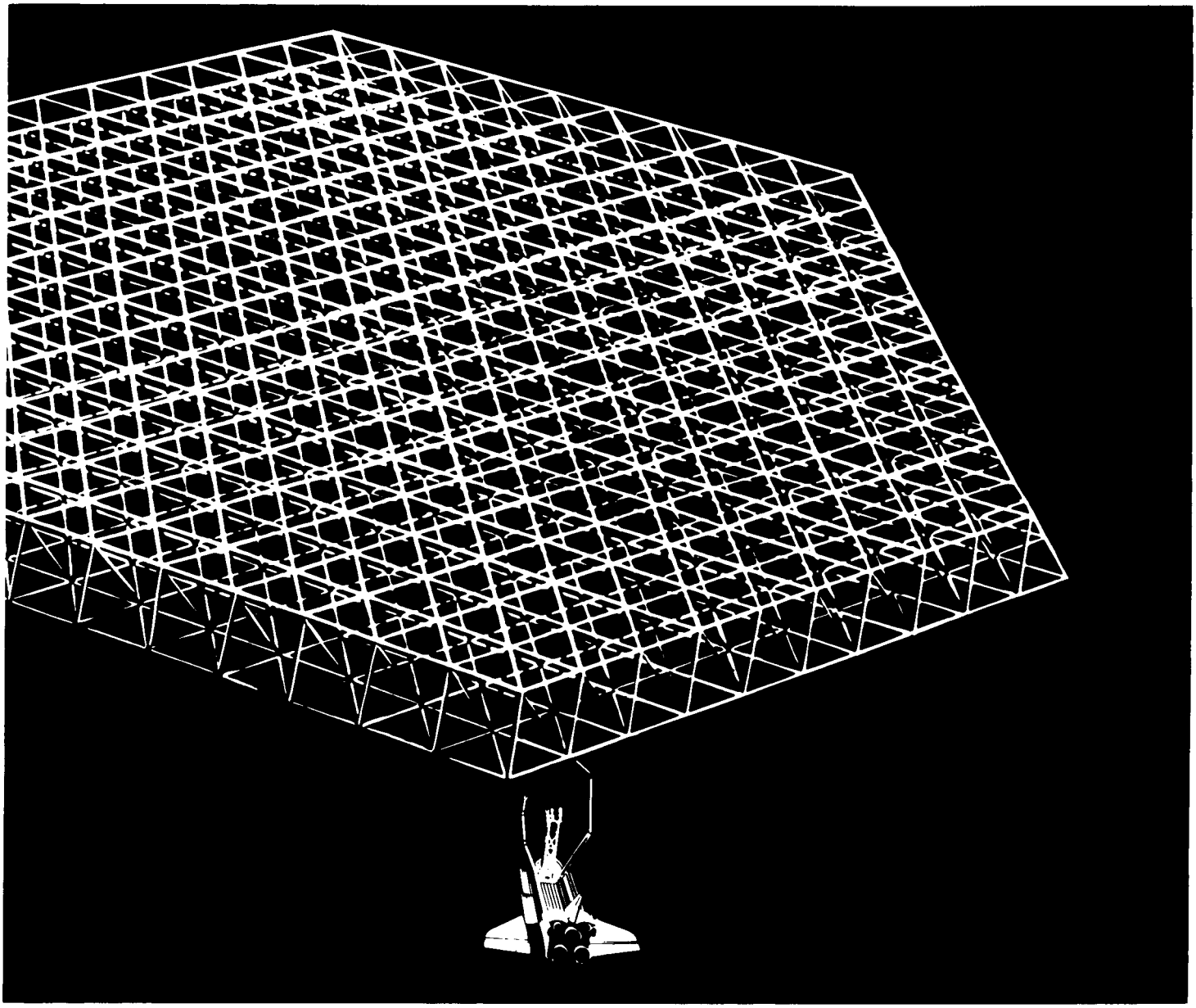
NASA

Technology for Large Space Systems

A Bibliography
with Indexes

NASA SP-7046(19)
November 1988



NASA SP-7046(19)

TECHNOLOGY FOR LARGE SPACE SYSTEMS

A BIBLIOGRAPHY WITH INDEXES

Supplement 19

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

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system between January 1 and June 30, 1988 in

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

Scientific and Technical Information Division 1988
National Aeronautics and Space Administration
Washington, DC

NOTE TO AUTHORS OF PROSPECTIVE ENTRIES:

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

This supplement is available from the National Technical Information Service (NTIS), Springfield , Virginia 22161 at the price code A07.

INTRODUCTION

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

This literature survey lists 526 reports, articles and other documents announced between January 1, 1988 and June 30, 1988 in *Scientific and Technical Aerospace Reports (STAR)*, and *International Aerospace Abstracts (IAA).*

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

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

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

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

Robert L. Wright, *Space Systems Division*
Sue K. Seward, *Technical Library Branch*

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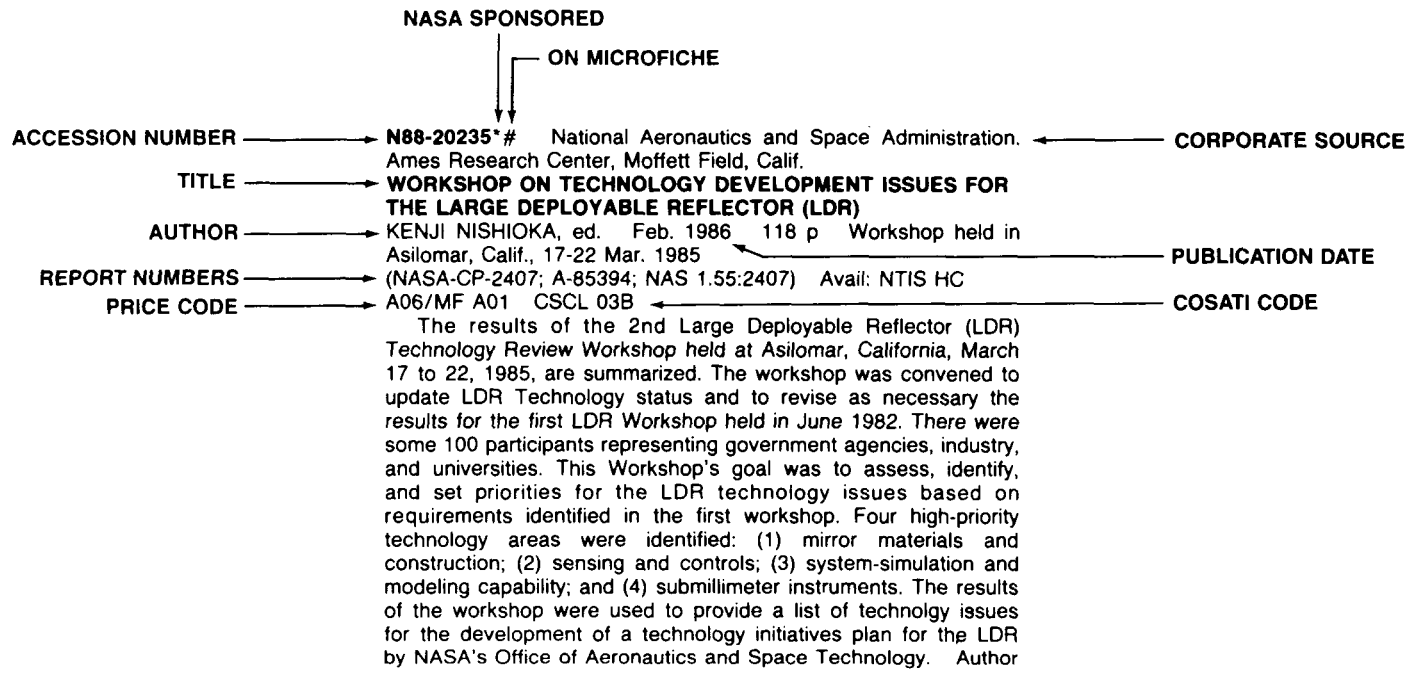
TYPICAL REPORT CITATION AND ABSTRACT



