on fluid behavior in microgravity environments. The requirements and restrictions to be taken into account in designing and manufacturing an APTF are listed. Mechanisms employed in each part of the prototype are described. Results of parabolic and orbital flights having shown higher gravity levels than predicted, new experiments to correct and update theoretical models are called for. ESA

N90-26042*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.
PROJECT LOCOST: LASER OR CHEMICAL HYBRID ORBITAL SPACE TRANSPORT
ALAN DIXON, ALICIA KOST, GREGORY LAMPSHIRE, ROB LARSEN, BOB MONAHAN, and GEOFF WRIGHT 19 Jun. 1990 115 p
(Contract NGT-21-002-800)
(NASA-CR-186822; NAS 1.26:186822) Avail: NTIS HC A06/MF A01 CSCL 22/2

A potential mission in the late 1990s is the servicing of spacecraft assets located in GEO. The Geosynchronous Operations Support Center (GeoShack) will be supported by a space transfer vehicle based at the Space Station (SS). The vehicle will transport cargo between the SS and the GeoShack. A proposed unmanned, laser or chemical hybrid orbital space transfer vehicle (LOCOST) can be used to efficiently transfer cargo between the two orbits. A preliminary design shows that an unmanned, laser/chemical hybrid vehicle results in the fuel savings needed while still providing fast trip times. The LOCOST vehicle receives a 12 MW laser beam from one Earth orbiting, solar pumped, iodide Laser Power Station (LPS). Two Energy Relay Units (ERU) provide laser beam support during periods of line-of-sight blockage by the Earth. The baseline mission specifies a 13 day round trip transfer time. The ship's configuration consist of an optical train, one hydrogen laser engine, two chemical engines, a 18 m by 29 m box truss, a mission-flexible payload module, and propellant tanks. Overall vehicle dry mass is 8,000 kg. Outbound cargo mass is 20,000 kg, and inbound cargo mass is 6,000 kg. The baseline mission needs 93,000 kg of propellants to complete the scenario. Fully fueled, outbound mission mass is 121,000 kg. A regeneratively cooled, single plasma, laser engine design producing a maximum of 768 N of thrust is utilized along with two traditional chemical engines. The payload module is designed to hold 40,000 kg of cargo, though the baseline mission specifies less. A proposed design of a laser/chemical hybrid vehicle provides a trip time and propellant efficient means to transport cargo from the SS to a GeoShack. Its unique, hybrid propulsion system provides safety through redundancy, allows baseline missions to be efficiently executed, while still allowing for the possibility of larger cargo transfers. Author

N90-26868# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany, F.R.). Inst. fuer Raumfahrttechnik.
HYDROELASTIC PROBLEMS IN SPACE FLIGHT VEHICLES
HELMUT FRANZ BAUER 1989 34 p
(LRT-WE-9-FB-11(1989); ETN-90-97342) Avail: NTIS HC A03/MF A01

The hydroelastic behavior of an incompressible and frictionless liquid with a free surface was investigated for a cylindrical container. Coupled frequencies for non-rotating and rotating containers are presented. Through the coupling of liquid and structure the frequency may be removed from areas dangerous to the overall stability of the space vehicle. The instability may be removed by the inclusion of liquid. ESA

N90-27785*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCED PROPULSION FOR LEO AND GEO PLATFORMS
JAMES S. SOVEY and DAVID J. PIDGEON (George Washington Univ., Hampton, VA.) 1990 27 p Presented at the 21st International Electric Propulsion Conference, Orlando, FL, 18-20 Jul. 1990; cosponsored by AIAA, DGLR, and JSASS
(NASA-TM-103228; E-5644; NAS 1.15:103228; AIAA-90-2551)
Avail: NTIS HC A03/MF A01 CSCL 21/8

Mission requirements and mass savings applicable to specific low earth orbit and geostationary earth orbit platforms using three highly developed propulsion systems are described. Advanced hypergolic bipropellant thrusters and hydrazine arcjets can provide about 11 percent additional instrument payload to 14,000 kg LEO platforms. By using electric propulsion on a 8,000 kg class GEO platform, mass savings in excess of 15 percent of the beginning-of-life platform mass are obtained. Effects of large, advanced technology solar arrays and antennas on platform propulsion requirements are also discussed. Author

18

COMMERCIALIZATION

Use of space stations for large scale commercial operations.

A90-33580
THE ECONOMIC AND POLITICAL ORGANIZATION OF A SPACE-DWELLING SOCIETY
CONSTANCE V. ELLIOTT Journal of Practical Applications in Space (ISSN 1046-8757), vol. 1, Winter 1990, p. 51-61. refs
Copyright

A proposal for the social organization of space dwellers is presented. A space-dwelling society must be economically viable. Attention is given to the proper allocation and efficient use of resources. The three basic ways societies organize are described. The relation between markets and free societies is examined. Government allocation of public goods using a decentralized system of government is discussed. I.F.

A90-33629
COLUMBUS IN THE FRAMEWORK OF SPACE STATION FREEDOM
FREDRIK ENGSTROM (ESA, Paris, France) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 9-18.
Copyright

Elements and implementation of the ESA Columbus program are reviewed. Structural and functional characteristics of the attached laboratory, the free flying laboratory, and an unmanned polar platform are described. Consideration is also given to the ground segment of the European in-orbit infrastructure which will support European and international requirments for mission control and payload operations coordination; test and verification of the space elements and payload; and training of crew and support personnel. Utilization preparation activities and the Columbus Exploitation Program are defined. N.B.

A90-33634
THE USO TEAM AT WORK AT DLR
F. UNZ (DLR, Cologne, Federal Republic of Germany) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 57-59.
Copyright

The task and first working results of the User Support Organization (USO) Definition Team in the present working period are reviewed. The four major parts of the task, ground infrastructure concept, user center specifications, management proposal for USO, and final documents, are described. Activities and responsibilities of the team in the subsequent phases of the Columbus program

are defined. This phase is expected to cover all disciplines and produce results in the fields of microgravity, space sciences, earth observation, and user relevant technology. N.B.

A90-33640
EXPERIENCE AND CONCEPTS IN MICROGRAVITY USER SUPPORT
B. FEUERBACHER, K. WITTMANN (DLR, Cologne, Federal Republic of Germany), C. MIRRA, and L. G. NAPOLITANO (Microgravity Advanced Research and Support Center, Naples, Italy) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 109-115. refs
Copyright

An overview of activities of the Microgravity User Support Center (MUSC) and the Microgravity Advanced Research and Support Center (MARS) is presented, and the concepts leading to an effective user support infrastructure for the Columbus era are discussed. The requirements of the user community are discussed and classified, and according to this classification, two different classes of centers with different tasks and functions are determined, i.e., a scientific and an operational center. The user support concept is evaluated with a special emphasis on advanced techniques for high scientific and operational support. It is concluded that centralization will improve the efficiency of space operations in the functional and financial sense, and will also contribute to a widening of the user community. N.B.

A90-42311#
PROMOTING COLUMBUS UTILIZATION [LA PROMOTION DE L'UTILISATION DE COLUMBUS]
J.-J. DORDAIN, J.-L. COLLETTE, G. NAJA, and PH. WILLEKENS (ESA, Paris, France) ESA Bulletin (ISSN 0376-4265), no. 62, May 1990, p. 24-39. In French and German.
Copyright

The current status of ESA efforts to promote commercial and scientific utilization of the Columbus Attached Laboratory, Free-Flying Laboratory, and Polar Platform is surveyed. The problems involved in identifying and attracting users are considered; program elements intended to maximize accessibility and flexibility are reviewed; the types of information provided by the utilization-promotion program are described; the target audiences are characterized; and the importance of preparatory activities (ground simulations and experiments on Eureca and Spacelab) is stressed. Particular attention is given to the Columbus Pictures Data Bank, the Columbus Utilization Information System, the Columbus Marketing Data Base, the User Support Organization, and the full-scale Attached Laboratory mockup in use at ESTEC. Diagrams, drawings, and photographs are included. T.K.

A90-43464
INDUSTRY VIEW OF SPACE STATION
CHARLES A. ORDAHI (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 65-71.
(AAS PAPER 88-164) Copyright

The industry view of Space Station Freedom is said to be one of optimism and anticipation of the future. It is pointed out that those in industry view their participation in the Space Station development and operations as an important part of their strategic business plans. It is concluded that industry foresees major progress in the following areas in connection with the Space Station project: automation and robotics, power, materials and structures, information and control systems, sensors, life sciences, and environmental control and life support systems. B.J.

A90-47107*# Alabama Univ., Huntsville.
LOW-GRAVITY ELECTRODEPOSITION OF METALS AND METAL/CERMET COMPOSITES
CLYDE RILEY, HIND ABI-AKAR, BRIAN BENSON (Alabama, University, Huntsville), and GEORGE MAYBEE (McDonnell Douglas Space Systems Co., Huntsville, AL) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, July-Aug. 1990, p. 386-390. Research supported by McDonnell Douglas Space Systems Co. Previously cited in issue 09, p. 1327, Accession no. A89-25262. refs
(Contract NAGW-812)
Copyright

A90-52696
THE UTILIZATION OF OUTER SPACE - A CHALLENGE TO SCIENCE AND THE ECONOMY [NUTZUNG DES WELTRAUMS - EINE HERAUSFORDERUNG AN WISSENSCHAFT UND WIRTSCHAFT]
HEINZ STOEWER (Deutsche Agentur fuer Raumfahrtangelegenheiten GmbH, Bonn, Federal Republic of Germany) Luft- und Raumfahrt (ISSN 0173-6264), vol. 11, 3rd Quarter, 1990, p. 22-28. In German.
Copyright

Scientific, technological, economic, and policy aspects of the FRG space program and of FRG participation in ESA are examined by a senior official of the German space affairs agency DARA. The importance of developing both a space infrastructure and space utilization capabilities is pointed out, and particular attention is given to projects in space science and exploration, terrestrial remote sensing, telecommunication, and microgravity applications. Also discussed are the experiments and commercial uses planned for the attached laboratory and free-flying spacecraft of Columbus, the ESA contribution to the NASA International Space Station. The need to limit both the costs of Columbus utilization and the complexity of the application, hardware development, qualification, and operation processes is stressed. T.K.

N90-22428*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION WORKSHOP: COMMERCIAL MISSIONS AND USER REQUIREMENTS
23 Feb. 1988 326 p Workshop held in Nashville, TN, 3-5 Nov. 1987
(NASA-TM-102912; NAS 1.15:102912) Avail: NTIS HC A15/MF A02 CSCL 05/1

The topics of discussion addressed during a three day workshop on commercial application in space are presented. Approximately half of the program was directed towards an overview and orientation to the Space Station Project; the technical attributes of space; and present and future potential commercial opportunities. The remaining time was spent addressing technological issues presented by previously-formed industry working groups, who attempted to identify the technology needs, problems or issues faced and/or anticipated by the following industries: extraction (mining, agriculture, petroleum, fishing, etc.); fabrication (manufacturing, automotive, aircraft, chemical, pharmaceutical and electronics); and services (communications, transportation and retail robotics). After the industry groups presented their technology issues, the workshop divided into smaller discussion groups composed of: space experts from NASA; academia; industry experts in the appropriate disciplines; and other workshop participants. The needs identified by the industry working groups, space station technical requirements, proposed commercial ventures and other issues related to space commercialization were discussed. The material summarized and reported are the consensus from the discussion groups. B.H.A.

N90-24172*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION FREEDOM PRE-WORKSHOP SESSION
1988 245 p Workshop held in Denver, CO, 25 Oct. 1988
(NASA-TM-102913; NAS 1.15:102913) Avail: NTIS HC A11/MF A02 CSCL 05/1

This is a report of a pre-workshop session held before the 1988 Space Station Workshop; it details space station opportunities for commercial users and providers. Aspects covered are: an

overview of commercial uses of space; and overview of the Space Station Freedom Program; attributes of space and some practical uses of them; a description of commercial space activities by country, including various statistics; information on each of NASA's Centers for Commercial Development; and monetary and other resources available to help support commercial ventures in space. J.P.S.

N90-26724# Roussel-Uclaf, Paris (France). Direction de l'Innovation et de la Prospective.
SPACE MANUFACTURE: PROTECTION AND VALUATION OF INNOVATIONS FROM A USERS POINT OF VIEW [LES FABRICATIONS DANS L'ESPACE: PROTECTION ET VALOORISATION DES INNOVATIONS LE POINT DE VUE D'UN UTILISATEUR]
J. P. RAYNAUD and V. VACHE *In* ESA, Manned Space Stations: Legal Aspects p 115-116 Jan. 1990 In FRENCH
Copyright Avail: NTIS HC A10/MF A02; also available from EPD, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

Various technological and economic aspects of space manufacturing and space commercialization are addressed. Research carried out in reduced gravity manufacturing are described. Difficulties in promoting more research in space while protecting the secrecy of the test results carried out by industrial investors are discussed. The need for legislation protecting the patent rights of discoveries made in space is called for. Possible developments in the field of biotechnology due to spaceborne experiments are described. The Space Bio Separation (SBS) program is used as an example of the kind of legal problems facing industrial development in space. ESA

N90-29257# Congressional Budget Office, Washington, DC.
PRELIMINARY ANALYSIS OF NASA COMMERCIALIZATION INITIATIVES
D. H. MOORE and M. SIEVERTS 17 Feb. 1989 18 p
(PB90-202706) Avail: NTIS HC A03/MF A01 CSCL 05/1

The NASA budget request includes support for industry and university collaboration in exploring the potential uses of space for future economic gain and for procurement of launch services from the private sector for NASA missions, and announces NASA's intention to seek private-sector financing for portions of its space transportation and space station programs. The intention to seek private financing for NASA facilities and hardware programs represents a new direction for the NASA program. It would defer some budgetary outlays to the future by means of service contracts and leases to private investors. A complete analysis of these space commercialization initiatives must await more specific information concerning the proposed agreements between the government and private investors, since a variety of options would be open to both parties. Nevertheless, the initiatives included in the 1990 budget raise a number of general issues. Some of these issues are addressed in examining the larger policy behind the proposals, estimating their cost to the government, and briefly examining some budgetary and scoring concerns. GRA

19

EXPERIMENTS

Design and description of experiments to be performed or managed from the space station.