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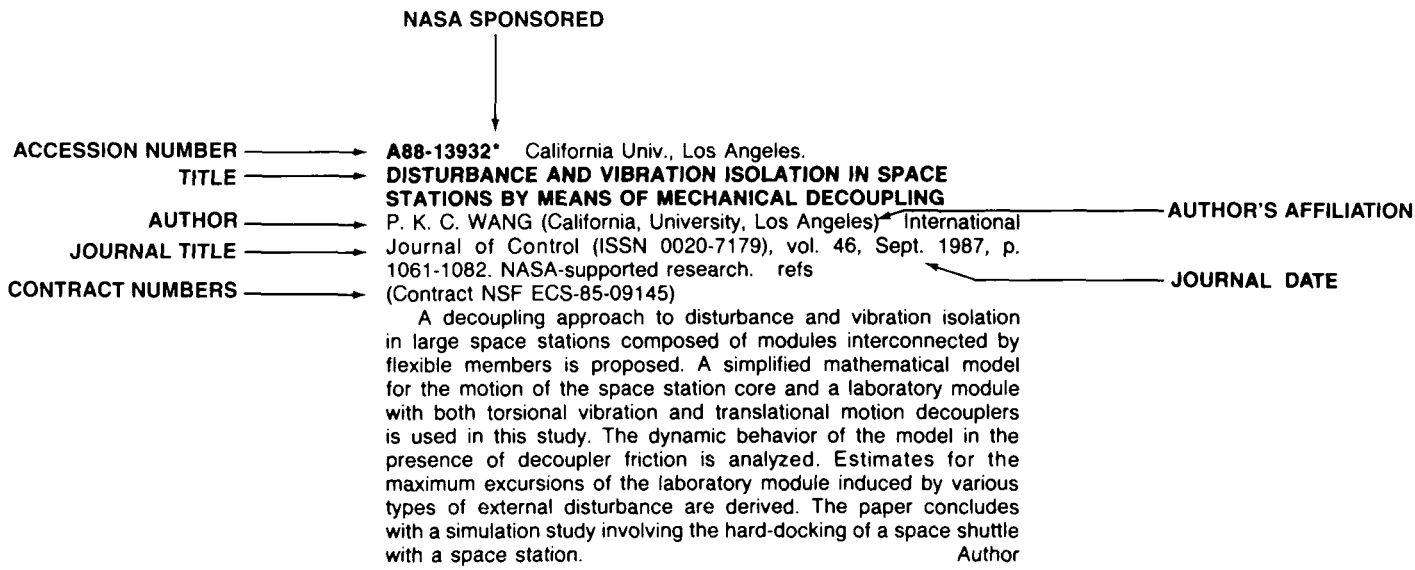

TECHNOLOGY FOR LARGE SPACE SYSTEMS

A Bibliography (Suppl. 19)

NOVEMBER 1988

01

SYSTEMS

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

A88-10366*# National Aeronautics and Space Administration, Washington, D.C.
PREPARING FOR THE FUTURE
ANDREW J. STOFAN (NASA, Washington, DC) Aerospace America (ISSN 0740-722X), vol. 25, Sept. 1987, p. 16-18, 20, 22.

Technologies and programs related to the development, construction, and operation of the Space Station are examined. A phase approach has been chosen for the construction of the Space Station, which is to have a revised baseline configuration. Consideration is given to the use of automation on the Space Station; the assembly and servicing of the Station; user requirements; and Space Station operations. The benefits the Space Station will provide to space exploration are discussed. I.F.

A88-11726*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
CAPTURE-EJECTOR SATELLITES
IAN MACCONOCHIE, CHARLES H. ELDRED, and JAMES A. MARTIN (NASA, Langley Research Center, Hampton, VA) (SAWE, Annual Conference, 41st, San Jose, CA, May 17-19, 1982, SAWE Paper 1455) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, July-Aug. 1987, p. 289, 290. Abridged. Previously cited in issue 21, p. 3291, Accession no. A82-43265.

A88-12571#
AUTONOMOUS SPACECRAFT OPERATIONS - PROBLEMS AND SOLUTIONS
PHILIP C. DALEY and ALLISON L. THORNBRUGH (Martin Marietta Corp., Astronautics Group, Denver, CO) IN: AIAA Computers in Aerospace Conference, 6th, Wakefield, MA, Oct. 7-9, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1987, p. 332-336. refs
(Contract F30602-86-C-0062)
(AIAA PAPER 87-2850)

In view of the utility projected for AI in NASA Space Station and SDI-related spacecraft operations, an evaluation is made of the systems engineering and acquisition management aspects of spaceborne knowledge-based system (KBS) components. Space platform testing, validation and verification methods, as well as management methods and procedures, must be modified in light of the unique characteristics of KBSs. Functional pipelining is suggested to be the basis of solutions for many problems encountered in the tradeoff between KBS verification, on the one hand, and the complexity and functionality of spacecraft systems, on the other. O.C.

A88-12719
DESIGN, ANALYSIS, FABRICATION AND TEST OF THE LAMAR PROTOFLIGHT MIRROR ASSEMBLY
LESTER M. COHEN, DANIEL G. FABRICANT, and PAUL GORENSTEIN (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA) IN: X-ray imaging II; Proceedings of the Meeting, San Diego, CA, Aug. 21, 22, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 126-137.

An X-ray telescope for the LAMAR instrument has been designed, built and tested at the Smithsonian Astrophysical Observatory. In addition, telescope performance has been verified at the NASA Marshall Space Flight Center's long X-ray beam facility. After X-ray testing and data reduction is complete, the telescope will undergo vibration testing. Postvibration visible light tests will then verify no change in performance. The design and fabrication of this high-throughput Kirkpatrick-Baez geometry telescope incorporates the use of advanced composite materials (aluminum-graphite/epoxy) to provide a thermally stable structure. A computerized figure formation system is used to attain the approximate parabolic curve of each optic. Each optic is supported by ten titanium flexures to provide the necessary decoupling between the stiff structural support module and the glass mirrors. The design, analysis and fabrication of this module is described, as well as the numerous problems encountered and the solutions developed, in this protoflight project. Author

A88-12814* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
LASER DOCKING SYSTEM RADAR FLIGHT EXPERIMENT
HARRY O. ERWIN (NASA, Johnson Space Center, Houston, TX) IN: Laser radar technology and applications; Proceedings of the Meeting, Quebec, Canada, June 3-5, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 105-114.

Flight experiments to verify the Laser Docking System Radar are discussed. The docking requirements are summarized, and the breadboarded hardware is described, emphasizing the two major scanning concepts being utilized: a mechanical scanning technique employing galvanometer beamsteerers and an electronic scanning technique using an image dissector. The software simulations used to apply hardware solutions to the docking requirements are briefly discussed, the tracking test bed is described, and the objectives of the flight experiment are reviewed. C.D.

A88-15278
ERM, THE DEPLOYABLE MAST FOR COLUMBUS
HERMANN RIEGER (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Space Congress, 24th, Cocoa Beach, FL, Apr. 21-24, 1987, Proceedings. Cape Canaveral, FL, Canaveral Council of Technical Societies, 1987, 18 p.

For application in the European Columbus project, the ERM (Extendable and Retractable Mast) has been selected as the most universal concept. Both the Resource Module and the Polar Platform require large solar generators of different sizes up to 18 kW. The modular design of the ERM can easily be adapted to different deployment lengths. Though the rollable array type has been chosen as the baseline, the ERM is also able to deploy rigid panel arrays. In addition the ERM will be used to position reflector antennas away from the module. The design is based on the telescopic principle using circular shaped graphite/epoxy tube sections for high stiffness and good thermal stability. The telescope is driven by a spindle/nut system, allowing the extension of the mast section by section. Author

A88-15801#
THE INDUSTRIAL SPACE FACILITY
MAXIME A. FAGET and C. C. JOHNSON (Space Industries, Inc., Houston, TX) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 6 p.
(IAF PAPER 87-01)

The design and operational capabilities of the Industrial Space Facility (ISF), a man-tended space platform that is to be placed on the Space Station, are described. The ISF is composed of two types of modules: facility modules and auxiliary modules. The facility is to operate in a circular orbit inclined 28.5 deg at orbital altitudes ranging from 160-220 nm and is to provide about 10 kW of power and cooling and telemetry capabilities. The ISF is to be used primarily for research and manufacturing of materials, and its modular design will permit easy growth to meet additional service and power demands. The initial deployment sequence and the servicing mission to resupply the ISF are discussed. Diagrams of the ISF and its modules are provided. I.F.