A90-31999* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A LIDAR SYSTEM FOR REMOTE SENSING OF AEROSOLS AND WATER VAPOR FROM NSTS AND SPACE STATION FREEDOM
JOSEPH F. DELORME (NASA, Langley Research Center, Hampton, VA) IN: Laser applications in meteorology and earth and atmospheric remote sensing; Proceedings of the Meeting, Los Angeles, CA, Jan. 16-18, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 117-126.
Copyright

The Tropical Atmospheric Lidar Observing System (TALOS) is proposed to be developed as a Differential Absorption Lidar (DIAL) system for flight aboard the earth orbiting Space Station Freedom. TALOS will be capable of making high resolution vertical profile measurements of tropospheric water and tropospheric and stratospheric aerosols, clouds and temperature. Author

A90-32010* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
LASER ATMOSPHERIC WIND SOUNDER (LAWS)
R. G. BERANEK, J. W. BILBRO, D. E. FITZJARRALD, W. D. JONES, V. W. KELLER (NASA, Marshall Space Flight Center, Huntsville, AL) et al. IN: Laser applications in meteorology and earth and atmospheric remote sensing; Proceedings of the Meeting, Los Angeles, CA, Jan. 16-18, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 234-248. refs
Copyright

The principle of operation of a space based Doppler lidar wind measuring system is discussed along with laser wavelength selection considerations. Differences in accommodating the Laser Atmospheric Wind Sounder (LAWS) on the Earth Observing System (EOS) polar platform and the Manned Space Station are presented. The impact of the LAWS instrument support subsystems are specifically discussed. Author

A90-32047*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE COSMIC DUST COLLECTION FACILITY ON SPACE STATION FREEDOM
FRIEDRICH HORZ and DENNIS GROUNDS (NASA, Johnson Space Center, Houston, TX) AIAA, NASA, and DOD, Orbital Debris Conference: Technical Issues and Future Directions, Baltimore, MD, Apr. 16-19, 1990. 8 p. refs
(AIAA PAPER 90-1351) Copyright

The Cosmic Dust Collection Facility is an attached payload on board the Freedom Station that will serve as a long-term observatory of all dust-sized particles, typically of much less than 1 mm, either natural or man-made. Its instruments will measure the trajectories of individual hypervelocity particles and will trap the fragmented, melted or vaporized impactor residues in suitable capture media. The latter will be periodically returned to earth for detailed mineralogic and chemical characterization of these residues. The trajectory information will permit reconstruction of the astrophysical source(s) of natural dust grains, such that the compositional information may serve as proxy-analysis of primitive solar system objects among which comets and asteroids are known to be the most prolific dust sources. Trajectory information and chemical composition of man-made particles will yield clues about the most prolific anthropogenic sources. Direct measurement of the dynamic properties of all particles will contribute substantially toward an understanding of the collisional hazards to current and future space operations in LEO. Author

A90-33635
SPACE SCIENCE WITH COLUMBUS. V - SMALL AND RAPID RESPONSE PAYLOADS (SARRS)
H. OLTHOF (ESTEC, Noordwijk, Netherlands) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 79, 80.
Copyright

The activities of an international working group composed of scientists from partner nations are reported. The group has the task of identifying classes of high-priority astrophysics and space physics payloads to be carried out as small attached payloads on the Space Station. Objectives of the program in launching small, simple, light-weight and inexpensive experiments which can be carried out within 2.5-3 years are described. Characteristics of the

small payload, estimated requirements for the Space Station resources, and problems of international cooperation are reviewed. N.B.

A90-33636
THE ESA MICROGRAVITY PROGRAMME AND ITS USE OF THE COLUMBUS INFRASTRUCTURE
G. SEIBERT (ESA, Paris, France) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 81-92.
Copyright

The concept of major multiuser experiment facilities for microgravity research in space is presented. The currently existing multiuser facilities incorporated in the Spacelab and in the Eureca mission, and their utilization for microgravity research are described. The projected flight opportunities are addressed, together with the plans for flight opportunities for smaller experiments, such as sounding rockets. The objectives of ESA's microgravity program, named In Orbit 2000, and some strategic programmatic aspects based on these objectives are discussed. N.B.

A90-33638
ATTACHED PAYLOAD SUPPORT SYSTEMS (APLSS) STUDY
GEORGE P. HASKELL (ESA, Paris, France) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 101-104.
Copyright

The objectives of the study on payload support systems for the Space Station Freedom (SSF) which are not included in the present design of the infrastructure of the Space Station are reviewed, as well as two specific topics discussed by the User Working Team (UWT), i.e., monitoring of the external environment of the SSF, and use of the planned precursor Spacelab flights for external payloads. In addition to the conceptual design of the user support hardware, the study includes the definition of an assembly, integration and verification program, a logistics program, and a typical operations program, leading to an assessment of total program cost and schedule. N.B.

A90-33641
TELESCIENCE - A TEST BED FOR OPERATIONS
G. NAJA (ESA, Space Station and Platforms Directorate, Paris, France), C. RICAUD, and J. TAILHADES (Matra Espace, Toulouse, France) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 117-120.
Copyright

Telescience will help promote a wide use of space facilities, by providing on-ground investigators with a 'transparent' and interactive access to their payloads in orbit. It is essential to test how transparent the whole infrastructure can be and what are the system requirements to achieve it. The Test Bed developed by MATRA and now installed in ESTEC intends to answer these questions and gives potential users an efficient tool to test their procedures. This paper recalls what is the telescience concept and the points addressed by the Test Bed. It describes the different experiments already connected to it and gives the essential technical details. After a status overview, perspectives are sketched. Author

A90-33642
TELESCIENCE CONCEPT - FROM TEXUS TO SPACE STATION
H. P. SCHMIDT, E. BENNET, G. KAUL, K. WITTMANN (DLR, Institut fuer Raumsimulation, Cologne, Federal Republic of Germany), and C. PUTZ (Kayser-Threde GmbH, Munich, Federal Republic of Germany) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 121-126. Research supported by DLR. refs
Copyright

Two scientific experiments with applied telescience in microgravity conditions, performed within the framework of the Texus program in April-May 1989, are described. Two parts of the task of establishing various communication links, transmission of a video signal and transmission of digital data, are discussed. The objectives achieved as a result of the experiments are formulated. It is demonstrated that telescience is an adequate method for performing experimental research in the space environment; that telescience techniques improve the experimental capacity of the Texus program, while Texus provides telescience with a fast and low cost testbed for future applications; and that the tools for telescience developed and applied at the Microgravity User Support Center are feasible for an application on future user home bases. N.B.

A90-33643
TELETEXUS EXPERIMENT - PRELIMINARY EXPERIENCE FOR THE COLUMBUS PROGRAMME
R. MONTI (Napoli, Universita, Naples, Italy) and R. FORTEZZA (Microgravity Advanced Research and Support Center, Naples, Italy) (ESA, BMFT, Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, et al., Columbus Symposium on Space Station Utilization, 5th, Capri, Italy, July 3-7, 1989) Space Technology - Industrial and Commercial Applications (ISSN 0892-9270), vol. 10, no. 1-2, 1990, p. 127-134.
Copyright

The telescience aspect of an experiment on Marangoni oscillations planned to be carried out on board the Texus sounding rocket is discussed. The experiment and technical aspects of its preparation are described. The operational capacity of four control levels, and their implementation are discussed. It is demonstrated that, without the telescience control, Texus would have to be flown three or four times to obtain the same results, which means that the experiment would last not 1-2 years but 10 years. A comparison between the possible Columbus scenario and the Texus telescience implementation shows many similarities, which makes it possible to utilize the basic Texus concepts for the Columbus mission. The Columbus V testbed is described, and its results demonstrate that the validity and efficiency of the hardware and software developed for Teletexus guarantee a sufficient level of confidence. N.B.

A90-34953
NEW GENERATION OF SPACE MULTICHANNEL SPECTROMETRIC SYSTEMS
D. N. MISHEV, S. T. KOVACHEV, and D. D. KREZHOVA (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia za Kosmicheski Izsledvaniia, Sofia, Bulgaria) Bolgarskaia Akademiia Nauk, Doklady (ISSN 0366-8681), vol. 43, no. 1, 1990, p. 53-56. refs
Copyright

The Spectrum 256 multichannel spectrometric system on the Mir space station is described. The system's spectral analyser, data recording subsystem, computer subsystem are described. A diagram illustrating the Spectrum 256 system is presented and sample data is given to demonstrate the system. R.B.

A90-35604* California Univ., Berkeley.
CRYOGENICS - ITS INFLUENCE ON THE SELECTION OF THE ASTROMAG SUPERCONDUCTING MAGNET COILS
M. A. GREEN (California, University, Berkeley) (NASA, Space Cryogenic Workshop, 8th, Pasadena, CA, July 31, Aug. 1, 1989) Cryogenics (ISSN 0011-2275), vol. 30, March 1990, p. 178-183. Research supported by NASA. refs
(Contract DE-AC03-76SF-00098)
Copyright

ASTROMAG, a particle astrophysics experimental facility

proposed for running alongside a Space Station, has a large superconducting magnet to analyze particles coming from deep space. Several types of magnets were investigated for use in the ASTROMAG central facility. The factors which influence the selection of the magnet coil design include: (1) the upper limit of particle momentum resolved (proportional to the integrated field) as a function of solid angle; (2)cryogenic design and its effect on cryogen lifetime for a given central facility mass; and (3) the overall cost of the magnet coils and cryostat. Four magnet types are analyzed in this paper. These include a simple two-coil solenoid (the baseline design),two disk coils at the ends of the helium tank, a two-coil toroid and a thin solenoid plus bucking coil. A balance must be struck between cryostat lifetime, total mass and the integrated field through the detectors. This balance tends to favor coils which are in the same vacuum vessel as the cryogen. Author

A90-41821
NEW TECHNIQUES FOR COLLECTING DATA AROUND THE SPACE STATION
ENRICO C. LORENZINI (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA), JAMES D. SULLIVAN, and RICHARD S. POST (MIT, Cambridge, MA) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 38, Apr.-June 1990, p. 121-141. refs
Copyright

The interaction in the upper ionosphere between the ambient medium and the Space Station will require measurements from essentially nonintrusive instrumentation. A spin-cast diagnostic package (SCDP) can complement free flyers and attached instrumentation in the region from 10 m to 1 km which is prohibited to free flyers. The basic concept for the SCDP is to cast off on an umbilical line in some chosen direction a small, battery powered, instrumentation package and then to reel it back in while taking measurements. A typical package might include pressure monitors, various plasma probes, magnetometers, plasma wave, and optical sensors which could include video imaging. This paper proposes a method for rapid deployment and retrieval of the constrained plasma package. The paper also proposes a complementary method for collecting data beyond the restricted zone whereby a free-flying plasma package is injected into a moon orbit around the Space Station Author

A90-42276
THE ENVIRONMENT - A CHALLENGE TO AIR AND SPACE FLIGHT [UMWELT - EINE HERAUSFORDERUNG AN LUFT- UND RAUMFAHRT]
W. KROELL and R. BACKHAUS (DLR, Cologne, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 14, June 1990, p. 139-144. In German. refs
Copyright

The significance of remote sensing by aircraft and spacecraft for the study of the environment is addressed. The environmental applications of the ERS-1, Atmos satellite, and polar platforms are considered, and related plans being made for the International Space Year and by the DLR are examined. The compatibility of various aircraft and spacecraft systems with the environment is discussed. C.D.

A90-43478* National Aeronautics and Space Administration, Washington, DC.
SPACE SCIENCES - KEYNOTE ADDRESS
JOSEPH K. ALEXANDER (NASA, Washington, DC) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 297-308.
(AAS PAPER 88-220) Copyright

The present status and projected future developments of the NASA Space Science and Applications Program are addressed. Emphasis is given to biochemistry experiments that are planned for the Space Station. Projects for the late 1990s which will study the sun, the earth's magnetosphere, and the geosphere are briefly discussed. C.D.

A90-45938* Stanford Univ., CA.
THE ULTRA HIGH RESOLUTION XUV SPECTROHELIOGRAPH
ARTHUR B. C. WALKER, JR., JOAKIM F. LINDBLOM, J. GETHYN TIMOTHY (Stanford University, CA), TROY W. BARBEE, JR. (Lawrence Livermore National Laboratory, Livermore, CA), RICHARD B. HOOVER, and EINAR TANDBERG-HANSSEN (NASA, Marshall Space Flight Center, Huntsville, AL) Optical Engineering (ISSN 0091-3286), vol. 29, July 1990, p. 698-710. refs
Copyright

The Ultra High Resolution XUV Spectroheliograph (UHRXS), a solar observatory planned for the Space Station Freedom, is described. The UHRXR instruments include nine XUV Ritchey-Chretien telescopes covering a spectral range of 70-350 A, which will provide images of solar atmosphere structures ranging in temperature from 50,000 to 20,000,000 K. The images will be obtained with spatial resolution that is an order of magnitude better than any other currently planned solar satellite experiment. I.S.

A90-46246* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LOW FREQUENCY VIBRATION ISOLATION TECHNOLOGY FOR MICROGRAVITY SPACE EXPERIMENTS
C. M. GRODSINSKY and G. V. BROWN (NASA, Lewis Research Center, Cleveland, OH) IN: Machinery dynamics - Applications and vibration control problems; Proceedings of the Twelfth Biennial ASME Conference on Mechanical Vibration and Noise, Montreal, Canada, Sept. 17-21, 1989. New York, American Society of Mechanical Engineers, 1989, p. 295-302. Previously announced in STAR as N89-20324. refs
Copyright

The dynamic acceleration environment observed on Space Shuttle flights to date and predicted for the Space Station has complicated the analysis of prior microgravity experiments and prompted concern for the viability of proposed space experiments requiring long-term, low-g environments. Isolation systems capable of providing significant improvements in this environment exist, but have not been demonstrated in flight configurations. This paper presents a summary of the theoretical evaluation for two one degree-of-freedom (DOF) active magnetic isolators and their predicted response to both direct and base excitations, that can be used to isolate acceleration sensitive microgravity space experiments. Author

A90-48314
X-RAY EXPERIMENT ONBOARD THE ASTRON SPACE STATION [RENTGENOVSKII EKSPERIMENT NA AVTOMATICHESKOI STANTSII 'ASTRON']
S. I. BABICHENKO, M. S. BURGIN, S. M. VOINAKOV, E. D. GERNET, D. A. GOGANOV et al. Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 28, July-Aug. 1990, p. 587-618. In Russian. refs
Copyright

The general design and operation of the X-ray spectrometer SKR-02M on board the Astron space station, launched to near-earth orbit on March 23, 1983, are described. Preliminary results of observations of several X-ray sources are then presented. These include Crab nebula, NP 0532 pulsar, A 0535+26, Her X-1, and Cen X-3. V.L.

A90-49298* National Aeronautics and Space Administration, Washington, DC.
LIFESAT - A SATELLITE FOR SPACE BIOLOGICAL RESEARCH
THORA W. HALSTEAD and EMILY R. MOREY-HOLTON (NASA, Washington, DC) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 6 p.
(SAE PAPER 901225) Copyright

The LifeSat Program addresses the need for continuing access by biological scientists to space experimentation by accommodating

a wide range of experiments involving animals and plants for durations up to 60 days in an unmanned satellite. The program will encourage interdisciplinary and international cooperation at both the agency and scientist levels, and will provide a recoverable, reusable facility for low-cost missions addressing key scientific issues that can only be answered by space experimentation. It will provide opportunities for research in gravitational biology and on the effects of cosmic radiation on life systems. The scientific aspects of LifeSat are addressed here. Author

A90-49354
SPACE STATION FREEDOM SCIENCE SUPPORT EQUIPMENT
J. M. SMITH, W. G. DEAN, JR., and J. W. ANGELI (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 9 p.
(SAE PAPER 901302) Copyright

Space Station Freedom equipment is being developed to support future research in the life sciences and material sciences. This pape focuses on the preservation and storage equipment, and the trace contaminant control system. The preservation and storage equipment includes cryogenic freezers (-196 C) for specimen quick-freezing and storage, a freeze drier, and a -70 C freezer for general storage. A predevelopment Trace Contaminant Control System has been built to support Environmental Control and Life Support System testing. The hardware will be used in the Predevelopment Operational System Test to verify design interfaces with other subsystems of the air revitalization system. Author

A90-49355* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FACILITIES FOR ANIMAL RESEARCH IN SPACE WITH SPECIAL REFERENCE TO SPACE STATION FREEDOM
SJOERD L. BONTING (SETI Institute, Moffett Field, CA), JENNY S. KISHIYAMA, and ROGER D. ARNO (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 24 p. refs
(SAE PAPER 901303) Copyright

The facilities being planned for animal research on Space Station Freedom are considered in the context of the development of animal habitats from early ballistic and orbital flights to long-term missions aimed at more detailed scientific studies of the effects of space conditions on the vertebrate organism. Animal habitats are becoming more elaborate, requiring systems for environmental control, waste management, physiological monitoring, as well as ancillary facilities such as a 1-G control centrifuge and a glovebox. Habitats in use or to be used in various types of manned and unmanned spacecraft, and particularly those planned for Space Station Freedom, are described. The characteristics of the habitats are compared with each other and with current standards for animal holding facilities on the ground. Author

A90-49356* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
RESEARCH CENTRIFUGE ACCOMMODATIONS ON SPACE STATION FREEDOM
ROGER D. ARNO and MICHAEL J. HORKACHUK (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901304) Copyright

Life sciences research using plants and animals on the Space Station Freedom requires the ability to maintain live subjects in a safe and low stress environment for long durations at microgravity and at one g. The need for a centrifuge to achieve these accelerations is evident. Programmatic, technical, and cost considerations currently favor a 2.5 meter diameter centrifuge located either in the end cone of a Space Station Freedom node or in a separate module. A centrifuge facility could support a mix of rodent, plant, and small primate habitats. An automated cage extractor could be used to remove modular habitats in pairs without stopping the main rotor, minimizing the disruption to experiment protocols. The accommodation of such a centrifuge facility on the Space Station represents a significant demand on the crew time, power, data, volume, and logistics capability. It will contribute to a better understanding of the effects of space flight on humans, an understanding of plant growth in space for the eventual production of food, and an understanding of the role of gravity in biological processes. B.P.

A90-49357
HIGH TEMPERATURE HEAT PIPE FURNACES FOR MATERIAL PROCESSING
O. BROST (Stuttgart, Universitaet, Federal Republic of Germany) and P. BEHRMANN (ESTEC, Noordwijk, Netherlands) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 15 p. Research supported by ESA. refs
(SAE PAPER 901305) Copyright

A heat pipe furnace development was carried out to demonstrate the potential of the heat pipe heating technique at temperatures up to 1500 C for future material processing purposes and for process temperature control in a microgravity environment. Two different types of heat pipes were developed, a variable conductance heat pipe and a specially modified constant conductance heat pipe. Both types utilizing molybdenum 41 wt pct rhenium and lithium as containment material and working fluid, respectively, were successfully operated in the temperature range 900 C to 1500 C. The constant conductance heat pipe equipped with special provisions for vapor pressure measurement provides the furnace with a temporal temperature stability of 0.4 K in the temperature range 900 C to 1500 C and a temperature measurement accuracy like that of the variable conductance heat pipe. Author

A90-49393* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SCIENTIFIC USES AND TECHNICAL IMPLEMENTATION OF A VARIABLE GRAVITY CENTRIFUGE ON SPACE STATION FREEDOM
C. C. JOHNSON and A. R. HARGENS (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 11 p. refs
(SAE PAPER 901360) Copyright

The potential need and science requirements for a centrifuge to be designed and flown on Space Station Freedom are discussed, with a focus on a design concept for a centrifuge developed at NASA Ames. Applications identified for the centrifuge include fundamental studies in which gravity is a variable under experimental control, the need to provide a 1-g control, attempts to discover the threshold value of gravitation force for psychological response, and an effort to determine the effects of intermittent hypergravity. Science requirements specify the largest possible diameter at approximately 2.5 m, gravity levels ranging from 0.01 to 2 g, a nominal ramp-up rate of 0.01 g/sec, and life support for plants and animals. Ground-based studies using rats and squirrel monkeys on small-diameter centrifuges have demonstrated that animals can adapt to centrifugation at gravity gradients higher than those normally used in ground-based hypergravity studies. L.K.S.

A90-49427
INTERNAL ARCHITECTURE DESIGN CONCEPTS FOR A VARIABLE GRAVITY RESEARCH FACILITY
RAYMOND J. LEVESQUE, II, T. J. TITTERUD, and ZINA T. BLECK (McDonnell Douglas Space Systems Co., Space Station Div., Huntington Beach, CA) SAE, Intersociety Conference on Environmental Systems, 20th, Williamsburg, VA, July 9-12, 1990. 15 p. refs
(SAE PAPER 901419) Copyright

The paper deals with the role of a Variable Gravity Research Facility (VGRF) in low-earth orbit (LEO) as a testbed for generating and collecting data pertaining to the region between the 1.4-g

upper limit provided by ground-based experiments and the microgravity (0-g) operational environment provided by the Space Station Freedom (SSF). The phases of a piloted mission to Mars are simulated, and planetary surface operations, vehicle configuration, and operational and sizing assumptions are covered. Three internal architecture concepts are considered and assessed from a system point of view, and it is suggested that hardware from the SSF program represent a preferred starting point for creating reduced- and variable-gravity internal architectures. Among the main arguments for this selection are its higher corridor, its operational capabilities, and its less massive floor and ceiling racks. V.T.

A90-50266* Lockheed Missiles and Space Co., Palo Alto, CA.
SONGS - A HIGH RESOLUTION IMAGING GAMMA-RAY SPECTROMETER FOR THE SPACE STATION
G. H. NAKANO, L. F. CHASE, J. R. KILNER, W. G. SANDIE (Lockheed Research Laboratories, Palo Alto, CA), G. J. FISHMAN, W. S. PACIESAS (NASA, Goddard Space Flight Center, Greenbelt, MD) et al. IN: EUV, X-ray, and gamma-ray instrumentation for astronomy and atomic physics; Proceedings of the Meeting, San Diego, CA, Aug. 7-11, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 165-176. Research supported by DARPA, U.S. Navy, and Lockheed Independent Research Program. refs
Copyright

The overall design and the instrumental features of the Space-Station Observer for Nuclear Gamma-ray Spectroscopy (SONGS) instrument are described. SONGS comprises an array of 19 two-segment n-type Ge detectors, which have the capability of determining the interaction site in either the upper or the lower segment or in both segments. The detectors provide high energy resolution of 1 keV at 100 keV and of 2 keV at 1 MeV. The close-packed Ge sensor array provides a natural sensitivity for the measurement of gamma ray polarization in the 100 keV to 1 MeV energy range, making it possible to obtain information on the structure of the magnetosphere of neutron stars and of the accretion disk of black holes. I.S.

A90-50276* California Univ., La Jolla.
THE PINHOLE/OCCULTER FACILITY
HUGH S. HUDSON (California, University, La Jolla) and JOHN M. DAVIS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: EUV, X-ray, and gamma-ray instrumentation for astronomy and atomic physics; Proceedings of the Meeting, San Diego, CA, Aug. 7-11, 1989. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1989, p. 318-328. refs
(Contract NAG8-773)
Copyright

To image X-radiation efficiently at energies above about 10 keV requires the use of 'shadow optics' techniques. The Pinhole/Occulter Facility (P/OF) represents an application of these techniques for observations in high-energy astrophysics, especially the study of solar coronal activity in hard X-rays and gamma rays. P/OF will achieve angular resolutions on the order of 0.2 arcsec for an instrument deployment length of 50 m. Because of this large structural scale, P/OF has been proposed as an attached payload for the Space Station. Meanwhile, several smaller-scale instruments are being developed. Author

A90-51659* Alabama Univ., Huntsville.
LOW-GRAVITY EXPERIMENT SENSITIVITY TO RESIDUAL ACCELERATION - A REVIEW
J. IWAN D. ALEXANDER (Alabama, University, Huntsville) Microgravity Science and Technology (ISSN 0938-0108), vol. 3, Sept. 1990, p. 52-68. refs
(Contract NAG8-724)
Copyright

Work related to the analysis of experiment sensitivity to residual acceleration experienced in LEO spacecraft is reviewed. Most of the work discussed concerns heat, mass, and momentum transfer in fluid physics and materials science experiments. On the basis of the current understanding of experiment sensitivity, it is concluded that, in general, experimenters should be concerned about the effect of residual acceleration, and that careful modeling included as part of an experiment program will enable optimal use of the limited experiment time available in space. Author

N90-20238# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Raumsimulation.
CENTER OF GRAVITY: METALLIC SOLIDIFICATION [SCHWERPUNKT: METALLISCHE ERSTARRUNG]
G. OTTO, ed. Jun. 1989 220 p In ENGLISH and GERMAN Presented at 3rd Summer School Session on Microgravity, Cologne, Fed. Republic of Germany, 19-22 Jun. 1989
(DFVLR-IB-333-89/3; ETN-90-95850) Avail: NTIS HC A10/MF A02

An introduction to the principles of the germ formation and growth and the interaction of a solidification front with scattered particles is presented. The main topics were: German microgravity program and flight opportunities; user center and assistance; principles of the metallic solidification; supercooling and germ formation; dynamics of the solidification front; dispersion reinforced materials; systems with a miscibility gap in the liquid state; molding solidification; microgravity conditions of a space vehicle; fusion furnaces for Spacelab; electromagnetic fusion process and position research; diffusion and germ formation in glasses.

N90-20239# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Haupabteilung Projekte und Mikrogravitation.
GERMAN MICROGRAVITY PROGRAM AND FLIGHT OPPORTUNITIES [DEUTSCHES MIKROGRAVITATIONSPROGRAMM UND FLUGGELEGENHEITEN]
H. BINNENBRUCK *In its* Center of Gravity: Metallic Solidification p 1-18 Jun. 1989 In GERMAN
Avail: NTIS HC A10/MF A02

A research on weightlessness was carried out covering three themes: the scientific program, the flight program and the program assistance measures. The scientific program is particularly centered on the boundary surface and transfer phenomena (form and stability of capillary surfaces, thermodynamics), the metals and binder materials (fusion, supercooling), the crystals, and the physical chemical and technical questions. The problems of biology, biotechnology and medicine are also examined. Some information about the Columbus shuttle module is given in example. ESA

N90-20240# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Raumsimulation.
USER CENTER AND ASSITANCE [NUTZERZENTRUM UND NUTZERUNTERSTUETZUNG]
K. WITTMANN *In its* Center of Gravity: Metallic Solidification p 19-32 Jun. 1989 In GERMAN
Avail: NTIS HC A10/MF A02

The user center of Cologne (Germany, F.R.) is dedicated to weightlessness experiments in medical, biological, and chemical areas. It is based on the research results that were gathered during the first Spacelab flight. The aims of this center are to facilitate the access to the space experiments, to reduce the costs by efficient utilization of the expensive space experiment time and by the use of concentrated experience. The center works principally for the D2-Spacelab mission and for Eureca, an uninhabited experiment platform of ESA. The structure studies were sufficiently advanced for the preparation phase for these flights to begin by 1987. The future achievement for the space station was flexibly planned, so that the center can be adaptated to the immediate need. ESA

N90-21098*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
COSMIC DUST COLLECTION FACILITY: SCIENTIFIC OBJECTIVES AND PROGRAMMATIC RELATIONS
FRED HOERZ, ed., D. E. BROWNLEE, T. E. BUNCH, D. GROUNDS, E. GRUN, Y. RUMMEL, W. L. QUAIDE, and R. M.

WALKER Mar. 1990 32 p
(NASA-TM-102160; S-602; NAS 1.15:102160) Avail: NTIS HC A03/MF A01 CSCL 22/2

The science objectives are summarized for the Cosmic Dust Collection Facility (CDCF) on Space Station Freedom and these objectives are related to ongoing science programs and mission planning within NASA. The purpose is to illustrate the potential of the CDCF project within the broad context of early solar system sciences that emphasize the study of primitive objects in state-of-the-art analytical and experimental laboratories on Earth. Current knowledge about the sources of cosmic dust and their associated orbital dynamics is examined, and the results are reviewed of modern microanalytical investigations of extraterrestrial dust particles collected on Earth. Major areas of scientific inquiry and uncertainty are identified and it is shown how CDCF will contribute to their solution. General facility and instrument concepts that need to be pursued are introduced, and the major development tasks that are needed to attain the scientific objectives of the CDCF project are identified. Author

N90-24496# University Coll. of North Wales, Bangor. School of Electronic Engineering Science.
PROGRESS IN THE DESIGN OF A MICROGRAVITY FACILITY FOR IN-ORBIT EXPERIMENTS
A. R. OWENS, D. I. JONES, R. G. OWEN, G. ROBERTS, and A. A. ROBINSON (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 229-234 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

Progress in the design of a microgavity isolation mount is described. A design for incorporation within a Columbus orbital replacement rack is presented. Non-contact position sensing and control and non-contact heat removal are essential factors in the design. Solutions to these problems are described. The design relies on the concept of a platform combined with a lock, cage and liner as an integrated design. The design of cooling fins is investigated in great detail. Design of a combined unit of non-salient sensors and actuators is described. ESA

N90-24498# Sira Inst. Ltd., Chislehurst (England).
SHUTTER MECHANISM FOR CONTROLLING THE EXPOSURE OF SAMPLES TO SOLAR RADIATION
W. A. HENTON-JONES *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 241-248 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

A shutter mechanism used to control the amount of exposure of biological specimens to solar ultraviolet radiation is described. The biological specimens are carried aboard the Eureca 1 microgravity mission exobiology and radiation assembly. As the biological samples are installed in the facility shortly before launch, the shutter must be simple to install and check out. The modular approach used in the final design and the principal functional details of the shutter are described. ESA

N90-24499# Sira Inst. Ltd., Chislehurst (England).
MECHANISM FOR DEPLOYMENT AND RETRACTION OF BIOLOGICAL SAMPLES
W. A. HENTON-JONES *In* ESA, Fourth European Space Mechanisms and Tribology Symposium p 249-256 Mar. 1990
Copyright Avail: NTIS HC A14/MF A02

The Exobiology and Radiation Assembly (ERA) carried aboard the Eureca 1 microgavity mission is discussed. A mechanism for exposing biological specimens to solar radiation is described. The spacecraft is Shuttle launched and retrieved. The samples must therefore be safely stowed after exposure. The mechanical aspects of the deployment mechanism are described and shown in diagrammatic and photographic form. Limit switches and the flexible cable link are shown. The influence of thermal considerations in the design process is discussed. ESA