A88-15802#
CONCEPTUAL DESIGN OF THE ADVANCED TECHNOLOGY PLATFORM
RYOICHI IMAI, MASANORI HOMMA, and NORIKAZU HARA (National Space Development Agency of Japan, Tokyo) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 10 p.
(IAF PAPER 87-02)

This paper presents the concept of the ATP (Advanced Technology Platform) which is a co-orbiting platform planned to be launched in 1995. The ATP has two major objectives. One is to establish the advanced technologies essential to the future space platforms. The other is to conduct autonomous and in-orbit serviceable space experiments. To meet the various mission demands and to attain the high performance, the ATP adopts modular design, in-orbit servicing capability and advanced subsystem technologies. As subsystem technologies for the ATP, rendezvous-docking, two phase fluid loop thermal control and retractable flexible solar array are under development. The mission profile of the ATP is divided into two phases. Many space experiments such as material processing are conducted after the technology demonstration mission. Author

A88-15803#
THE IN-ORBIT TECHNOLOGY DEMONSTRATION PROGRAMME OF THE EUROPEAN SPACE AGENCY
G. G. REIBALDI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 10 p.
(IAF PAPER 87-03)

An increasing number of advanced space technologies require in-orbit demonstration as the final stage in their development before they can be integrated, without excessive risk, into new projects or embraced by industry in commercial ventures. To cope with those needs, ESA has already initiated the first phase (1987-1990) of its In-Orbit Technology Demonstration Program (TDP). This Program will extend well into the 1990s, as envisaged in the European Long-Term Space Plan, with a steadily increasing number of in-orbit tests being conducted each year. Such in-orbit testing reduces the risk element in more complex missions and provides European industry with the rapid flight testing of components and subsystems that it needs to compete in world markets. The content, status and planning of the present and future TDP phase shall be presented. Author

A88-15810*# National Aeronautics and Space Administration, Washington, D.C.
INTERNATIONAL SPACE STATION OPERATIONS: NEW DIMENSIONS - OCTOBER 13, 1987
GRANVILLE E. PAULES, PETER LYMAN, and CARL B. SHELLEY (NASA, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 17 p.
(IAF PAPER 87-13)

One of the principal goals of the participants in the International Space Station program is to provide a management support structure which is equitable and fair to all participants, responsive to the needs of users, responsible to other partners, and mutually supportive to the participation of other partners. Shared-utilization, shared-cost, and shared-operations policies considerations are discussed. Special attention is given to the methodology for identifying costs and benefits of this program, in which each partner should be provided with benefits in proportion to his contribution, and no partner would be forced to share in cost the inefficiencies introduced by other partners. The Space Station hierarchy of operations functions are identified, and the recommended framework planning and control hierarchy is presented. I.S.

A88-15827#
A NEW ITALIAN PROPOSAL FOR A SPACE STATION ASSEMBLY AND SERVICING VEHICLE (ASMV)
E. VALLERANI, G. OELKER, and L. BASILE (Aeritalia S.p.A., Settore Spazio, Turin, Italy) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 5 p.
(IAF PAPER 87-37)

An Assembly and Servicing Manned Vehicle (ASMV) to be used for the construction and maintenance of the Space Station is proposed. The design and operation of the ASMV are described. The use of EVA or the ASMV to assemble the Space Station is examined. It is determined that the ASMV will provide better protection for the astronauts, require no preparation time, and require less of the astronaut's time. The ASMV is to have the following capabilities: walking on the Space Station structure and flying around it; the same pressurization as the Space Station; an automatic attitude control system; manual, programmable, or automatic rendezvous and docking capabilities; an autonomous gas propulsion system; and compatibility with the Shuttle and Space Station. Possible modifications to the vehicle to increase its capabilities are discussed. I.F.

A88-15833*# National Aeronautics and Space Administration, Washington, D.C.
TECHNOLOGY - THE BASIS FOR THE PAST, THE KEY TO THE FUTURE
LEONARD A. HARRIS and RAYMOND S. COLLADAY (NASA, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 8 p.
(IAF PAPER 87-47)

The relationship between new technology and space missions, and the objectives of the Civil Space Technology Initiative (CSTI) are studied. The CSTI is concerned with technologies for safe and efficient access to space, earth-orbiting operations, and future science missions. The initiative focuses on research in the areas of propulsion, vehicles, information systems, large space structures and their control, power, and automation and robotics. Consideration is given to the development of high-performance engines for next-generation vehicles, booster technology for hybrid and pressure-fed propulsion systems, and a space OTV based on the aerobrake concept. Research involved with the application of automation and robotics to earth-orbiting operations are discussed. The control of flexible structure flight experiment, the use of nuclear systems for space propulsion, and the development of sensor devices and high-rate, high-capacity data systems are examined. I.F.

A88-15840*# National Aeronautics and Space Administration, Washington, D.C.
A RESEARCH LABORATORY IN SPACE
ANDREW J. STOFAN (NASA, Office of Space Station, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 6 p.
(IAF PAPER 87-60)

The current status of the Space Station program is briefly reviewed. A three-year definition and preliminary design study, now completed, has produced the Revised Baseline Configuration featuring a 110-m-long horizontal boom with four pressurized models attached that are connected by resource nodes outfitted with Station subsystems. One of the modules is a habitat; the

other three are laboratories provided by the U.S., Europe, and Japan. The main components and systems of the Revised Baseline Configuration are characterized, and some aspects of project management and international cooperation are discussed. V.L.

A88-15843*# National Aeronautics and Space Administration, Washington, D.C.
NASA AND THE SPACE STATION - CURRENT STATUS
THOMAS L. MOSER (NASA, Office of Space Station, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 6 p.
(IAF PAPER 87-64)

In the baseline configuration of the Space Station, NASA engineers have provided for a range of modifications that will enlarge the capabilities available to future users. An extensive definition and design study has been completed which is supplemented by a critical evaluation of the Space Station configuration; a three-year technology-development effort has also drawn to a close which examined operational factors and restructured program management responsibilities. Costs have been estimated on the basis of the revised configuration in order to insure full consistency for program funding plans. O.C.

A88-15844*# National Aeronautics and Space Administration, Washington, D.C.
UNITED STATES SPACE STATION TECHNICAL AND PROGRAMMATIC INTERFACES
RICHARD F. CARLISLE and WILLIAM E. RICE (NASA, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 15 p.
(IAF PAPER 87-65)

This paper describes the design of the U.S. Space Station and explains the control factors used for internal and external interfaces among the various government and contractor participants. It discusses the documentation of the U.S. Space Station Program including the Program Approval Document (PAD), the Program Plans (PPs), the Program Requirements Document (PRD), the Program Definition and Requirements Document (PDRD), the Level III project plans, and the Level III project design requirements documents. It discusses the relationship of Space Station documentation to the international Memoranda of Understanding (MOUs) and the Joint PP, PRD, and PDRD, the interrelationship of the Architectural Control Documents (ACDs), the Baseline Control Document (BCD), and the Interface Requirement Documents (IRDs) and Interface Control Documents (ICDs). Also included are the controlling functions of the various NASA and contractor participants and the international partners. Author

A88-15848*# National Aeronautics and Space Administration, Washington, D.C.
THE IMPACT OF LAUNCH VEHICLE CONSTRAINTS ON U.S. SPACE STATION DESIGN AND OPERATIONS
JUDITH H. AMBRUS and DANIEL H. HERMAN (NASA, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 3 p.
(IAF PAPER 87-72)

The assembly of the Space Station is examined in terms of user and operational requirements. The Space Shuttle/Space Station interface is analyzed. The effect of the changing space transportation environment on the Space Station assembly requirements and the lift capabilities of the Shuttle are investigated. Consideration is given to crew replacement and the Shuttle launch rate; the use of the advanced solid rocket motor to increase the lifting capability of the Shuttle to 52,000 lbs; and the use of ELVs for launching modules of the Space Station. I.F.

A88-15854#
SELECTED ADVANCED TECHNOLOGY STUDIES FOR THE U.S. SPACE STATION
R. W. HAGER (Boeing Aerospace Co., Huntsville, AL) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 9 p.
(IAF PAPER 87-79)

Results of three of the most significant studies completed as part of Work Package 1 of the U.S. Space Station are reported. In particular, water reclamation techniques have been developed using multifiltration methods and reverse osmosis with both longitudinal hollow fibers and spiral wound sheet structures. In the course of another study, methods of on-orbit pressurized module repair have been tested using the Neutral Buoyancy Test Facility at the Marshall Space Flight Center (MSFC). The discussion also covers the development and fabrication of a full scale flight weight, flight quality prototype pressurized module. V.L.

A88-15855*# National Aeronautics and Space Administration, Washington, D.C.
THE UNITED STATES SPACE STATION REVISED BASELINE
RAYMOND ROBERTS (NASA, Space Station Program Office, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 12 p.
(IAF PAPER 87-81)

This paper describes the current U.S. Space Station baseline configuration. The Space Station Revised Baseline (IAF-87-81) includes an historical perspective, a rationale for the current configuration, definitions of major Space Station and international elements and distributed systems, functional descriptions of the Space Station at key milestones in its construction, and possible directions for Station growth. Author

A88-15856*# National Aeronautics and Space Administration, Washington, D.C.
SPACE STATION PROGRAM IMPLICATIONS FROM THE VIEWPOINT OF THE SPACE STATION OPERATIONS TASK FORCE
GRANVILLE E. PAULES, PETER LYMAN, and CARL B. SHELLEY (NASA, Space Station Operations Task Force, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 8 p.
(IAF PAPER 87-82)

An operational concept for the Space Station which has been developed by the Space Station Operations Task Force is described. The operations functions are described, and the relationships of these functions to the overall framework for operations are defined. Product flows for the recommended framework are discussed, and the roles and responsibilities for the proposed operations organization during both the development and the mature operations phases of the Space Station Program are examined. C.D.