N90-25025# Ruhr Univ., Bochum (Germany, F.R.). Fakultaet fuer Physik und Astronomie.
DIFFERENTIATION OF THREE DIMENSIONAL MODELS OF THE ZODIACAL INTERPLANETARY DUST CLOUD FOR EXPERIMENTS WITH MICROMETEOROIDS DECAY DETECTORS ON THE SPACE STATION Ph.D. Thesis [DIE UNTERSCHEIDUNG DREIDIMENSIONALER MODELLE DER ZODIAKALEN INTERPLANETAREN STAUBWOLKE IM HINBLICK AUF EXPERIMENTE MIT RAUMFAHRZEUGGESTUETZTEN MIKROMETEORITENEINSCHLAGSDETEKTOREN]
BERNHARD KNEISSEL 1988 187 p In GERMAN Sponsored by BMFT
(ETN-90-96488) Avail: NTIS HC A09/MF A01

The spatial distribution of the zodiacal dust is presented as a result of inversion of the radiation or light integrales, and described by models from observations in visible and infrared spectra. The particle concentration and the flux densities are measured and the inclination is infrared, since the micrometeoroid detector Cosmic Dust Facility on the satellite platform space station does not take into account the vectors of the relative velocity. It is shown that all zodiacal particles cut across the ecliptic plane in its trajectory node so that the inclination distribution density can be estimated with consideration of the observation choice effects. ESA

N90-25167*# Texas Univ., Austin. Dept. of Aerospace Engineering.
SPACE STATION BASED MICROACCELERATION EXPERIMENT PLATFORM Final Report
KATY BARBER, TONY ECONOMOPOULOS, ERIK EVENSON, RAUL GONZALEZ, STEVE HENSON, ENRIQUE PARADA, RICK ROBINSON, MIKE SCOTT, and BILL SPOTZ May 1990 104 p (Contract NASW-4435)
(NASA-CR-186659; NAS 1.26:186659) Avail: NTIS HC A06/MF A01 CSCL 22/2

Normal Space Station Freedom activities, such as docking, astronauts' movement, equipment vibrations, and space station reboosts, exert forces on the structure, resulting in static or transient accelerations greater than many microgravity experiments can tolerate. A solution to this problem is to isolate experiments on a separate platform free from such disturbances. The Space Station Based Microacceleration Experiment Platform, a proposed solution to the Space Station microgravity experiment problem is described. It is modular in design and can be telerobotically assembled and operated. The Microacceleration Experiment Platform (MEP) consists of a minimum configuration platform to which power, propulsion, propellant, and experiment modules are added. The platform's layout is designed to take maximum advantage of the microgravity field structure in orbit. Author

N90-27141*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SPACE STATION ATTACHED PAYLOADS
LENWOOD G. CLARK *In its* Earth Sciences Requirements for the Information Sciences Experiment System p 7-20 Jul. 1990
Avail: NTIS HC A10/MF A02 CSCL 22/2

The Space Station Freedom is being designed and developed with user requirements being used to shape the configuration. Plans include accommodation provisions for a wide variety of attached payloads including the Earth sciences research activities which are the focus of this conference. The station program is even beginning some preliminary payload manifesting which involves planning for accommodation of payload during the station's assembly flights. Potential payload organizations should be aware of the station's plans for payload accommodations so as to guide their own payload activities for future space station use. Author

N90-27279*# Arizona Univ., Tucson. AI-Simulation Group.
DEVS-BASED INTELLIGENT CONTROL OF SPACE ADAPTED FLUID MIXING
SUNG-DO CHI and BERNARD P. ZEIGLER *In* NASA, Marshall Space Flight Center, Fifth Conference on Artificial Intelligence for

Space Applications p 25-32 May 1990
(Contract NCC2-525)
Avail: NTIS HC A25/MF A04 CSCL 09/2

The development is described of event-based intelligent control system for a space-adapted mixing process by employing the DEVS (Discrete Event System Specification) formalism. In this control paradigm, the controller expects to receive confirming sensor responses to its control commands within definite time windows determined by its DEVS model of the system under control. The DEVS-based intelligent control paradigm was applied in a space-adapted mixing system capable of supporting the laboratory automation aboard a Space Station. Author

N90-27578*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
RESEARCH OPPORTUNITIES ON THE SPACE STATION
GUY FOGLEMAN *In its* Carbon in the Galaxy: Studies from Earth and Space p 303-308 Apr. 1990
Avail: NTIS HC A15/MF A02 CSCL 03/2

Two interdisciplinary facilities that have been proposed for the Space Station, the Gas-Grain Simulation Facility and the Cosmic Dust Collector Facility, are reviewed. Both of these facilities provide opportunities for scientists interested in carbon related research to perform experiments in earth orbit. Author

20

PLATFORMS & TETHERS

Descriptions and requirements of independent experimental platforms or missions using tethers aboard space stations.

A90-43498
ON THE CONTROL OF SPACE STATION BASED TETHERED SYSTEMS
A. K. MISRA (McGill University, Montreal, Canada), S. KALAYCIOGLU, B. KALAYCIOGLU (Thomson-CSF Systems Canada, Inc., Nepean, Canada), and V. J. MODI (British Columbia, University, Vancouver, Canada) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 157-170.
(AAS PAPER 89-182) Copyright

Prominent among Space Station-based applications of the tether principle is the Tethered Microgravity Facility (MTF), whose g-level variation capability (on the basis of changes in the distance from the system's center-of-mass) will be of use to experimenters in materials, fluid dynamics, and life sciences research. A fundamental developmental requirement for the MTF lies in the field of dynamics and control for multibodied tethered systems; attention is accordingly given to feedforward and feedback control and tension control laws applicable to the three-dimensional attitude dynamics of the MTF, with a view to maintaining its acceleration level. O.C.

A90-46248
DYNAMICS AND CONTROL OF TETHERED SATELLITE SYSTEMS
A. K. MISRA (McGill University, Montreal, Canada) and V. J. MODI (British Columbia, University, Vancouver, Canada) IN: Machinery dynamics - Applications and vibration control problems; Proceedings of the Twelfth Biennial ASME Conference on Mechanical Vibration and Noise, Montreal, Canada, Sept. 17-21, 1989. New York, American Society of Mechanical Engineers, 1989, p. 333-345. refs
Copyright

Emphasizing the vast potential of tethered satellite systems, the paper reviews their dynamics and control during deployment, stationkeeping and retrieval phases. To start with, the studies involving the pre-Shuttle era cable connected system are cited briefly. This is followed by a review of the Shuttle-borne tethered systems in depth. Representative results of dynamics and control available in the literature are also presented considering several deployment and retrieval schemes. Unlike deployment, retrieval of tethered systems is basically unstable making it necessary to use a control system to arrest the growth of rotational and vibrational motions. Control laws used by various investigators are discussed. Also considered are the relatively few dynamical studies associated with tethered platforms, tethered constellations and orbital transfer using a tether. It is recommended that more attention be directed toward this potentially important area. Finally, it is observed that there is a need for experimental validation of the existing dynamical models and control schemes through both ground based and flight experiments. Author

A90-46828
OFFSET CONTROL STRATEGY FOR THE SPACE STATION BASED TETHERED PAYLOAD
V. J. MODI, P. K. LAKSHMANAN (British Columbia, University, Vancouver, Canada), and A. K. MISRA (McGill University, Montreal, Canada) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 1287-1308. refs
(Contract NSERC-5-80029)
(AAS PAPER 89-453) Copyright

Using a ground based experimental facility, the paper demonstrates validity of the mathematical model aimed at studying offset control of an orbiting platform supported tethered satellite system. The mathematical model for the system is discussed first and some representative control data presented. This is followed by a description of the ground based experimental simulation involving controller, actuator and sensors used in the test program. Results confirm effectiveness of the offset control strategy during both the stationkeeping and retrieval phases. Author

A90-46829
EFFECTS OF DEPLOYMENT SCHEMES AND OUT-OF-PLANE LIBRATIONS ON TETHERED PAYLOAD RAISING
K. KUMAR, A. K. MISRA (Indian Institute of Technology, Kanpur, India), and RAJEEVA KUMAR IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 1309-1325. refs
(AAS PAPER 89-454) Copyright

Raising a payload by deploying it from an orbiter on a long tether and then releasing it represents a rather important application involving significant fuel economy. The effects of various deployment schemes as well as out-of-plane librations on tethered payload raising are systematically studied. Equations of motion have been obtained for a general two-body dumb-bell tethered system in an elliptic orbit executing the three-dimensional librational motion. This analysis accounts for the tether mass as well. Contrary to the observations made by Kyroudis and Conway, an increase in deployment rate does not lead to a monotonic increase in apogee altitude of the payload at release. Typical plots of the altitude gain vs deployment rate are presented showing widely differing and separated 'peaks' and 'valleys'. These could be used to select the optimum deployment scheme for raising payloads to higher altitudes. Finally, attention is focused on the effect of roll motion on the resulting change of orbital plane. Author

A90-46830
ELASTIC OSCILLATIONS OF LONG TETHER-TYPE STRUCTURES USED FOR PROPELLANT TRANSFER
A. EL CHEBAIR (Universite Laval, Sainte Foy, Canada) and A. K. MISRA (McGill University, Montreal, Canada) IN: Astrodynamics 1989; Proceedings of the AAS/AIAA Astrodynamics Conference, Stowe, VT, Aug. 7-10, 1989. Part 2. San Diego, CA, Univelt, Inc., 1990, p. 1327-1340. refs
(AAS PAPER 89-455) Copyright

This paper presents a theoretical study of the transverse elastic oscillations of a tether conveying fluid in space between two stations. The fluid is assumed to be incompressible and inviscid.

Tether motions are described by beam theory; however, the bending rigidity of the tether is small and is neglected in the final analysis. Galerkin's method has been used in formulating the problem. It is found that the frequencies associated with the axial modes decrease as the flow velocity is increased, and the system loses stability by divergence (buckling) in its first axial mode. Author

A90-47643#
COLUMBUS GUIDANCE, NAVIGATION AND CONTROL REQUIREMENTS
C. J. REIMERS (ESTEC, Noordwijk, Netherlands) IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 661-666.
(AIAA PAPER 90-3388) Copyright

The guidance, navigation, and control (GNC) system requirements for the ESA Columbus spacecraft are reviewed. The history, aims, and organization of the Columbus program are recalled, and the major Columbus components briefly characterized, including the Attached Laboratory, the Free Flying Laboratory (FFL), the Polar Platform, Eureca, and Hermes. Particular attention is then given to stages of the FFL mission scenario imposing specific demands on the GNC systems (launch, operational phase, servicing by Hermes, and controlled destructive deorbiting). Drawings, diagrams, and photographs are provided. T.K.

A90-47711#
NONLINEAR FEEDBACK DEPLOYMENT AND RETRIEVAL OF TETHERED SATELLITE SYSTEMS
SRINIVAS R. VADALI (Texas A & M University, College Station) and EUISOK KIM IN: AIAA Guidance, Navigation and Control Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 1304-1312. Research supported by Texas Advanced Research and Technology Program. refs
(AIAA PAPER 90-3460) Copyright

The Liapunov approach for controller design is applied to the tethered subsatellite deployment and retrieval problem. The tether dynamic model includes tether mass as well as in-plane and out-of-plane librations. The nonlinear feedback tension control law developed guarantees stability of the closed loop system and is used in combination with out-of-plane thrusting during retrieval. Simulation results show the tension and the combined tension and thruster control laws perform well for deployment and retrieval respectively even when aerodynamic drag is considered. Author

A90-48976
INTERNATIONAL CONFERENCE ON TETHERS IN SPACE - TOWARD FLIGHT, 3RD, SAN FRANCISCO, CA, MAY 17-19, 1989, ADDITIONAL CONFERENCE PRESENTATIONS
Conference sponsored by AIAA, NASA, ASI, and ESA. Arlington, VA, SRS Technologies, 1989, 250 p. For individual items see A90-48977 to A90-48981.

Recent advances in the technology and applications of tethered spacecraft are discussed in reviews and reports. Topics addressed include Italian (ASI) and ESA tether programs, NASA/ASI flight demonstrations of tether systems, a high-current plasma-contactor neutralizer system, theoretical and experimental studies of plasma contactor clouds, and a satellite-tethered upper-atmospheric research facility. Consideration is given to passive tethered-satellite retrieval, the use of the Spider robot manipulator in conjuction with the Tethered Satellite System (TSS), spatial processing to improve the detection of tether EM radiation, the payload-operation control center for TSS science experiments, and the development of a tether deployment monitoring system. T.K.

A90-53031#
IN-PLANE AND OUT-OF-PLANE ROTATIONAL DYNAMICS AND CONTROL OF THREE BODY TETHERED SYSTEM
A. EL CHEBAIR, M. RICHARD (Universite Laval, Sainte Foy, Canada), A. K. MISRA (McGill University, Montreal, Canada), and N. BEN SALAH IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 698-703. refs
(AIAA PAPER 90-2948) Copyright

The dynamics and control of three-body tethered systems are presented. Both in-plane and out-of-plane rotational motions are analyzed and the effect of tether length oscillations (in the station keeping situation) on the dynamics of the system is considered. A Lagrangian procedure is used to derive the equations of motion, which are linearized and put in the state-space form. It is determined that, for a small oscillation in the tether length around an equilibrium configuration, the system might become unstable. Therefore, in order to render the system stable, a tether control law is proposed. To arrive at the desired system performance, the weighting matrices are adjusted to provide control law gains. Finally, the nonlinear and coupled differential equations are numerically integrated to investigate the nonlinear response to various control and disturbance inputs when the system is in the station keeping operation. R.E.P.

A90-53049#
NEWTONIAN DERIVATION OF THE EQUATIONS OF MOTION FOR A TETHERED SATELLITE SYSTEM
KENNETH D. KOPKE, LELAND E. HERDER, CYNTHIA L. TROWBRIDGE, and THOMAS J. ELLER (Kaman Sciences Corp., Colorado Springs, CO) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 875-887. refs
(Contract F05603-87-C-0001)
(AIAA PAPER 90-2989) Copyright

This paper applies Newton's laws to derive differential equations (in rectangular coordinates) which describe the three-dimensional orbital motion of two point masses connected by a massless tether, and under the influence of any selected external forces. Similar techniques may be employed for systems of more than two masses. Equilibrium points are analyzed. It is shown that, in general, the system center of mass does not follow Keplerian motion. Deployment, retrieval, and elastic tethers are discussed; energy and momentum integrals are derived. Author

N90-22594# Howard Univ., Washington, DC. School of Engineering.
DYNAMICS AND CONTROL OF TETHERED ANTENNAS/REFLECTORS IN ORBIT Annual Report, 1 Nov. 1988 - 31 Oct. 1989
PETER M. BAINUM Dec. 1989 86 p
(Contract F49620-89-C-0002; AF PROJ. 2302)
(AD-A219316) Avail: NTIS HC A05/MF A01 CSCL 09/1

A study is conducted of the dynamics and control of a class of large antenna/reflector systems in orbit which are also partially stabilized using a tether connected subsatellite. The system equations of motion are developed and linearized about the equilibrium position where the reflector's (shell's) symmetry axis nominally follows the local vertical. The shell roll, yaw, tether out-of-plane swing motion and out-of-plane elastic vibrations are decoupled from the shell and tether in-plane pitch motions and in-plane elastic vibrations. The in-plane motion of the system could be asymptotically stable based on Rupp's tether tension control law using only length and length rate information. However, the transient responses can be improved significantly by using an optimal tension feedback control law. When tether flexibility is included, the system dynamics could be further improved by including the state feedback of the tether vibrational modes into the tension control law. GRA

N90-24297# Aeritalia S.p.A., Turin (Italy). Space Systems Group.
PERSPECTIVE FEATURES OF INTERNAL AUTOMATION AND ROBOTICS FOR SUPPORTING COLUMBUS ATTACHED LABORATORY PAYLOAD OPERATIONS
MARIO CARDANO, MARIA STELLA LAVITOLA, IGNAZIO BARRACO, and MARC TOUSSAINT (European Space Agency,

Paris, France) *In* ESA, Second European In-Orbit Operations Technology Symposium p 99-112 Dec. 1989
Copyright Avail: NTIS HC A19/MF A03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 80 Dutch guilders

A payload operations simulation exercise was carried out in the frame of the ESA rider study on Robotics Spacecraft Servicing and Assembly (ROSSA), aimed at analyzing the perspective scenarios and relevance for internal automation and robotics support to the Columbus Attached Laboratory payload mission. Detailed flight operations sequences were generated and analyzed for a set of pressurized payload elements. The preliminary results show that many opportunities for supporting crew activities with internal automation and robotics exist, but internal automation and robotics for some tasks may not be trivial. Additional requirement reviews and preparation activities will lead to the identification of promising concepts to be further investigated in the frame of automation and robotics ground testbed activities. ESA

N90-25166*# Texas Univ., Austin. Dept. of Aerospace Engineering and Engineering Mechanics.
AN EARTH ORBITING SATELLITE SERVICE AND REPAIR FACILITY Final Design Report
ANDREW BERNDT, MIKE CARDOZA, JOHN CHEN, GUNTER DALEY, ANDY FRIZZELL, RICHARD LINTON, and WAYNE RAST 15 Dec. 1989 140 p
(Contract NASW-4435)
(NASA-CR-186669; NAS 1.26:186669) Avail: NTIS HC A07/MF A01 CSCL 22/2

A conceptual design was produced for the Geosynchronous Satellite Servicing Platform (GSSP), an orbital facility capable of repairing and servicing satellites in geosynchronous orbit. The GSSP is a man-tended platform, which consists of a habitation module, operations module, service bay and truss assembly. This design review includes an analysis of life support systems, thermal and power requirements, robotic and automated systems, control methods and navigation, and communications systems. The GSSP will utilize existing technology available at the time of construction, focusing mainly on modifying and integrating existing systems. The entire facility, along with two satellite retrieval vehicles (SRV), will be placed in geosynchronous orbit by the Advanced Launch System. The SRV will be used to ferry satellites to and from the GSSP. Technicians will be transferred from Earth to the GSSP and back in an Apollo-derived Crew Transfer Capsule (CTC). These missions will use advanced telerobotic equipment to inspect and service satellites. Four of these missions are tentatively scheduled per year. At this rate, the GSSP will service over 650 satelites during the projected 25 year lifespan. Author

N90-25416# European Space Agency. ESRIN, Frascati (Italy). Earthnet Programme Office.
FUTURE DEVELOPMENTS OF REMOTE SENSING SYSTEMS: DATA MANAGEMENT AND PROCESSING
LUIGI FUSCO *In its* Remote Sensing and the Earth's Environment p 151-158 Mar. 1990
Copyright Avail: NTIS HC A08/MF A01; also available from EPB, ESTEC, Noordwijk, Netherlands, 40 Dutch guilders

The status of remote sensing data management, with particular emphasis on the ESA Earthnet program is presented. Plans for handling the data from ERS-1 are outlined. The planned international contribution to the Space Station Polar Platforms systems is described. Details of the NASA and ESA plans for polar platforms data management and the international coordination of efforts are presented. Comparison of data handling aspects are made to illustrate the increased complexity of the systems. ESA

N90-26059# Aeritalia S.p.A., Turin (Italy). Space Systems Group.
PERSPECTIVE FEATURES OF THE TETHERED SYSTEMS FOR SPACE APPLICATIONS
CARLO BUONGIORNO (Italian Space Agency, Rome.) and ERNESTO VALLERANI 1989 13 p Previously announced in IAA as A90-13249
(ETN-90-97279) Avail: NTIS HC A03/MF A01

Some of the possible new applications beyond the tethered missions already manifested are reviewed. Particular emphasis is given to the International Space Station Scenario. Applications of the tethered systems as supporting tools in the field of the reentry technology research are addressed. A tethered system deployed from the Space Station provides a cleaner and safer environment for particularly sensitive experiments. The management of the Station center of gravity, by controlling its vertical position at low frequencies or in DC mode, allow the minimization of the microgravity levels within the laboratory module. The choice of the characteristics of the tethered system can improve the performance of the Station attitude control system by augmenting the stabilizing effect. ESA

N90-27770*# National Aeronautics and Space Administration, Washington, DC.
FLIGHT MECHANICS APPLICATIONS FOR TETHERS IN SPACE: COOPERATIVE ITALIAN-US PROGRAMS
FRANCO BEVILACQUA, PIETRO MERLINA (Aeritalia S.p.A., Turin, Italy), and JOHN L. ANDERSON *In* AGARD, Space Vehicle Flight Mechanics 12 p Jun. 1990
Copyright Avail: NTIS HC A21/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 22/2

Since the 1974 proposal by Giuseppe Colombo to fly a tethered subsatellite from the Shuttle Orbiter, the creative thinking of many scientists and engineers from Italy and U.S. has generated a broad range of potential tether applications in space. Many of these applications have promise for enabling innovative research and operational activities relating to flight mechanics in earth orbit and at suborbital altitudes. From a flight mechanics standpoint the most interesting of the currently proposed flight demonstrations are: the second Tethered Satellite System experiment which offers both the potential for aerothermodynamics and hypersonics research and for atmospheric science research; the Tethered Initiated Space Recovery System which would enable orbital deboost and recovery of a re-entry vehicle and waste removal from a space station; and the Tether Elevator/Crawler System which would provide a variable microgravity environment and space station center of mass management. The outer atmospheric and orbital flight mechanics characteristics of these proposed tether flight demonstrations are described. The second Tethered Satellite System mission will deploy the tethered satellite earthward and will bring it as low as 130 km from ground and thus into the transition region between the atmosphere (non-ionized) and the partially ionized ionosphere. The atmospheric flight mechanics of the tethered satellite is discussed and simulation results are presented. The Tether Initiated Space Recovery System experiment will demonstrate the ability of a simple tether system to deboost and recover a reentry vehicle. The main feature of this demonstration is the utilization of a Small Expendable Deployment System (SEDS) and the low-tension deployment assumed to separate the reentry vehicle from the Shuttle. This low-tension deployment maneuver is discussed and its criticalities are outlined. The Tether Elevator/Crawler System is a new space element able to move in a controlled way between the ends of a deployed tethered system. A Shuttle test of an Elevator model is planned to demonstrate the unique capability of this element as a microgravity facility and to test the transfer motion control. The basic dynamical features of the Elevator system are presented and a preliminary assessment of the Elevator-induced tether vibrations is discussed. Author

N90-29844*# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
CONCEPT SYNTHESIS OF AN EQUIPMENT MANIPULATION AND TRANSPORTATION SYSTEM EMATS
W. DEPEUTER and E. WAFFENSCHMIDT (Dornier-Werke G.m.b.H., Friedrichshafen, Germany, F.R.) *In* JPL, California

Inst. of Tech., Proceedings of the NASA Conference on Space Telerobotics, Volume 4 p 135-143 31 Jan. 1989
Avail: NTIS HC A19/MF A03 CSCL 05/8

The European Columbus Scenario is established. One of the Columbus Elements, the Man Tended Free Flyer will be designed for fully autonomous operation in order to provide the environment for micro gravity facilities. The Concept of an autonomous automation system which perform servicing of facilities and deals with related logistic tasks is discussed. Author

21

TRANSPORTATION NODE

Use of the space station as a node for the launching, assembly or support of lunar or other exploratory missions.

A90-33149* National Aeronautics and Space Administration, Washington, DC.
SOLAR SYSTEM EXPLORATION - SOME THOUGHTS ON TECHNIQUES AND TECHNOLOGIES
IVAN BEKEY (NASA, Office of Exploration, Washington, DC) Planetary Report (ISSN 0736-3680), vol. 10, Mar.-Apr. 1990, p. 6-11.
Copyright

Some techniques and technologies for proposed interplanetary missions are described. Methods for reducing the effect of zero gravity on humans during missions to Mars and the moon, and the need for launch vehicles with increased lift capability are discussed. The use of nuclear power, liquid oxygen from the moon, and helium 3 as propellants for spacecraft is examined. The development and capabilities of the Shuttle Z vehicle are considered. Attention is given to the Space Station Freedom and Energia. A launch vehicle concept which utilizes the Shuttle Z for a mission to Mars is presented. I.F.

A90-36012*# General Dynamics Corp., Huntsville, AL.
A COMPARISON OF TRANSPORTATION NODE COSTS AND THEIR PRIMARY DRIVERS
DOUGLAS A. COMSTOCK (General Dynamics Corp., Space Systems Div., Huntsville, AL), KYLE M. SHEPARD, and JACK M. YOUNGS (General Dynamics Corp., Space Systems Div., San Diego, CA) IAA, Symposium on Space Systems Cost Estimation Methodologies and Applications, San Diego, CA, May 10, 11, 1990, Paper. 16 p. refs
(Contract NAS8-37588)

This paper describes the process for defining and evaluating the costs of alternative transportation node concepts for Space Station Freedom. A cost estimating methodology including costs of development, production, delivery, assembly, steady state operations, and mission-specific operations is described in detail. The primary drivers of transportation node costs are identified and discussed. C.D.

A90-43465* 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 (NASA, Langley Research Center, Hampton, VA) IN: The 21st century in space; Proceedings of the Thirty-fifth Annual AAS Conference, Saint Louis, MO, Oct. 24-26, 1988. San Diego, CA, Univelt, Inc., 1990, p. 75-92. refs
(AAS PAPER 88-167) Copyright

This paper presents preliminary results of studies currently being conducted by NASA for constructing very large spacecraft. The paper discusses the various approaches for constructing spacecraft and their relative merits. As currently planned, Space Station Freedom has incorporated all of the basic design characteristics to permit its growth into an in-space construction facility for very large spacecraft. If disturbances from construction operations are intolerable to other experiments on Space Station Freedom, a co-orbiting construction facility could be built using truss hardware and systems previously for developed Space Station Freedom. The new PATHFINDER research initiative for on-orbit assembly and construction is also discussed. 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

A90-43500* Boeing Aerospace Co., Huntsville, AL.
EARTH ORBITAL OPERATIONS SUPPORTING MANNED INTERPLANETARY MISSIONS
BRENT SHERWOOD, PATRICIA A. BUDDINGTON (Boeing Aerospace, Huntsville, AL), and WILLIAM L. WHITTAKER (RedZone Robotics, Inc., Pittsburgh, PA) IN: Orbital mechanics and mission design; Proceedings of the AAS/NASA International Symposium, Greenbelt, MD, Apr. 24-27, 1989. San Diego, CA, Univelt, Inc., 1989, p. 191-207.
(Contract NAS2-12108)
(AAS PAPER 89-184) Copyright

The orbital operations required to accumulate, assemble, test, verify, maintain, and launch complex manned space systems on interplanetary missions from earth orbit are as vital as the flight hardware itself. Vast numbers of orbital crew are neither necessary nor desirable for accomplishing the required tasks. A suite of robotic techniques under human supervisory control, relying on sensors, software and manipulators either currently emergent or already applied in terrestrial settings, can make the job tractable. The mission vehicle becomes largely self-assembling, using its own rigid aerobrake as a work platform. The Space Station, having been used as a laboratory testbed and to house an assembly crew of four, is not dominated by the process. A feasible development schedule, if begun soon, could emplace orbital support technologies for exploration missions in time for a 2004 first interplanetary launch. Author

A90-52624
THE MARS TRANSIT SYSTEM
BUZZ ALDRIN Air and Space (ISSN 0886-2257), vol. 5, Oct.-Nov. 1990, p. 40-47.
Copyright

Reusable spacecraft, called 'Cyclers', permanently cycling on gravity-assisted trajectories between the orbits of the earth and Mars and providing support for manned trips to Mars, are discussed. The idea is then expanded into a concept of a relatively inexpensive and reusable Mars transportation system relying on permanent orbital facilities and a series of smaller spacecraft to transfer crew members to and from these spacecraft and the planets. The system in effect creates a new economic and philosophic approach to the Mars mission. B.P.