A88-15872*# National Aeronautics and Space Administration, Washington, D.C.
EVOLUTIONARY SPACE STATION INFRASTRUCTURE
ALPHONSO V. DIAZ and BARBARA S. ASKINS (NASA, Office of Space Station, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 8 p.
(IAF PAPER 87-103)

This paper discusses the approach to Space Station evolution planning and the preliminary analysis of options for the evolution of the infrastructure. The approach emphasizes the analysis of evolution paths, driven by specific user requirements, and evolution modes, i.e., the infrastructure required to support the evolution paths. The objective is to determine the near-term actions that must be taken to protect the future options. These include the identification of evolution 'hooks and scars' on the baseline Space Station and the establishment of an evolution advanced development program. The near term emphasis of the evolution planning is on methods of increasing the efficiency and productivity of the Space Station and on requirements to support new initiatives currently being studied by NASA. Author

A88-15934*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THE AEROASSIST FLIGHT EXPERIMENT
G. D. WALBERG, P. M. SIEMERS, III, R. L. CALLOWAY (NASA,

Langley Research Center, Hampton, VA), and J. J. JONES (Analytical Mechanics Associates, Inc., Hampton, VA) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 11 p. refs
(IAF PAPER 87-197)

The key design drivers for the Aeroassist Flight Experiment are discussed and a description is given of the flight test vehicle, its flight conditions, and instrumentation. The aeroassisted orbital transfer vehicle (AOTV) operates at higher velocities than the Space Shuttle and at higher altitudes than Apollo. Issues such as the effect of shock-layer nonequilibrium on the levels of radiative and convective heating and of viscous and real-gas effects on vehicle aerodynamic characteristics are mentioned. K.K.

A88-15966*# National Aeronautics and Space Administration, Washington, D.C.
PAST, PRESENT, AND FUTURE ACTIVITIES IN SPACE POWER TECHNOLOGY IN THE UNITED STATES OF AMERICA
JUDITH H. AMBRUS (NASA, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 2 p.
(IAF PAPER 87-245)

Space power technology research in the U.S. is examined. The objectives for advanced power systems are long life, safety, flexibility, modularity, growth capability, and autonomy. Research in the areas of photovoltaic arrays, electrical energy storage, and the development of solar dynamic power systems and radio thermal generators is described. The applications of advances in power generation, energy storage, and power management and distribution to the Space Station are discussed. I.F.

A88-16013#
LARGE INFLATABLE, SPACE-RIGIDIZED ANTENNA REFLECTORS - LAND MOBILE SERVICES DEVELOPMENT
M. C. BERNASCONI (Contraves AG, Zurich, Switzerland), E. PAGANA (Centro Studi e Laboratori Telecomunicazioni S.p.A., Turin, Italy), and G. G. REIBALDI (ESA, Mechanical Systems Div., Noordwijk, Netherlands) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 19 p. refs
(Contract ESA-5505/83/NL/PB; ESA-6244/85/NL/PB)
(IAF PAPER 87-315)

Inflatable, chemically rigidized space structures are applicable to a wide range of functions. A 2.8-m offset antenna reflector, for operation at 3.63 GHz, has been subjected to mechanical and electrical tests, to serve as a precursor for larger structures, such as those discussed for land mobile applications. Surface accuracies of 0.6 mm rms were achieved. Both folding and curing processes were found to have a negligible impact on the reflector's quality. The electrical performance has been shown to be predictable on the basis of the mechanical measurements. Author

A88-16015#
RESEARCH AND DEVELOPMENT OF THE TENSION TRUSS ANTENNA
KORYO MIURA, MASAMORI SAKAMAKI (Tokyo, University, Japan), TETSUO YASAKA, ISAO OHTOMO, JIN MITSUGI (Nippon Telegraph and Telephone Public Corp., Tokyo, Japan) et al. IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 10 p.
(IAF PAPER 87-317)

This paper presents the result of recent research and development of the tension truss antenna. The tension truss antenna is the deployable, mesh-surfaced space antenna, whose geodesic-truss-like reflector surface is realized by a pre-tensioned cable structure. A 3-m-diameter engineering model has been built for the purpose of identifying the technical problem area and testing the surface shape control algorithm. The principal feature of the tension truss antenna is that the surface shape is uniquely determined by the lengths and arrangement of truss cable composing the reflector surface, and is independent of the cable tension. An algorithm of surface shape control has been established taking advantage of this intrinsic nature of the concept. Any local deviation of the reflector surface can be adjusted by changing the length of said local cables and it does not influence the other part of the reflector. This algorithm has been tested using the model and the result has shown its effectiveness. In view of these results, the tension truss antenna has the potential for a variety of space antenna missions. Author

A88-16074#
THIRTY YEARS OF THE SPACE AGE
B. V. RAUSHENBAKH (AN SSSR, Moscow, USSR) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987, Paper. 9 p.

The history of space science and technology in the 30 years since the launch of Sputnik is surveyed. The early history of rocketry is reviewed, and consideration is given to the crucial role of multistage rocket boosters in the beginning of space flight, the focus on manned missions in the late 1950s and 1960s, and the more pragmatic orientation of the space programs in the 1970s and 1980s. It is predicted that the predominant space activity in the near future will be the construction and industrial utilization of large manned space stations. T.K.

A88-16097*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
MANNED MARS MISSION ACCOMODATION BY THE EVOLUTIONARY SPACE STATION
E. BRIAN PRITCHARD and ROBERT N. MURRAY (NASA, Langley Research Center, Hampton, VA) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 11 p.
(IAF PAPER 87-438)

It is shown that an unmanned launch capability of about 90 metric tons to the Space Station altitude and inclination is required to support the buildup of the manned Mars mission. The paper presents details of the assembly sequence including the analysis and conceptual design of additional truss and other facilities required at the Space Station. It is noted that the The Critical Evaluation Task Force configuration (dual keel) can evolve to accommodate the Mars space vehicle buildup. K.K.

A88-16113*# Perkin-Elmer Corp., Danbury, Conn.
AN ADVANCED IMAGING SPACE TELESCOPE CONCEPT
MICHAEL H. KRIM (Perkin-Elmer Corp., Danbury, CT) and JAMES W. STEINCAMP (NASA, Marshall Space Flight Center, Huntsville, AL) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 9 p.
(IAF PAPER 87-460)

This paper describes the results of a recent study of possible configurations for a next-generation optical space telescope with order-of-magnitude improvements over the Hubble Space Telescope. Overall configuration characteristics including optical performance, weights, and dimensions are given. Launch vehicle packaging concepts are described, and a scenario for orbital assembly developed. Finally, an assessment of technology readiness is provided. Author

A88-16119#
THE DFS PLATFORM AND ITS APPLICATIONS
J. NAUCK and H. J. HEIDMANN (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 7 p.
(IAF PAPER 87-470)

The German 'DFS-Kopernikus' domestic communications satellite platform, scheduled for initial operations in 1989, is applicable to other missions and may be extended to meet increased future requirements. Attention is given to the various possibilities for FDS platform modification and extension that will yield a next-generation communications satellite. An important feature of the platform's design is its modularity, which divides service and communications functions; the communications module is further divided into repeater and antenna modules. Maximum launch mass is 1500 kg for a 10-year service life. O.C.

A-16146#
UCATIONAL AND PEDAGOGICAL IMPORTANCE OF STRONAUTICS
LADYSLAW GEISLER and KRYSTYNA LUKASIK (Polskie owarzystwo Astronautyczne, Katowice, Poland) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 6 p.
(IAF PAPER 87-520)

The benefits provided to man by astronautics are discussed. Particular emphasis is given to the effect of future astronautical activities on the education and development of youth. The evolution of space flight, the development of spacecraft, and advances in space capabilities are examined. Some of the U.S. and USSR manned missions and experiments are described. Consideration is given to artificial satellites, space probes, space stations, and extending space flights. I.F.

A88-16186#
DEPARTMENT OF DEFENSE SPACE POLICY AND THE DEVELOPMENT OF A GLOBAL POLICY FOR THE CONTROL OF SPACE DEBRIS
L. PARKER TEMPLE, III (DOD, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 9 p. refs
(IAF PAPER 87-575)

In 1986, the U.S. Department of Defense conducted a study to determine whether the hazard potential to spacecraft from space debris was sufficiently great to warrant efforts to reduce any further contributions to existing debris levels. The hazard has been found to be serious; technologies supporting the implementation of a policy restraining additional debris growth have been identified. Attention is presently given to the pressing need for the development of global policy guidelines for space debris minimization. O.C.

A88-16211#
COSTS AND BENEFITS OF FUTURE HEAVY SPACE FREIGHTERS
H. AREND (Berlin, Technische Universitaet, Federal Republic of Germany) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 10 p.
(IAF PAPER 87-617)

A class of two-stage reusable ballistic Space Freighters with nominal launch masses of 7000 metric tons for transport of heavy payloads into low earth orbits is investigated in this paper with special regard to vehicle cost efficiency. A life-cycle cost analysis shows that Space Freighters with a conventional aluminum structure offer significantly lower specific transportation costs than today's systems for large payload markets and high launch rates. Advanced structural materials and thermal protection systems offer further important reductions not only with regard to vehicle mass but also with respect to specific transportation cost. A phased introduction of these technologies is cost efficient for larger programs with more than 100 vehicles. Author

A88-16237#
PROJECT HORIZON - AN EARLY STUDY OF A LUNAR OUTPOST
FREDERICK I. ORDWAY, III, MITCHELL R. SHARPE (Alabama Space and Rocket Center, Tranquility Base, Huntsville), and RONALD C. WAKEFORD (U.S. Army, Corps of Engineers Technical Committee, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 32 p. refs
(IAF PAPER 87-659)

Project Horizon was a pioneering study prepared by the US Army in the late 1950s to further the exploration of space. It strived to (1) design and establish a lunar outpost from which further investigations of, and operations on, the lunar surface could be undertaken, and (2) provide a supporting capability for other operations in space. Consideration is given to the lunar outpost design and construction, scientific programs proposed to be undertaken on the moon, launch and transfer vehicles, launch facilities, and communications. Background facts on Project Horizon are also described. K.K.

A88-16290
ADAPTATION OF THE OLYMPUS AOCS FOR USE IN LOW EARTH ORBIT
K. G. BAKER and R. K. HUSBAND (British Aerospace, PLC, Space and Communications Div., Bristol, England) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 103-109. Research supported by the Department of Trade and Industry of England.

The Attitude and Orbit Control Subsystem (AOCS) of the Olympus GEO satellites, which is microprocessor-based and therefore capable of accommodating alternative missions by means of inexpensive software modifications, is presently adapted for LEO missions. Sensors and actuators are coupled to the processing unit by a serial data bus, allowing sensor/actuator combinations appropriate to other missions to be selected without impact on hardware design. The present adaptation is that of the Radarsat earth resources mission. O.C.

A88-21521#
FUTURE IN-ORBIT TECHNOLOGY DEMONSTRATIONS
H. STOEWER and G. G. REIBALDI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 52, Nov. 1987, p. 22-29.

The First Phase of the ESA In-Orbit Technology Demonstration Programme was initiated in 1987 and is scheduled to be completed in 1990. This Programme is considered with respect to experiments of common interest to existing and future programs (materials, dynamics of flexible structures, and AOCS thrusters and propellants); support for the development and utilization of new programs (rendezvous and docking, fluid management, EVA, thermal control, reentry, life support, and robotics); performance testing (antennas, sensors, and propulsion); and Columbus as a carrier for technology experiments. B.J.

A88-21561
FOKKER SUBSYSTEM RESPONSIBILITIES IN COLUMBUS B PHASE STUDIES
J. H. DE KOOMEN (Fokker, Amsterdam, Netherlands) (Columbus II; Proceedings of the Second Workshop, Hanover, Federal Republic of Germany, June 9-11, 1986) Space Technology - Industrial and Commercial Applications (ISSN 0277-4488), vol. 7, no. 1-2, 1987, p. 81-87.

The designs of the Polar Platform (PPF) and Resource Module (RM) solar arrays and the Pressurized Module (PM) equipment airlock for the ESA Columbus program are presented in extensive drawings and briefly characterized, summarizing the results of phase B studies. Both flexible 'roll-out' and rigid versions of the 16-kW 150-V dc solar arrays are being studied. Additional factors to be considered include commonality of design among PPF, RM, and enhanced Eureca; stowage volume and weight; rigidity; AOCS constraints; complexity and reliability; maintainability; the Orbital Replacement Unit philosophy, and cost. The equipment airlock is a self-contained unit of internal diameter 980 mm to be attached to an aperture of the PM and controlled from within. It is based on the Spacelab airlock but has electric-motor drive and must meet an unlimited lifetime requirement. T.K.

A88-21639* Texas Christian Univ., Fort Worth.
NASA SYSTEMS AUTONOMY DEMONSTRATION PROGRAM - A STEP TOWARD SPACE STATION AUTOMATION
S. A. STARKS (Texas Christian University, Fort Worth), D. RUNDUS (South Florida, University, Tampa, FL), W. K. ERICKSON (NASA Ames Research Center, Moffett Field, CA), and K. J. HEALE (NASA, Johnson Space Center, Houston, TX) IN: Space Stati automation II; Proceedings of the Meeting, Cambridge, MA, C 28-30, 1986. Bellingham, WA, Society of Photo-Opt Instrumentation Engineers, 1987, p. 80-85.

This paper addresses a multiyear NASA program, the Sys Autonomy Demonstration Program (SADP), whose main objec include the development, integration, and demonstrati

automation technology in Space Station flight and ground support systems. The role of automation in the Space Station is reviewed, and the main players in SADP and their roles are described. The core research and technology being promoted by SADP are discussed, and a planned 1988 milestone demonstration of the automated monitoring, operation, and control of a complete mission operations subsystem is addressed. C.D.

A88-21644* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PLAN-IT - KNOWLEDGE-BASED MISSION SEQUENCING
ERIC W. BIEFELD (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation II; Proceedings of the Meeting, Cambridge, MA, Oct. 28-30, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 126-130. refs

PLAN-IT (Plan-Integrated Timelines), a knowledge-based approach to assist in mission sequencing, is discussed. PLAN-IT uses a large set of scheduling techniques known as strategies to develop and maintain a mission sequence. The approach implemented by PLAN-IT and the current applications of PLAN-IT for sequencing at NASA are reported. C.D.

A88-22044*# Martin Marietta Corp., Denver, Colo.
HUMAN EXPLORATION OF MARS
BENTON C. CLARK (Martin Marietta Planetary Sciences Laboratory, Denver, CO) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 6 p. refs
(Contract NAS8-37126)
(AIAA PAPER 88-0064)

A systems study is underway of astronaut missions to Mars that could be accomplished over the next four decades. In addition to an emphasis on the transportation and facility infrastructure required for such missions, other relevant technologies and mission constraints are also being considered. These induce on-orbit assembly, trajectory type, launch opportunities, propellant storage, crew size, cabin pressure, artificial gravity, life-support systems, radiation hazards, power/energy storage, thermal control, human factors, communications, abort scenarios, landing techniques, exploration strategies, and science activities. A major objective of the study is to identify enabling and significantly enhancing technologies for accomplishing the goal of the human exploration of Mars. Author

A88-22321#
SHUTTLE EXPERIMENTS TO MEASURE THE OPTICAL ENVIRONMENTS SURROUNDING LARGE SPACE STRUCTURES
BYRON DAVID GREEN, GEORGE E. CALEDONIA, ANDREW LINTZ, JAMES PERSON, PRAKASH JOSHI (Physical Sciences, Inc., Andover, MA) et al. AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 7 p. refs
(AIAA PAPER 88-0432)

This paper describes two projects which will probe different aspects of the environment surrounding spacecraft in low-earth orbit. Both are presently in the design stage. The first, the GLOS/SKIRT payload, will measure the spacecraft glow across the ultraviolet to mid-infrared spectral regions. The second payload will attempt to prove the Critical Ionization Velocity hypothesis and will monitor electrostatic and optical emissions generated by the interaction of released gases with the ionosphere. Author

A88-22484#
INDUSTRIAL SPACE FACILITY
OLAV SMISTAD (Space Industries, Inc., Houston, TX) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 7 p.
(AIAA PAPER 88-0649)

The design and capabilities of the proposed Industrial Space Facility (ISF), a permanently deployed, man-tended space platform, are described. The ISF is to be utilized for materials research and manufacturing in space, scientific research, and storage applications, and as a test platform and laboratory. Unique features of the facility include abundant power, cooling, and large pressurized volumes. The ISF is composed of a facility module (FM), an auxiliary module (AM), and a docking system. The facility module is to be 35 ft long, 14.5 ft in diameter, and to have 2500 cu ft of pressurized internal volume. The ISF is to operate in a circular 220 nautical mile orbit, and facility resupply is to be provided by exchanging a restocked AM for a depleted AM. The design of the facility is modular to allow for growth and it can be customized for user's needs. The initial deployment sequence, servicing mission, and mission profile are examined. Diagrams of the ISF and FM are provided. I.F.