A90-53004*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ASTEROID MISSION DEPARTURE STRATEGIES FROM A PRECESSING SPACE STATION ORBIT
JAYANT SHARMA (JPL, Pasadena, CA) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 479-487. refs
(AIAA PAPER 90-2913) Copyright

In using the Space Station as a point of departure for interplanetary missions, the precission of its orbit complicates the process of determining the available departure period. The constantly changing ascending node of the Space Station orbit defines the departure geometry. Severe Delta V penalties occur if favorable departure opportunities are missed and a plane change is required at departure. This paper compares two strategies to reduce the cost of the plane change maneuver, and increase the available departure opportunities. A 3-impulse injection strategy is compared to a deep space plane change for two asteroid rendezvous missions. Results indicate that the deep space plane change strategy has lower propellant mass requirements for the

two missions studied. The difference in propellant requirements for the two strategies is a function of the departure geometry.
Author

A90-53009*# Science Applications International Corp., Schaumburg, IL.
LAUNCHING LUNAR MISSIONS FROM SPACE STATION FREEDOM
ALAN FRIEDLANDER (Science Applications International Corp., Schaumburg, IL) and ARCHIE YOUNG (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA/AAS Astrodynamics Conference, Portland, OR, Aug. 20-22, 1990, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1990, p. 525-529.
(AIAA PAPER 90-2938) Copyright

The relative orbital motion of Space Station Freedom and the moon places practical constraints on the timing of launch/return transfer trajectories. This paper describes the timing characteristics as well as the Delta-V variations over a representative cycle of launch/return opportunities. On average, the minimum-Delta-V transfer opportunities occur at intervals of 9 days. However, there is a significant nonuniform variation in this timing interval, as well as the minimum stay time at the moon, over the short cycle (51 days) and the long cycle (18.6 years). The advantage of three-impulse transfers for extending the launch window is also described.
Author

N90-25164*# Washington Univ., Seattle. Dept. of Aeronautics and Astronautics.
ADVANCED SOLAR-PROPELLED CARGO SPACECRAFT FOR MARS MISSIONS Final Report
JACQUELINE AUZIASDETURENNE, MARK BEALL, JOSEPH BURIANEK, ANNA CINNIGER, BARBRINA DUNMIRE, ERIC HABERMAN, JAMES IWAMOTO, STEPHEN JOHNSON, SHAWN MCCRACKEN, MELANIE MILLER et al. 9 Jun. 1989 297 p
(Contract NASW-4435)
(NASA-CR-186218; NAS 1.26:186218) Avail: NTIS HC A13/MF A02 CSCL 22/2

Three concepts for an unmanned, solar powered, cargo spacecraft for Mars support missions were investigated. These spacecraft are designed to carry a 50,000 kg payload from a low Earth orbit to a low Mars orbit. Each design uses a distinctly different propulsion system: A Solar Radiation Absorption (SRA) system, a Solar-Pumped Laser (SPL) system and a solar powered magnetoplasmadynamic (MPD) arc system. The SRA directly converts solar energy to thermal energy in the propellant through a novel process. In the SPL system, a pair of solar-pumped, multi-megawatt, CO2 lasers in sunsynchronous Earth orbit converts solar energy to laser energy. The MPD system used indium phosphide solar cells to convert sunlight to electricity, which powers the propulsion system. Various orbital transfer options are examined for these concepts. In the SRA system, the mother ship transfers the payload into a very high Earth orbit and a small auxiliary propulsion system boosts the payload into a Hohmann transfer to Mars. The SPL spacecraft and the SPL powered spacecraft return to Earth for subsequent missions. The MPD propelled spacecraft, however, remains at Mars as an orbiting space station. A patched conic approximation was used to determine a heliocentric interplanetary transfer orbit for the MPD propelled spacecraft. All three solar-powered spacecraft use an aerobrake procedure to place the payload into a low Mars parking orbit. The payload delivery times range from 160 days to 873 days (2.39 years).
Author

N90-25921*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ASSEMBLY VS. DIRECT LAUNCH OF TRANSFER VEHICLES
STEPHEN J. KATZBERG and E. BRIAN PRITCHARD Jun. 1990 22 p
(NASA-TM-102686; NAS 1.15:102686) Avail: NTIS HC A03/MF A01 CSCL 03/2

A top level assessment is performed of the relative impacts of on-orbit assembly of the lunar or Mars transfer vehicles versus direct launch. The objective is to identify the major option paths for the Earth-to-orbit, ETO, transportation systems. Heavy lift launch vehicles, if large enough, could reduce or eliminate on-orbit assembly. However, with every new approach, there are always counter-balancing considerations and it is the objective to begin the delineation of the necessary follow-on trade study issues.
Author

N90-26026*# Maryland Univ., College Park. Dept. of Aerospace Engineering.
PROJECT EXODUS Final Report, 23 Jan. - 14 May 1990
RODNEY BRYANT, comp. and ed., JENNIFER DILLON, comp. and ed., GEORGE GREWE, comp. and ed., JIM MCMORROW, comp. and ed., CRAIG MELTON, comp. and ed., GERALD RAINEY, comp. and ed., JOHN RINKO, comp. and ed., DAVID SINGH, comp. and ed., and TZU-LIANG YEN, comp. and ed. May 1990 200 p
(Contract NGT-21-002-800)
(NASA-CR-186836; NAS 1.26:186836; ENAE-412; UM-AERO-90-28) Avail: NTIS HC A09/MF A02 CSCL 22/1

A design for a manned Mars mission, PROJECT EXODUS is presented. PROJECT EXODUS incorporates the design of a hypersonic waverider, cargo ship and NIMF (nuclear rocket using indigenous Martian fuel) shuttle lander to safely carry out a three to five month mission on the surface of Mars. The cargo ship transports return fuel, return engine, surface life support, NIMF shuttle, and the Mars base to low Mars orbit (LMO). The cargo ship is powered by a nuclear electric propulsion (NEP) system which allows the cargo ship to execute a spiral trajectory to Mars. The waverider transports ten astronauts to Mars and back. It is launched from the Space Station with propulsion provided by a chemical engine and a delta velocity of 9 km/sec. The waverider performs an aero-gravity assist maneuver through the atmosphere of Venus to obtain a deflection angle and increase in delta velocity. Once the waverider and cargo ship have docked the astronauts will detach the landing cargo capsules and nuclear electric power plant and remotely pilot them to the surface. They will then descend to the surface aboard the NIMF shuttle. A dome base will be quickly constructed on the surface and the astronauts will conduct an exploratory mission for three to five months. They will return to Earth and dock with the Space Station using the waverider.
Author

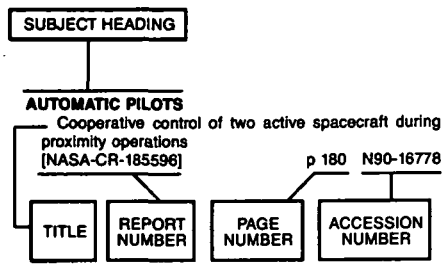
N90-26052*# Minnesota Univ., Minneapolis. Dept. of Aerospace Engineering and Mechanics.
BICONIC CARGO RETURN VEHICLE WITH AN ADVANCED RECOVERY SYSTEM. VOLUME 1: CONCEPTUAL DESIGN NASA/USRA Advanced Design Project
2 Jun. 1990 231 p
(Contract NGT-21-002-800)
(NASA-CR-186520; NAS 1.26:186520) Avail: NTIS HC A11/MF A02 CSCL 22/2

The conceptual design of the biconic Cargo Return Vehicle (CRV) is presented. The CRV will be able to meet all of the Space Station Freedom (SSF's) resupply needs. Worth note is the absence of a backup recovery chute in case of Advanced Recovery System (ARS) failure. The high reliability of ram-air parachutes does not warrant the penalty weight that such a system would create on successful missions. The CRV will launch vertically integrated with an Liquid Rocket Booster (LRB) vehicle and meets all NASA restrictions on fuel type for all phases of the mission. Because of the downscaled Orbital Maneuvering Vehicle (OMV) program, the CRV has been designed to be able to transfer cargo by docking directly to the Space Station Freedom as well as with OMV assistance. The CRV will cover enough crossrange to reach its primary landing site, Edwards Airforce Base, and all secondary landing sites with the exception of one orbit. Transportation back to KSC will be via the Boeing Super Guppy. Due to difficulties with man-rating the CRV, it will not be used in a CERV role. A brief summary of the CRV's specifications is given.
Author

LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA / *A Bibliography (Supplement 02)*

MAY 1991

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 document content, a title extension is added, separated from the title by three hyphens. The 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.

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

SPACE STORAGE

SPACE SUITS

SPACE SURVEILLANCE (GROUND BASED)

SPACE SURVEILLANCE (SPACEBORNE)

SPACE TOOLS

SPACE TRANSPORTATION

T

U

V

W

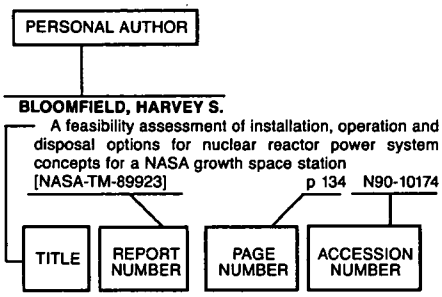
X

Z

LARGE SPACE STRUCTURES AND SYSTEMS
IN THE SPACE STATION ERA / *A Bibliography (Supplement 02)*

MAY 1991

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.

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

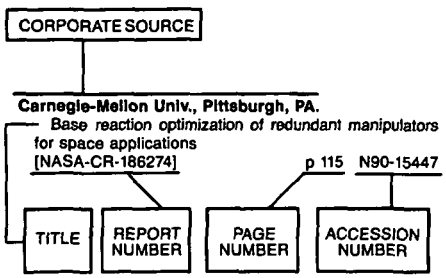
X

Y

Z

LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA / A Bibliography (Supplement 02)

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.

A

Academy of Sciences (USSR), Moscow.
MIR: A Soviet Space Station. Some legal aspects of international cooperation p 9 N90-26715

Acurex Corp., Mountain View, CA.
Conceptual design of a self-deployable, high performance parabolic concentrator for advanced solar-dynamic power systems p 43 A90-38162

Advanced Decision Systems, Mountain View, CA.
The astronaut and the banana peel: An EVA retriever *scenario* p 98 N90-29897

Advanced Research and Applications Corp., Sunnyvale, CA.
Radiation and thermal effects on the time-dependent response of T300/934 graphite/epoxy p 33 A90-31582

Aeritalia S.p.A., Turin (Italy).
Perspective features of internal automation and robotics for supporting Columbus attached laboratory payload operations p 191 N90-24297
Some remarks on a hinge actuator for large spot antenna arm deployers p 49 N90-24486
Long cycle pressurized logistics module: An Italian contribution to the Space Station Freedom logistics *scenario*
[IAF-89-083] p 50 N90-26058
Perspective features of the tethered systems for space *applications*
[ETN-90-97279] p 192 N90-26059
A new method for a tethered system aided space station assembly p 97 N90-27765

Aerospace Corp., El Segundo, CA.
The effect of mechanical deformation on the radiation patterns of large space-based arrays
[AD-A219288] p 77 N90-22719
Performance constraints and compensation for teleoperation with delay p 114 N90-29881

Aerospatiale, Cannes (France).
Wearing of cryomechanisms at 4 K p 119 N90-24476
Mechanisms to assemble space structures in extravehicular environment p 95 N90-24480
ADELE: Deployment hinge using wraparound strips p 49 *N90-24485*

Aerospatiale, Les Mureaux (France).
Possible solutions p 10 N90-26726

Aerospatiale Aquitaine, Saint-Medard en Jalles (France).
Study and sizing of bonded joints in space structures
[REPT-892-430-124] p 48 N90-22591

Air Force Aero Propulsion Lab., Wright-Patterson AFB, OH.
Solar array automation limitations p 143 N90-25513

Air Force Astronautics Lab., Edwards AFB, CA.
Thermal effects on fiber optic strain sensors embedded in graphite-epoxy composites p 34 A90-32894
Initial operational capability of the ASTREX large space structures test bed p 76 N90-21091

Air Force Geophysics Lab., Hanscom AFB, MA.
Photovoltaic array space power plus diagnostics *experiment* p 143 N90-25559
Laboratory study of ion-neutral collisions at suprathermal energies
[AD-A222117] p 31 N90-27475

Air Force Inst. of Tech., Wright-Patterson AFB, OH.
Discrete-time control of a spacecraft with retargetable flexible antennas
[AD-A218345] p 72 N90-20125
Analysis of the use of a methane propellant in a biowaste resistojet
[AD-A220475] p 181 N90-23473
Statistical techniques for designing a decoupled *controller to be robust to model and sensor noise*
[AD-A220476] p 84 N90-23745
Integrated structural/control design via multiobjective *optimization*
[AD-A223088] p 87 N90-27459

Air Force Office of Scientific Research, Bolling AFB, Washington, DC.
AX-5 space suit reliability model
[SAE PAPER 901361] p 91 A90-49394

Air Force Systems Command, Hanscom AFB, MA.
Spacecraft contamination programs within the Air Force Systems Command Laboratories p 40 N90-25507

Air Force Systems Command, Wright-Patterson AFB, OH.
SDIO robotics in space applications p 107 N90-25514

Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.
Optimization of the structural and control system for LSS with reduced-order model p 74 N90-21075
Space truss zero gravity dynamics p 46 N90-21087
In-house experiments in large space structures at the Air Force Wright Aeronautical Laboratories Flight Dynamics Laboratory p 76 N90-21092

Air Force Wright Research and Development Center, Wright-Patterson AFB, OH.
Implementation of generalized optimality criteria in a multidisciplinary environment p 48 N90-23048

Alabama A & M Univ., Normal.
A proposal to demonstrate production of salad crops in the space station mockup facility with particular attention *to space, energy, and labor constraints*
[NASA-CR-186811] p 166 N90-25500

Alabama Univ., Huntsville.
Exterior spacecraft subsystem protective shielding analysis and design p 42 A90-36189
Low-gravity electrodeposition of metals and metal/cermet composites p 183 A90-47107
Human subjects concerns in ground based ECLSS testing - Managing uncertainty in closely recycled systems
[SAE PAPER 901251] p 158 A90-49320
Low-gravity experiment sensitivity to residual acceleration - A review p 188 A90-51659
Effective techniques for the identification and accommodation of disturbances p 73 N90-21072
Space station contamination study: Assessment of contaminant spectral brightness
[NASA-CR-186173] p 28 N90-25169
Literature concerning control and display technology applicable to the Orbital Maneuvering Vehicle (OMV)
[NASA-CR-186790] p 152 N90-26048
Establishing a communications-intensive network to resolve artificial intelligence issues within NASA's Space Station Freedom research centers community p 17 N90-27291
Definition of a near real time microbiological monitor for space vehicles
[NASA-CR-185599] p 169 N90-29430

Allied-Signal Aerospace Co., Des Plaines, IL.
Characterization of metal oxide absorbents for regenerative carbon dioxide and water vapor removal for advanced portable life support systems
[SAE PAPER 901431] p 92 A90-49432

Allied-Signal Aerospace Co., Torrance, CA.
Characterization of metal oxide absorbents for *regenerative carbon dioxide and water vapor removal* for advanced portable life support systems
[SAE PAPER 901431] p 92 A90-49432
An air bearing fan for EVA suit ventilation
[SAE PAPER 901432] p 92 A90-49433

Analex Corp., Cleveland, OH.
Control/structure interactions of Freedom's solar dynamic modules
[AIAA PAPER 90-3323] p 64 A90-47585
Space Station Freedom electric power system availability study
[NASA-CR-185181] p 139 N90-20120

Analex Corp., Fairview Park, OH.
Development and refinement of test bed simulations p 131 A90-38081

Analytical Mechanics Associates, Inc., Hampton, VA.
Predicted torque equilibrium attitude utilization for Space Station attitude control
[AIAA PAPER 90-3318] p 63 A90-47580

Applied Dynamics International, Ann Arbor, MI.
A new second-order integration algorithm for simulating mechanical dynamic systems p 81 N90-23064

Arinc Research Corp., Annapolis, MD.
Space Station Freedom power - A reliability, availability, and maintainability assessment of the proposed Space Station Freedom electric power system p 130 A90-38074
Space Station Freedom electric power system availability study
[NASA-CR-185181] p 139 N90-20120

Arizona State Univ., Tempe.
Robust H(infinity) control design for the Space Station with structured parameter uncertainty
[AIAA PAPER 90-3319] p 63 A90-47581
Active control synthesis for flexible space structures excited by persistent disturbances
[AIAA PAPER 90-3427] p 66 A90-47681

Arizona Univ., Tucson.
Systematic generation of multibody equations of motion suitable for recursive and parallel manipulation p 78 N90-22992
Autonomous space processor for orbital debris
[NASA-CR-186691] p 30 N90-26044
DEVS-based intelligent control of space adapted fluid mixing p 189 N90-27279

Armstrong State Coll., Savannah, GA.
Effect of low air velocities on thermal homeostasis and comfort during exercise at space station operational temperature and humidity p 165 N90-24975

Army Armament Research, Development and Engineering Center, Picatinny Arsenal, NJ.
Tip-position control of a flexible beam: Modeling *approaches and experimental verification*
[AD-A224249] p 89 N90-29643

AS&M, Inc., Hampton, VA.
Thermal effects on fiber optic strain sensors embedded in graphite-epoxy composites p 34 A90-32894

Astro Aerospace Corp., Carpinteria, CA.
Structures for remotely deployable precision antennas
[NASA-CR-182065] p 50 N90-26061

Auburn Univ., AL.
Power flow for spacecraft power systems p 128 A90-38054
Harmonic analysis of spacecraft power systems using a personal computer p 128 A90-38055

SOURCE

B

C

D

E

F

G

H

I

J

K

L

M

O

P

R

S

T

U

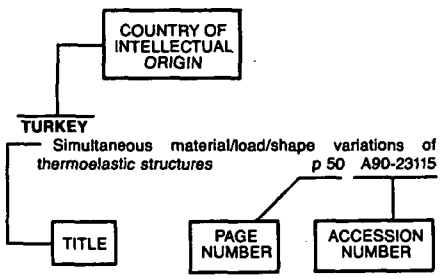
V

W

LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA / *A Bibliography (Supplement 02)*

MAY 1991

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. If applicable, a report number is also included as an aid in identifying the document.