A88-22486*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
THE X-RAY LARGE ARAY. II - IMPLEMENTATION
JOSEPH DABBS, BILLY DAVIS, and JOHN DAVIS (NASA, Marshall Space Flight Center, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 6 p.
(AIAA PAPER 88-0654)

The design of the X-ray Large Array (XLA) which is to be assembled and operated in space is discussed. The XLA is a 100 sq m array of 64 detector modules with a total of 512 detectors, each similar to the ones flown on the HEAO-1 spacecraft, packaged in groups of eight to form a module. The XLA will be able to deal with many extremely fast processes which occur in compact X-ray sources and will be used to study black hole candidates; its fine time resolution will make it possible to resolve the spatial structure of celestial X-ray sources using lunar occulatation, the angular structure of quasars, and active galactic nuclei. Details of the XLA configuration, and the assembly and packaging options are described together with systems requirements. Multiple configuration diagrams are included. I.S.

A88-22567#
SPACEWARD HO
JOHN F. YARDLEY (McDonnell Douglas Astronautics Co., Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 7 p.
(AIAA PAPER 88-0750)

The paper compares the differences between the U.S. and Soviet space programs in the past 30 years to determine what steps the U.S. can take to regain its leadership position in space. After briefly examining the space flight technology and the development processes utilized by the two space programs, it is suggested that the U.S. become more evolutionary in its programs and more streamlined in its development practices. Most important, however, is the gaining of public support for a robust, long-range space plan. The key is effective communication with the American people; it is suggested that the AIAA take the lead in organizing this communication thrust. Author

A88-22677
SPACE POWER NEEDS AND FORECASTED TECHNOLOGIES FOR THE 1990S AND BEYOND
DAVID BUDEN and THOMAS ALBERT (Science Applications International Corp., Albuquerque, NM) IN: Space nuclear power systems 1986; Proceedings of the Third Symposium, Albuquerque, NM, Jan. 13-16, 1986. Malabar, FL, Orbit Book Co., Inc., 1987, p. 15-24. Research sponsored by the Science Applications International Corp. refs

A new generation of reactors for electric power will be available for space missions to satisfy military and civilian needs in the 1990s and beyond. To ensure a useful product, nuclear power plant development must be cognizant of other space power technologies. Major advances in solar and chemical technologies need to be considered in establishing the goals of future nuclear power plants. In addition, the mission needs are evolving into new regimes. Civilian and military power needs are forecasted to exceed anything used in space to date. Technology trend forecasts have been mapped as a function of time for solar, nuclear, chemical, and storage systems to illustrate areas where each technology provides minimum mass. Other system characteristics may dominate the usefulness of a technology on a given mission.

This paper will discuss some of these factors, as well as forecast future military and civilian power needs and the status of technologies for the 1990s and 2000s. Author

A88-26364#
SMALL REENTRY VEHICLES [KLEINE RE-ENTRY VOERTUIGEN]
K. J. SUDMEIJER (Fokker, Schiphol, Netherlands) Ruimtevaart, vol. 36, Dec. 1987, p. 15-26. In Dutch.

The design and potential applications of a small modular unguided reentry vehicle (SMURV) being developed for ESA are discussed. The first studies of the SMURV concept in the Spacemail program (for transporting small payloads from the Space Shuttle to earth) are recalled; the steps in a typical Spacemail operation are listed and briefly characterized; and the smaller version of SMURV (40 kg instead of 120 kg) developed for a Space Station Spacemail project (requiring 1000-1500 SMURVs) is described. This SMURV configuration comprisés a detachable propulsion module and a reentry module (containing the parachute system and the recovery module). Consideration is given to a SMURV-type vehicle to return microgravity processing samples from the ESA Interim Flight Opportunity spacecraft, the technological challenges posed by SMURV design, and SMURV applications to the Comet Nucleus Sample Return and Cassini Titan Lander missions. Diagrams and drawings are provided. T.K.

A88-27356
DECENTRALIZED CONTROL OF THIRD GENERATION SPACECRAFT
E. J. DAVISON (Toronto, University, Canada) and W. GESING (Citibank Canada, Toronto) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 963-969. refs
(Contract CDC-DSS-37ST,36001-5-3552)

A brief summary is given of a study on the decentralized control system design of a third-generation spacecraft as modeled by the MSAT vehicle configuration. Representative output simulations are given. Results obtained using centralized control are presented which show that the decentralized design is highly effective compared to the centralized case. C.D.

A88-27750*# National Aeronautics and Space Administration, Washington, D.C.
IN-SPACE RESEARCH, TECHNOLOGY AND ENGINEERING EXPERIMENTS AND SPACE STATION
RICHARD TYSON (NASA, Office of Aeronautics and Space Technology, Washington, DC) and CHARLES F. GARTRELL (General Research Corp., McLean, VA) AIAA, Meeting on Space Station Utilization, 1st, Arlington, VA, Mar. 7-9, 1988, Paper. 18 p. refs

The NASA Space Station will serve as a technology research laboratory, a payload-servicing facility, and a large structure fabrication and assembly facility. Space structures research will encompass advanced structural concepts and their dynamics, advanced control concepts, sensors, and actuators. Experiments dealing with fluid management will gather data on such fundamentals as multiphase flow phenomena. As requirements for power systems and thermal management grow, experiments quantifying the performance of energy systems and thermal management concepts will be undertaken, together with expanded efforts in the fields of information systems, automation, and robotics. O.C.

A88-27779#
DESIGN AND VERIFICATION OF THE FLECS TEST STRUCTURE
E. NELLESSEN ESA Journal (ISSN 0379-2285), vol. 11, no. 3, 1987, p. 317-341. refs

This paper reports the development and dynamic identification of the FLECS test structure, designed to represent a typical modular spacecraft in terms of mass properties and dynamic characteristics. FLECS is intended as a multipurpose test item when a structure with spacecraft properties is required, in particular for the validation of dynamic identification methods applied to a spacecraft-verification process. The generation of a finite-element model, a modal-survey test and the correlation of the analytical modal data with modal-survey test results are reported. Finally, an updating procedure for modular structures is presented. The method was tested using FLECS correlation data. Author

A88-28864
SOLAR SAILS AND THE ARSAT SATELLITE - SCIENTIFIC APPLICATIONS AND TECHNIQUES [LES VOILES SOLAIRES ET LE SATELLITE ARSAT - APPLICATIONS SCIENTIFIQUES ET TECHNIQUES]
CHRISTIAN MARCHAL L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 127, 1987, p. 53-57. In French.

The principle of the solar sail and projected applications for the space-deployable Arsat solar sail satellite are discussed. Their maneuverability, large size, reflector properties, and navigability, make solar sails ideal for the study of regions near the sun or those far away from the ecliptic plane. The 150-kg Arsat satellite has four inflatable masts and an area loading of 84 g/sq m, a value which is projected to be reduced to 20-30 g/sq m for more extended missions. Other applications include the elimination of debris in both geostationary and low orbits and the permanent support of geostationary satellites below a pole. R.R.

A88-31392*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SPACE STATION - A FOCUS FOR THE DEVELOPMENT OF STRUCTURAL DYNAMICS SCALE MODEL TECHNOLOGY FOR LARGE FLEXIBLE SPACE STRUCTURES
ROBERT LETCHWORTH, PAUL E. MCGOWAN (NASA, Langley Research Center, Hampton, VA), and MARC J. GRONET (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 121-130. refs
(AIAA PAPER 88-2483)

The paper discusses the scale model technology being developed at the NASA Langley Research Center in support of the development of structural dynamic prediction methods for large flexible space structures. Space Station is used as a focus. The Dynamic Scale Model Technology (DSMT) Program is described; results of the effect of scaling Space Station components are presented; and supporting scale model technology development activities are described and results presented. The conceptual design of a hybrid-scale Pathfinder model for developing test techniques and suspension methods is also discussed, and a summary of the broad application of the scale model technology being developed is presented. Author

A88-31395*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THE IMPACT OF ASYMMETRIC PHYSICAL PROPERTIES ON LARGE SPACE STRUCTURES
L. DERYDER (NASA, Langley Research Center, Hampton, VA), P. TROUTMAN, and M. HECK (Analytical Mechanics Associates, Inc., Hampton, VA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 155-161.
(AIAA PAPER 88-2486)

The Space Station Reference Configuration is assembled in 19 assembly flights of several large structure elements of varied size and shape that contribute to its overall asymmetrical nature. The elements include thousands of square feet of solar arrays and thermal radiators, several hundred feet of truss structure, and several hundred thousand pounds of large-diameter cylindrical-shaped pressure modules housing scientific experiments and astronaut habitation areas. This paper quantitatively describes these physical characteristics of the fully assembled Space Station configuration. Several flight control design considerations are

discussed relating to control system sizing, flight-path attitude orientation, payload pointing accommodation, and potential configuration modifications. C.D.