A

ARGENTINA
Numerical simulation in the deployment of space structures p 89 A90-32344

B

BELGIUM
Fluid connectors for operation in space p 181 N90-24465
Deployment of large flexible space structures p 97 N90-27766

BRAZIL
Optimization of actuators/sensors placement and derivation of reduced order models for the optimal control of flexible structures [AAS PAPER 89-441] p 62 A90-46806
Design of a digital model following controller of reaction wheel torques [INPE-4753-PRE/1425] p 116 N90-21093

BULGARIA
New generation of space multichannel spectrometric systems p 185 A90-34953
The international space project 'Priroda' p 4 A90-36124

C

CANADA
Space debris: Legal and policy implications p 18 A90-31775
An improved Mapham's inverter for high frequency *space power conversion* p 146 A90-38127
Canada's space programme p 5 A90-38849
Canadian space policy p 5 A90-38850
Towards modeling and control of large space stations p 57 A90-40843
On the control of Space Station based tethered systems [AAS PAPER 89-182] p 190 A90-43498
Dynamics and control of tethered satellite systems p 190 A90-46248
An approach to dynamics and control of a class of interconnected rigid/flexible orbiting bodies p 60 A90-46249
Dynamics and control of the Shuttle based SCOLE type large antenna system [AAS PAPER 89-436] p 61 A90-46802
Offset control strategy for the Space Station based tethered payload [AAS PAPER 89-453] p 190 A90-46828
Elastic oscillations of long tether-type structures used for propellant transfer [AAS PAPER 89-455] p 190 A90-46830
Thermal distortion behavior of graphite reinforced aluminum space structures p 38 A90-47106
Structural model verification with linear quadratic optimization theory p 62 A90-47322
Canada's critical role in Freedom p 6 A90-48421
Dynamics of general flexible multibody systems p 70 A90-52010
Vibration control of spacecraft appendages through base motion [AIAA PAPER 90-2917] p 70 A90-52998
Dynamics and control of multibody systems - An approach to formulation and implementation [AIAA PAPER 90-2985] p 71 A90-53013
On the control of the SCOLE type flexible multibody system [AIAA PAPER 90-2930] p 71 A90-53014
In-plane and out-of-plane rotational dynamics and control of three body tethered system [AIAA PAPER 90-2948] p 191 A90-53031
The development of the Canadian Mobile Servicing System Kinematic Simulation Facility p 102 N90-20676
Tribomaterial factors in space mechanism brake performance p 116 N90-22096
Modeling and control of flexible space stations (slew maneuvers) p 83 N90-23086
Crossborder movements: Goods, personnel and technologies p 10 N90-26722

CHINA, PEOPLE'S REPUBLIC OF
Stability robustness analysis of attitude control system of a flexible spacecraft in time domain p 56 A90-39334
Development of local liquid cooling garment p 90 A90-44553
Methods of controlling spacecraft magnetic properties p 25 A90-44558
Evaluation of conductivity of two surface paints for spacecraft p 38 A90-44569
Thin conductive films for charging state passive control on spacecraft surface p 25 A90-44574
Optimum design based on reliability for a composite structural system p 45 A90-50462

F

FINLAND
Generation of an axisymmetric cylindrical shell element using a shooting method [ACTA-POLYTEC-SCAND-CI-93] p 85 N90-25362

FRANCE
East-west cooperation in manned spaceflights - Why? p 5 A90-38930
Attitude and Relative position Measurement Assembly and GNC Computer Assembly on board the Columbus Free Flying Laboratory [AIAA PAPER 90-3391] p 172 A90-47646
Development of the suit enclosure of the European EVA space suit [SAE PAPER 901244] p 91 A90-49314
Emulation of the Eva Soviet suit for neutral buoyancy simulations [SAE PAPER 901246] p 91 A90-49316
Water recycling in space [SAE PAPER 901247] p 157 A90-49317
Hygiene and water in Space Station [SAE PAPER 901386] p 164 A90-49414
Computation of an active control in fracture mechanics using finite elements p 45 A90-51268
A dynamic motion simulator for future European docking systems p 174 N90-22085
Study and sizing of bonded joints in space structures [REPT-892-430-124] p 48 N90-22591
Second European In-Orbit Operations Technology Symposium [ESA-SP-297] p 103 N90-24280
In-orbit operations research and development program of the Toulouse Space Center p 8 N90-24290
The European EVA suit: An optimized tool for Hermes/MTFF in-orbit operations p 94 N90-24296
HERA teleoperation test facility p 104 N90-24303
The bi-arm servicer: A multimission concept and a technological model for space robotics p 105 N90-24307
DDTF improvements for more accurate space docking simulation p 48 N90-24311
Investigations on docking and berthing dynamics p 48 N90-24312
Interconnecting devices conceived for in-orbit operations p 49 N90-24323
Dynamic modeling and control of a flexible arm holding a non-rigid payload p 84 N90-24331
Fourth European Space Mechanisms and Tribology Symposium [ESA-SP-299] p 117 N90-24462
Interface tribology and space conditions p 118 N90-24469
Wearing of cryomechanisms at 4 K p 119 N90-24476
Wear of gold-plated contacts: Microscopic aspects, role of oxygen p 119 N90-24479
Mechanisms to assemble space structures in extravehicular environment p 95 N90-24480
ADELE: Deployment hinge using wraparound strips p 49 N90-24485
SPOT 4 magnetic tape recorder mechanisms p 119 N90-24500
Materials and processes for spacecraft: The ESTEC approach [ESA-STM-244] p 40 N90-25176
Heavy ion tests on programmable VLSI [ETN-90-97254] p 148 N90-26057
Manned Space Stations: Legal Issues [ESA-SP-305] p 8 N90-26711
Technical characteristics and functions of different types of space stations p 3 N90-26712
Damage responsibility and liability in space stations p 9 N90-26714
The partnership concept and international management p 9 N90-26717
The International Space Station: Conditions of access and use p 9 N90-26718
Space manufacture: Protection and valuation of innovations from a users point of view p 184 N90-26724
Possible solutions p 10 N90-26726
Space law put to the test by the International Space Station p 10 N90-26727
Hermes rendezvous with the space station p 177 N90-27753
CUIS user's manual [ESA-TM-03] p 153 N90-27775
Preliminary hazard analysis in design application to EVA space suit [ETN-90-97585] p 98 N90-29918
ESA's report to the 28th COSPAR meeting [ESA-SP-1124] p 10 N90-30141
Activities report of the European Space Agency [ISSN-0258-025X] p 11 N90-30169

G

GERMANY,FEDERAL REPUBLIC OF
Collision avoidance analysis [AIAA PAPER 90-1338] p 18 A90-32037

I

J

K

M

N

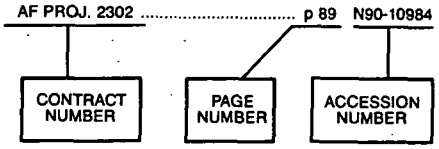
P

S

T

U

Typical Contract Number Index Listing



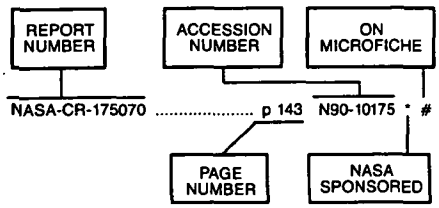
Listings in this index are arranged alphanumerically by contract number. Under each contract number, the accession numbers denoting documents that have been produced as a result of research done under the contract are shown. The accession number denotes the number by which the citation is identified in the abstract section. Preceding the accession number is the page number on which the citation may be found.

CONTRACT

LARGE SPACE STRUCTURES AND SYSTEMS IN THE SPACE STATION ERA / *A Bibliography (Supplement 02)*

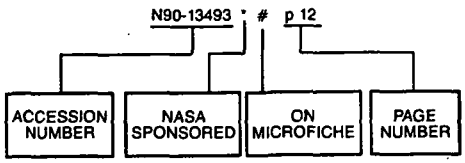
MAY 1991

Typical Report Number Index Listing



Listings in this index are arranged alphanumerically by report number. The page number indicates the page on which the citation is located. The accession number denotes the number by which the citation is identified. An asterisk (*) indicates that the item is a NASA report. A pound sign (#) indicates that the item is available on microfiche.

Typical Accession Number Index Listing



Listings in this index are arranged alphanumerically by accession number. The page number listed to the right indicates the page on which the citation is located. An asterisk (*) indicates that the item is a NASA report. A pound sign (#) indicates that the item is available on microfiche.

AVAILABILITY OF CITED PUBLICATIONS

IAA ENTRIES (A90-10000 Series)

Publications announced in *IAA* are available from the AIAA Technical Information Service as follows: Paper copies of accessions are available at $10.00 per document (up to 50 pages), additional pages $0.25 each. Standing order microfiche are available at the rate of $1.45 per microfiche for *IAA* source documents and $1.75 per microfiche for AIAA meeting papers.

Minimum air-mail postage to foreign countries is $2.50. All foreign orders are shipped on payment of pro-forma invoices.

All inquiries and requests should be addressed to: Technical Information Service, American Institute of Aeronautics and Astronautics, 555 West 57th Street, New York, NY 10019. Please refer to the accession number when requesting publications.

STAR ENTRIES (N90-10000 Series)

One or more sources from which a document announced in *STAR* is available to the public is ordinarily given on the last line of the citation. The most commonly indicated sources and their acronyms or abbreviations are listed below. If the publication is available from a source other than those listed, the publisher and his address will be displayed on the availability line or in combination with the corporate source line.

Avail: NTIS. Sold by the National Technical Information Service. Prices for hard copy (HC) and microfiche (MF) are indicated by a price code preceded by the letters HC or MF in the *STAR* citation. Current values for the price codes are given in the tables on NTIS PRICE SCHEDULES.

Documents on microfiche are designated by a pound sign (#) following the accession number. The pound sign is used without regard to the source or quality of the microfiche.

Initially distributed microfiche under the NTIS SRIM (Selected Research in Microfiche) is available at greatly reduced unit prices. For this service and for information concerning subscription to NASA printed reports, consult the NTIS Subscription Section, Springfield, VA 22161.

NOTE ON ORDERING DOCUMENTS: When ordering NASA publications (those followed by the * symbol), use the N accession number. NASA patent applications (only the specifications are offered) should be ordered by the US-Patent-Appl-SN number. Non-NASA publications (no asterisk) should be ordered by the AD, PB, or other *report number* shown on the last line of the citation, not by the N accession number. It is also advisable to cite the title and other bibliographic identification.

Avail: SOD (or GPO). Sold by the Superintendent of Documents, U.S. Government Printing Office, in hard copy. The current price and order number are given following the availability line. (NTIS will fill microfiche requests, as indicated above, for those documents identified by a # symbol.)

Avail: BLL (formerly NLL): British Library Lending Division, Boston Spa, Wetherby, Yorkshire, England. Photocopies available from this organization at the price shown. (If none is given, inquiry should be addressed to the BLL.)

Avail: DOE Depository Libraries. Organizations in U.S. cities and abroad that maintain collections of Department of Energy reports, usually in microfiche form, are listed in *Energy Research Abstracts.* Services available from the DOE and its depositories are described in a booklet, *DOE Technical Information Center - Its Functions and Services* (TID-4660), which may be obtained without charge from the DOE Technical Information Center.

Avail: ESDU. Pricing information on specific data, computer programs, and details on Engineering Sciences Data Unit (ESDU) topic categories can be obtained from ESDU International Ltd. Requesters in North America should use the Virginia address while all other requesters should use the London address, both of which are on the page titled ADDRESSES OF ORGANIZATIONS.

Avail: Fachinformationszentrum, Karlsruhe. Sold by the Fachinformationszentrum Energie, Physik, Mathematik GMBH, Eggenstein Leopoldshafen, Federal Republic of Germany, at the price shown in deutschmarks (DM).

Avail: HMSO. Publications of Her Majesty's Stationery Office are sold in the U.S. by Pendragon House, Inc. (PHI), Redwood City, CA. The U.S. price (including a service and mailing charge) is given, or a conversion table may be obtained from PHI.

Avail: NASA Public Document Rooms. Documents so indicated may be examined at or purchased from the National Aeronautics and Space Administration, Public Documents Room (Room 126), 600 Independence Ave., S.W., Washington, DC 20546, or public document rooms located at each of the NASA research centers, the NASA Space Technology Laboratories, and the NASA Pasadena Office at the Jet Propulsion Laboratory.

Avail: Univ. Microfilms. Documents so indicated are dissertations selected from *Dissertation Abstracts* and are sold by University Microfilms as xerographic copy (HC) and microfilm. All requests should cite the author and the Order Number as they appear in the citation.

Avail: US Patent and Trademark Office. Sold by Commissioner of Patents and Trademarks, U.S. Patent and Trademark Office, at the standard price of $1.50 each, postage free.

Avail: (US Sales Only). These foreign documents are available to users within the United States from the National Technical Information Service (NTIS). They are available to users outside the United States through the International Nuclear Information Service (INIS) representative in their country, or by applying directly to the issuing organization.

Avail: USGS. Originals of many reports from the U.S. Geological Survey, which may contain color illustrations, or otherwise may not have the quality of illustrations preserved in the microfiche or facsimile reproduction, may be examined by the public at the libraries of the USGS field offices whose addresses are listed in this Introduction. The libraries may be queried concerning the availability of specific documents and the possible utilization of local copying services, such as color reproduction.

Avail: Issuing Activity, or Corporate Author, or no indication of availability. Inquiries as to the availability of these documents should be addressed to the organization shown in the citation as the corporate author of the document.

FEDERAL DEPOSITORY LIBRARY PROGRAM

In order to provide the general public with greater access to U.S. Government publications, Congress established the Federal Depository Library Program under the Government Printing Office (GPO), with 51 regional depositories responsible for permanent retention of material, inter-library loan, and reference services. At least one copy of nearly every NASA and NASA-sponsored publication, either in printed or microfiche format, is received and retained by the 51 regional depositories. A list of the regional GPO libraries, arranged alphabetically by state, appears on the inside back cover. These libraries are *not* sales outlets. A local library can contact a Regional Depository to help locate specific reports, or direct contact may be made by an individual.

PUBLIC COLLECTION OF NASA DOCUMENTS

An extensive collection of NASA and NASA-sponsored publications is maintained by the British Library Lending Division, Boston Spa, Wetherby, Yorkshire, England for public access. The British Library Lending Division also has available many of the non-NASA publications cited in *STAR*. European requesters may purchase facsimile copy or microfiche of NASA and NASA-sponsored documents, those identified by both the symbols # and * from ESA – Information Retrieval Service European Space Agency, 8-10 rue Mario-Nikis, 75738 CEDEX 15, France.

ADDRESSES OF ORGANIZATIONS

American Institute of Aeronautics and Astronautics
Technical Information Service
555 West 57th Street, 12th Floor
New York, New York 10019

British Library Lending Division,
Boston Spa, Wetherby, Yorkshire,
England

Commissioner of Patents and Trademarks
U.S. Patent and Trademark Office
Washington, DC 20231

Department of Energy
Technical Information Center
P.O. Box 62
Oak Ridge, Tennessee 37830

European Space Agency-Information Retrieval Service
ESRIN
Via Galileo Galilei
00044 Frascati (Rome) Italy

Engineering Sciences Data Unit International
P.O. Box 1633
Manassas, Virginia 22110

Engineering Sciences Data Unit International, Ltd.
251-259 Regent Street
London, W1R 7AD, England

Fachinformationszentrum Energie, Physik, Mathematik
GMBH
7514 Eggenstein Leopoldshafen
Federal Republic of Germany

Her Majesty's Stationery Office
P.O. Box 569, S.E. 1
London, England

NASA Center for AeroSpace Information
P.O. Box 8757
BWI Airport, Maryland 21240

National Aeronautics and Space Administration
Scientific and Technical Information Program (NTT)
Washington, DC 20546

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Pendragon House, Inc.
899 Broadway Avenue
Redwood City, California 94063

Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402

University Microfilms
A Xerox Company
300 North Zeeb Road
Ann Arbor, Michigan 48106

University Microfilms, Ltd.
Tylers Green
London, England

U.S. Geological Survey Library National Center
MS 950
12201 Sunrise Valley Drive
Reston, Virginia 22092

U.S. Geological Survey Library
2255 North Gemini Drive
Flagstaff, Arizona 86001

U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

U.S. Geological Survey Library
Box 25046
Denver Federal Center, MS914
Denver, Colorado 80225

NTIS PRICE SCHEDULES

(Effective January 1, 1991)

Schedule A
STANDARD PRICE DOCUMENTS AND MICROFICHE**

PRICE CODE	NORTH AMERICAN PRICE	FOREIGN PRICE
A01	$ 8.00	$ 16.00
A02	11.00	22.00
A03	15.00	30.00
A04-A05	17.00	34.00
A06-A09	23.00	46.00
A10-A13	31.00	62.00
A14-A17	39.00	78.00
A18-A21	45.00	90.00
A22-A25	53.00	106.00
A99	*	*
N01	60.00	120.00
N02	59.00	118.00
N03	20.00	40.00

Schedule E
EXCEPTION PRICE DOCUMENTS AND MICROFICHE**

PRICE CODE	NORTH AMERICAN PRICE	FOREIGN PRICE
E01	$10.00	$ 20.00
E02	12.00	24.00
E03	14.00	28.00
E04	16.50	33.00
E05	18.50	37.00
E06	21.50	43.00
E07	24.00	48.00
E08	27.00	54.00
E09	29.50	59.00
E10	32.50	65.00
E11	35.00	70.00
E12	38.50	77.00
E13	41.00	82.00
E14	45.00	90.00
E15	48.50	97.00
E16	53.00	106.00
E17	57.50	115.00
E18	62.00	124.00
E19	69.00	138.00
E20	80.00	160.00
E99	*	*

* *Contact NTIS for price quote.*

** Effective January 1, 1991, the microfiche copy of any new document entering the NTIS collection will be priced the same as the paper copy of the document.

IMPORTANT NOTICE

NTIS Shipping and Handling Charges

U.S., Canada, Mexico — ADD $3.00 per TOTAL ORDER

All Other Countries — ADD $4.00 per TOTAL ORDER

Exceptions — Does NOT apply to:

ORDERS REQUESTING NTIS RUSH HANDLING

ORDERS FOR SUBSCRIPTION OR STANDING ORDER PRODUCTS *ONLY*

NOTE: Each additional delivery address on an order requires a separate shipping and handling charge.

☆U.S. GOVERNMENT PRINTING OFFICE:1991 -527 -064/A6001

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA SP-7085 (02)		

4. Title and Subtitle	5. Report Date
Large Space Structures & Systems in the Space Station Era A Bibliography with Indexes	May 1991
	6. Performing Organization Code NTT
7. Author(s)	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address NASA Scientific and Technical Information Program	11. Contract or Grant No.
	13. Type of Report and Period Covered Special Publication
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	14. Sponsoring Agency Code

15. Supplementary Notes

Compiled by Technical Library Branch and edited by Space Station Office, Langley Research Center, Hampton, Virginia.

16. Abstract

This bibliography lists 1219 reports, articles and other documents introduced into the NASA scientific and technical information system between July 1, 1990 and December 31, 1990. 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.

17. Key Words (Suggested by Authors(s))	18. Distribution Statement
Large Space Antenna Large Space Structures Large Space Systems Space Stations	Unclassified - Unlimited Subject Category - 18

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price *
Unclassified	Unclassified	328	A15

*For sale by the National Technical Information Service, Springfield, Virginia 22161

FEDERAL REGIONAL DEPOSITORY LIBRARIES

ALABAMA

AUBURN UNIV. AT MONTGOMERY LIBRARY
Documents Department
Montgomery, AL 36193
(205) 279-9110 ext.253

UNIV. OF ALABAMA LIBRARY
Reference Department/Documents
Box S
Tuscaloosa, AL 35486
(205) 348-6046

ARIZONA

DEPT. OF LIBRARY, ARCHIVES, AND PUBLIC RECORDS
Third Floor State Capitol
1700 West Washington
Phoenix, AZ 85007
(602) 255-4121

ARKANSAS

ARKANSAS STATE LIBRARY
Documents Service Section
One Capitol Mall
Little Rock, AR 72201
(501) 371-2090

CALIFORNIA

CALIFORNIA STATE LIBRARY
Govt. Publications Section
914 Capitol Mall
Sacramento, CA 95814
(916) 322-4572

COLORADO

UNIV. OF COLORADO
Norlin Library
Government Publications Division
Campus Box 184
Boulder, CO 80309
(303) 492-8834

DENVER PUBLIC LIBRARY
Govt. Pub. Department
1357 Broadway
Denver, CO 80203
(303) 571-2346

CONNECTICUT

CONNECTICUT STATE LIBRARY
231 Capitol Avenue
Hartford, CT 06106
(203) 566-4971

FLORIDA

UNIV. OF FLORIDA LIBRARIES
Documents Department
Library West
Gainesville, FL 32611
(904) 392-0367

GEORGIA

UNIV. OF GEORGIA LIBRARIES
Government Documents Dept.
Athens, GA 30602
(404) 542-8949

HAWAII

UNIV. OF HAWAII
Hamilton Library
Government Documents Collection
2550 The Mall
Honolulu, HI 96822
(808) 948-8230

IDAHO

UNIV. OF IDAHO LIBRARY
Documents Section
Moscow, ID 83843
(208) 885-6344

ILLINOIS

ILLINOIS STATE LIBRARY
Federal Documents
Centennial Building
Springfield, IL 62756
(217) 782-5012

INDIANA

INDIANA STATE LIBRARY
Serials Section
140 North Senate Avenue
Indianapolis, IN 46204
(317) 232-3686

IOWA

UNIV. OF IOWA LIBRARIES
Government Publications Dept.
Iowa City, IA 52242
(319) 335-5926

KANSAS

UNIVERSITY OF KANSAS
Spencer Research Library
Government Documents
Lawrence, KS 66045
(913) 864-4662

KENTUCKY

UNIV. OF KENTUCKY LIBRARIES
Government Publications/Maps Dept.
Lexington, KY 40506
(606) 257-8400

LOUISIANA

LOUISIANA STATE UNIVERSITY
Middleton Library
Government Documents Dept.
Baton Rouge, LA 70803
(504) 388-2570

LOUISIANA TECHNICAL UNIV.
Prescott Memorial Library
Government Documents Dept.
Ruston, LA 71272
(318) 257-4962

MAINE

UNIVERSITY OF MAINE
Raymond H. Fogler Library
Govt. Documents & Microforms Dept.
Orono, ME 04469
(207) 581-1680

MARYLAND

UNIVERSITY OF MARYLAND
McKeldin Library
Documents/Maps Room
College Park, MD 20742
(301) 454-3034

MASSACHUSETTS

BOSTON PUBLIC LIBRARY
Government Documents Dept.
666 Boylston Street
Boston, MA 02117
(617) 536-5400 ext.226

MICHIGAN

DETROIT PUBLIC LIBRARY
5201 Woodward Avenue
Detroit, MI 48202
(313) 833-1409

LIBRARY OF MICHIGAN
Government Documents
P.O. Box 30007
735 E. Michigan Avenue
Lansing, MI 48909
(517) 373-1593

MINNESOTA

UNIVERSITY OF MINNESOTA
Wilson Library
Government Publications
309 Nineteenth Avenue South
Minneapolis, MN 55455
(612) 373-7813

MISSISSIPPI

UNIV. OF MISSISSIPPI LIB.
Government Documents Dept.
106 Old Gym Bldg.
University, MS 38677
(601) 232-5857

MISSOURI

University of Missouri at Columbia Library
Government Documents
Columbia, MO 65201
(314) 882-6733

MONTANA

UNIV. OF MONTANA
Mansfield Library
Documents Division
Missoula, MT 59812
(406) 243-6700

NEBRASKA

UNIVERSITY OF NEBRASKA - LINCOLN
Love Memorial Library
Documents Department
Lincoln, NE 68588
(402) 472-2562

NEVADA

UNIV. OF NEVADA-RENO LIB.
Govt. Pub. Department
Reno, NV 89557
(702) 784-6579

NEW JERSEY

NEWARK PUBLIC LIBRARY
U.S. Documents Division
5 Washington Street
P.O. Box 630
Newark, NJ 07101
(201) 733-7812

NEW MEXICO

UNIVERSITY OF NEW MEXICO
General Library
Government Publications/Maps Dept.
Albuquerque, NM 87131
(505) 277-5441

NEW MEXICO STATE LIBRARY
325 Don Gaspar Avenue
Santa Fe, NM 87501
(505) 827-3826

NEW YORK

NEW YORK STATE LIBRARY
Documents Sect. Cultural Educ. Ctr.
Empire State Plaza
Albany, NY 12230
(518) 474-5563

NORTH CAROLINA

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Davis Library 080A
BA/SS Department Documents
Chapel Hill, NC 27514
(919) 962-1151

NORTH DAKOTA

NORTH DAKOTA STATE UNIVERSITY LIBRARY
Government Documents Dept.
Fargo, ND 58105
(701) 237-8352
In cooperation with Univ. of North Dakota, Chester Fritz Library
Grand Forks

OHIO

STATE LIBRARY OF OHIO
Documents Section
65 South Front Street
Columbus, OH 43266
(614) 644-7051

OKLAHOMA

OKLAHOMA DEPT. OF LIBRARIES
Government Documents
200 NE 18th Street
Oklahoma City, OK 73105
(405) 521-2502, ext. 252

OKLAHOMA STATE UNIV. LIB.
Documents Department
Stillwater, OK 74078
(405) 624-0489

OREGON

PORTLAND STATE UNIV.
Millar Library
934 SW Harrison - P.O. Box 1151
Portland, OR 97207
(503) 229-3673

PENNSYLVANIA

STATE LIBRARY OF PENN.
Government Publications Section
Box 1601
Walnut St. & Commonwealth Ave.
Harrisburg, PA 17105
(717) 787-3752

SOUTH CAROLINA

CLEMSON UNIV. COOPER LIB.
Documents Department
Clemson, SC 29634
(803) 656-5174
In cooperation with Univ. of South Carolina, Thomas Cooper Library, Columbia

TEXAS

TEXAS STATE LIBRARY
Public Services Department
P.O. Box 12927 - 1201 Brazos
Austin, TX 78711
(512) 463-5455

TEXAS TECH. UNIV. LIBRARY
Documents Department
Lubbock, TX 79409
(806) 742-2268

UTAH

UTAH STATE UNIVERSITY
Merrill Library & Learning Resources Center, UMC-30
Documents Department
Logan, UT 84322
(801) 750-2682

VIRGINIA

UNIVERSITY OF VIRGINIA
Alderman Library
Government Documents
Charlottesville, VA 22903
(804) 924-3133

WASHINGTON

WASHINGTON STATE LIBRARY
Document Section
Olympia, WA 98504
(206) 753-4027

WEST VIRGINIA

WEST VIRGINIA UNIV. LIB.
Government Documents Section
P.O. Box 6069
Morgantown, WV 26506
(304) 293-3640

WISCONSIN

ST. HIST SOC. OF WISCONSIN LIB.
Government Pub. Section
816 State Street
Madison, WI 53706
(608) 262-2781
In cooperation with Univ. of Wisconsin-Madison, Memorial Library

MILWAUKEE PUBLIC LIBRARY
Documents Division
814 West Wisconsin Avenue
Milwaukee, WI 53233
(414) 278-3065

WYOMING

WYOMING STATE LIBRARY
Supreme Court & Library Bldg.
Cheyenne, WY 82002
(307) 777-5919

National Aeronautics and
Space Administration
Code NTT

Washington, D.C.
20546-0001

Official Business
Penalty for Private Use, $300

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Postage an Fees Paid
National Aeronautics and
Space Administration
NASA-451

Official Business
Penalty for Private Use $300

SPECIAL FOURTH CLASS MAIL
BOOK

L2 001 SP-7085-02910607S090569A
NASA
CENTER FOR AEROSPACE INFORMATION
ACCESSIONING DEPT
P O BOX 8757 BWI ARPRT
BALTIMORE MD 21240

NASA

POSTMASTER: If Undeliverable (Section 158
Postal Manual) Do Not Return