A88-31399*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ORBIT LIFETIME CHARACTERISTICS FOR SPACE STATION
L. DERYDER (NASA, Langley Research Center, Hampton, VA), G. M. KELLY, and M. HECK (Analytical Mechanics Associates, Inc., Hampton, VA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 187-195. refs
(AIAA PAPER 88-2490)

The factors that influence the orbital lifetime characteristics of the NASA Space Station are discussed. These include altitude, attitude, launch date, ballistic coefficient, and the presence of large articulating solar arrays. Examples from previous program systems studies are presented that illustrate how each factor affects Station orbit lifetime. The effect of atmospheric density models on orbit lifetime predictions is addressed along with the uncertainty of these predictions using current trajectory analysis of the Long Duration Exposure Facility spacecraft. Finally, nominal reboost altitude profiles and fuel requirement considerations are presented for implementing a reboost strategy based on planned Shuttle Orbiter rendezvous strategy and contingency considerations. C.D.

N88-10080# Aeritalia S.p.A., Naples (Italy). Gruppo Sistemi Spaziale.
COLUMBUS PREPARATORY PROGRAM. PAYLOAD ELEMENT STUDY ON A TECHNOLOGY DEMONSTRATION MISSION, EXECUTIVE SUMMARY
F. BORLASTA, F. GIANI, R. SOCK, H. FRIEDERICH, T. WIERENGA, and J. PAIROT (MATRA Espace, Paris-Velizy, France) Paris, France ESA 15 Dec. 1986 77 p
(Contract ESA-6614/85-NL-PP(SC))
(CS-RP-AI-016; ESA-CR(P)-2401; ETN-87-90556) Avail: NTIS HC A05/MF A01

The review, further definition, and preliminary conceptual design of four technology demonstration model missions for possible performance on the Columbus module of the United States Space Station are summarized. Guidelines for potential users and the Columbus study team concerning the design of cost effective and user friendly space infrastructure for technology missions are given. The four technology model missions investigated were: Robotic Servicing Experiment; Fluid Transfer Management System; Large Structure Deployment/Assembly; and Tether System. Two additional concepts were selected by ESA for consideration: European Space Technology Exposure Facility and Technology Workbench. ESA

N88-10085*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
SPACECRAFT 2000 PROGRAM OVERVIEW
ROBERT W. BERCAW *In its* Spacecraft 2000 p 1-6 Jul. 1986
Avail: NTIS HC A11/MF A01 CSCL 22B

The goals are to identify the critical need and technologies for spacecraft of the 21st century, and to recommend technology development and validation programs and possible government/industrial roles and partnerships. The objectives of the workshop are to increase awareness and exchange ideas among participants, highlight the spacecraft as a focal point for technology, and facilitate industry-government coordination. B.G.

N88-10088*# National Aeronautics and Space Administration, Washington, D.C.
COMMUNICATION SATELLITE TECHNOLOGY TRENDS
LOUIS CUCCIA *In* NASA-Lewis Research Center, Spacecraft 2000 p 27-58 Jul. 1986
Avail: NTIS HC A11/MF A01 CSCL 22B

A chronology of space-Earth interconnectivity is presented. The Advanced Communications Technology Satellite (ACTS) system, Land Mobile Satellite, space-Earth antennas, impact of antenna size on coverage, intersatellite links are outlined. This presentation is represented by graphs and charts only. B.G.

N88-10625# Erlangen-Nuremberg Univ. (West Germany). Inst. fuer Physik.
ISIS: IMAGING SPECKLE INTERFEREOMETER IN SPACE
GERD WEIGELT *In* ESA, ESA Workshop on Optical Interferometry in Space p 69-72 Aug. 1987
Avail: NTIS HC A11/MF A01

The construction of a large multimirror interferometer in space is proposed. Resolution of 0.001 arcsec at 100 nm is feasible with a 20 m baseline. A shuttle launched 14 m linear array, a 2 dimensional, deployable 20 m array, and arrays of 6 to 20 free-flying telescopes with baselines up to 40 km and resolution of 0.000001 arcsec at 200 nm are possible. At short UV wavelengths a multimirror interferometer will produce speckle interferograms caused by misalignment of the interferometer. From the speckle interferograms true images can be reconstructed by the phase-closure method (if the exit pupil is a nonredundant array) or by speckle masking (for general pupils). In the case of bright objects the phase-closure method yields higher signal-to-noise ratio than speckle masking. In the case of faint objects speckle masking yields higher signal-to-noise ratio than the phase-closure method. The limiting magnitude of optical long-baseline interferometry in space is 24 or fainter. ESA

N88-10819*# National Academy of Sciences - National Research Council, Washington, D. C. Committee on Advanced Space Technology.
SPACE TECHNOLOGY TO MEET FUTURE NEEDS
1987 183 p Original contains color illustrations
(Contract NASW-4003)
(NASA-CR-181473; NAS 1.26:181473) Avail: NTIS HC A09/MF A01 CSCL 22A

Key technologies were identified where contemporary investments might have large payoffs in technological options for the future. The future needs were considered for space transportation, space science, national security, and manned missions. Eight areas were selected as being vital for the national future in space. Findings regarding representative mission and the recommendations concerning high priority technologies are summarized. B.G.

N88-10844*# Reliance Electric Co., Worthington, Ohio.
MOVING THE FACTORY INTO ORBIT
ROBERT DANNENFELSER, JR. *In* NASA- Goddard Space Flight Center, Greenbelt, Md. Fourteenth Space Simulation Conference: Testing for a Permanent Presence in Space p 163-174 1986
Avail: NTIS HC A19/MF A01 CSCL 22B

Prompted by the attention focused on the Space Shuttle Program's cost and safety problems and the publicity surrounding the intended U.S. space station, a review is given of the status of efforts being made to use space as a commercial manufacturing environment. Author

N88-10871*# National Aeronautics and Space Administration, Washington, D.C.
THE FLIGHT DEMONSTRATION PROGRAM AND SELECTION PROCESS
G. M. LEVIN *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 5-12 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The Orbital Refueling System (ORS); force torque sensor; Plasma Motor/Generator (PMG) proof of function; voice controlled system; infrared intercommunications; superfluid helium on orbit transfer; laser docking sensor; and the Small Expendable Deployment System (SEDS) are summarized. B.G.

N88-10873*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ACCESS FLIGHT HARDWARE DESIGN AND DEVELOPMENT

JOHN F. ROGERS and ROBIN D. TUTTEROW *In its* Space Construction p 31-53 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

Several items were found to be of immense value in the design and development of the Assembly Concept for Construction of Erectable Space Structures (ACCESS) hardware. The early availability of mock-up and engineering test hardware helped to develop the concept and prove the feasibility of the experiment. The extensive neutral buoyancy testing was invaluable in developing the procedures and timelines, proving that the hardware functioned as intended, and effectively trained the astronauts. The early involvement of the crew systems/astronaut personnel was extremely beneficial in shaping the design to meet the EVA compatibility requirements. Also, the early definition of coupled loads and on-orbit dynamic responses can not be overemphasized due to the relative uncertainty in the magnitude of these loads and their impact on the design. Author

N88-10875*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
MARSHALL SPACE FLIGHT CENTER'S ROLE IN EASE/ACCESS MISSION MANAGEMENT
GERALD W. HAWKINS *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 67-80 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The Marshall Space Flight Center (MSFC) Spacelab Payload Project Office was responsible for the mission management and development of several successful payloads. Two recent space construction experiments, the Experimental Assembly of Structures in Extravehicular Activity (EASE) and the Assembly Concept for Construction of Erectable Space Structures (ACCESS), were combined into a payload managed by the center. The Ease/ACCESS was flown aboard the Space Shuttle Mission 61-B. The EASE/ACCESS experiments were the first structures assembled in space, and the method used to manage this successful effort will be useful for future space construction missions. The MSFC mission management responsibilities for the EASE/ACCESS mission are addressed and how the lessons learned from the mission can be applied to future space construction projects are discussed. Author

N88-10876*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
A MONOGRAPH OF THE NATIONAL SPACE TRANSPORTATION SYSTEM OFFICE (NSTSO) INTEGRATION ACTIVITIES CONDUCTED AT THE NASA LYNDON B. JOHNSON SPACE CENTER FOR THE EASE/ACCESS PAYLOAD FLOWN ON STS 61-B
CHARLES CHASSAY *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 81-96 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The integration process of activities conducted at the NASA Lyndon B. Johnson Space Center (JSC) for the Experimental Assembly of Structures in Extravehicular activity (EASE)/Assembly Concept for Construction of Erectable Space Structures (ACCESS) payload is provided as a subset to the standard payload integration process used by the NASA Space Transportation System (STS) to fly payloads on the Space Shuttle. The EASE/ACCESS payload integration activities are chronologically reviewed beginning with the initiation of the flight manifesting and integration process. The development and documentation of the EASE/ACCESS integration requirements are also discussed along with the implementation of the mission integration activities and the engineering assessments supporting the flight integration process. In addition, the STS management support organizations, the payload safety process leading to the STS 61-B flight certification, and the overall EASE/ACCESS integration schedule are presented. Author

N88-10877*# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, Fla.
EASE/ACCESS GROUND PROCESSING AT KENNEDY SPACE CENTER
DEBORAH J. MOATES and ANA M. VILLAMIL *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 97-131 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The Kennedy Space Center (KSC) Payload Management and Operations Directorate is responsible for the processing of Space Shuttle payloads. The KSC responsibilities begin prior to hardware arrival at the launch site and extend until the experiments are returned to the investigators after the flight. The KSC involvement with the integration and checkout of payloads begins with participation in experiment, Mission Peculiar Equipment (MPE), and integrated payload design reviews. This involvement also includes participation in assembly and testing of flight hardware at the appropriate design center, university, or private corporation. Once the hardware arrives at the launch site, KSC personnel install the experiments and MPE onto a carrier in the Operations and Checkout (O & C) building. Following integration, the payload is functionally tested and then installed into the orbiter. After the mission, the payload is removed from the orbiter, deintegrated in the O & C building, and the experiments are turned over to the mission manager. One of the many payloads process at KSC consisted of two space construction experiments: the Experimental Assembly of Structures in Extravehicular Activity (EASE) and the Assembly Concept for Construction of Erectable Space Structures (ACCESS). The details of EASE/ACCESS integration, testing, and deintegration are addressed and how this mission can serve as a guide for future space construction payloads is discussed. Author

N88-10878*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
RESEARCH AND DEVELOPMENT AT THE MARSHALL SPACE FLIGHT CENTER NEUTRAL BUOYANCY SIMULATOR
VYGANTAS P. KULPA *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 142-152 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 14B

The Neutral Buoyancy Simulator (NBS), a facility designed to imitate zero-gravity conditions, was used to test the Experimental Assembly of Structures in Extravehicular Activity (EASE) and the Assembly Concept for Construction of Erectable Space Structures (ACCESS). Neutral Buoyancy Simulator applications and operations; early space structure research; development of the EASE/ACCESS experiments; and improvement of NBS simulation are summarized. B.G.

N88-10880*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
RESULTS OF THE ACCESS EXPERIMENT
WALTER L. HEARD, JR. and JUDITH J. WATSON *In its* Space Construction p 183-198 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

All basic EVA space construction tasks included in the experiment were accomplished on-orbit successfully, and the construction task time shows good correlation with neutral buoyancy data. However, the flight assembly times were slightly longer than the best times obtained in the water tank. This result was attributed by the EVA astronauts to the new, tighter tolerance truss hardware used on-orbit as opposed to the well-worn training hardware used in the neutral buoyancy and was, thus, not a space related phenomenon. The baseline experiment demonstrated that erectable structure can be assembled effectively by astronauts in EVA. The success of ACCESS confirmed the feasibility of EVA space assembly of erectable trusses and played a role in the decision to baseline the Space Station as a 5 meter erectable structure. Author

N88-10883# General Accounting Office, Washington, D. C. National Security and International Affairs Div.
SPACE STATION: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION'S 1987 COST ESTIMATE
Jul. 1987 20 p
(PB87-220760; NSIAD-87-180FS; B-227537) Avail: NTIS HC A03/MF A01 CSCL 22B

The report examines the coverage and methodology of the

National Aeronautics and Space Administration (NASA) space station cost review to explain how NASA had compiled and analyzed the data to support the cost estimate and to identify the categories of included costs. The GAO presented the results of the work in a briefing on 15 April 1987. The fact sheet summarizes and updates the information contained in that briefing. GRA

N88-12343*# Alabama Univ., Tuscaloosa. Dept. of Mathematics.
STOCHASTIC MODEL OF THE NASA/MSFC GROUND FACILITY FOR LARGE SPACE STRUCTURES WITH UNCERTAIN PARAMETERS: THE MAXIMUM ENTROPY APPROACH
WEI-SHEN HSIA 2 Dec. 1987 26 p
(Contract NAG8-081)
(NASA-CR-181489; NAS 1.26:181489) Avail: NTIS HC A03/MF A01 CSCL 12B

A stochastic control model of the NASA/MSFC Ground Facility for Large Space Structures (LSS) control verification through Maximum Entropy (ME) principle adopted in Hyland's method was presented. Using ORACLS, a computer program was implemented for this purpose. Four models were then tested and the results presented. B.G.

N88-12422# Committee on Science and Technology (U.S. House).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, 1988
Washington GPO 1987 19 p H.R. 2782 enacted into law by the 100th Congress, 2d session, 30 Oct. 1987
(PUB-LAW-100-147) Avail: US Capitol, House Document Room

Appropriations were authorized to the National Aeronautics and Space Administration for research and development; space flight, control, and data communications; constructions of facilities; and research and program management; and for other purposes. Author

N88-13374*# Massachusetts Inst. of Tech., Cambridge.
SURVEY ON LARGE SCALE SYSTEM CONTROL METHODS
MATHIEU MERCADAL 1987 20 p
(Contract NAG1-126)
(NASA-CR-181556; NAS 1.26:181556) Avail: NTIS HC A03/MF A01 CSCL 22B

The problem inherent to large scale systems such as power network, communication network and economic or ecological systems were studied. The increase in size and flexibility of future spacecraft has put those dynamical systems into the category of large scale systems, and tools specific to the class of large systems are being sought to design control systems that can guarantee more stability and better performance. Among several survey papers, reference was found to a thorough investigation on decentralized control methods. Especially helpful was the classification made of the different existing approaches to deal with large scale systems. A very similar classification is used, even though the papers surveyed are somehow different from the ones reviewed in other papers. Special attention is brought to the applicability of the existing methods to controlling large mechanical systems like large space structures. Some recent developments are added to this survey. Author

N88-13382* National Aeronautics and Space Administration, Washington, D.C.
SPACE STATION SYSTEMS: A BIBLIOGRAPHY WITH INDEXES
Nov. 1987 245 p
(NASA-SP-7056(05); NAS 1.21:7056(05)) Avail: NTIS HC A11 CSCL 22B

This bibliography lists 967 reports, articles, and other documents introduced into the NASA scientific and technical information system between January 1, 1987 and June 30, 1987. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design according to system, interactive analysis and design, structural and thermal analysis and design, structural concepts and control systems, electronics, advanced materials, assembly concepts, propulsion, and solar power satellite systems. The coverage includes documents that define major systems and subsystems, servicing and support requirements, procedures and operations, and missions for the current and future space station. Author

N88-14043# Committee on Appropriations (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION SPACE STATION PROPOSAL, FISCAL YEAR 1988
Washington GPO 1987 281 p Hearings before the Committee on Appropriations, 100th Congress, 1st Session, 1 and 20 May 1987
(S-HRG-100-328; GPO-76-948) Avail: Committee on Appropriations

Hearings were held to ascertain non-NASA expert opinion on the advisability of and options for a U.S. orbital space station. Scientists, academics, engineers, and businessmen expressed opinions on the desirability of funding a space station as opposed to other possible space priorities. The second day of hearings concentrated on opinions regarding the commercial potential of a space-station. J.P.B.

N88-14044# Committee on Science, Space and Technology (U.S. House).
THE 1988 NASA (NATIONAL AERONAUTICS AND SPACE ADMINISTRATION) AUTHORIZATION
Washington GPO 1988 77 p Hearing before the Subcommittee on Space Science and Applications of the Committee on Science, Space and Technology, 100th Congress, 1st Session, No. 43, 8 Apr. 1987
(GPO-80-245) Avail: Subcommittee on Space Science and Applications

Space Stations configuration and cost reviews are discussed in terms of the commitment of the United States to a permanently manned Space Station. Congressional approval to release Request for Proposals to industry for a phased development of the space station is sought, including estimates for an enhanced capability configuration. Also described is the revised baseline and the enhanced configuration. B.G.

N88-14854 Committee on Science, Space and Technology (U.S. House).
THE 1988 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA) AUTHORIZATION
Washington GPO 1987 1206 p Hearings before the Subcommittee on Space Science and Applications of the Committee on Science, Space and Technology, 100th Congress, 1st Session, No. 35, Vol. 2, 5, 24-25 Feb.; 3, 5, 10-11, 18-19, 31 Mar.; 23 Apr. and 6 May 1987
(GPO-76-600) Avail: Subcommittee on Space Science and Applications

The fiscal year 1988 budget request is examined for the National Aeronautics and Space Administration programs which include: orbital space station; resumption of shuttle flights; expendable launch vehicles (ELVs); research and development; space transportation system; construction; and Advanced Communication Technology Satellite (ACTS). B.G.

N88-15004# LABEN Space Instrumentation and Systems, Milan (Italy).
EXPERT SYSTEM STUDY FOR SPACECRAFT MANAGEMENT Final Report
P. DONZELLI, B. ANKERMOELLER, B. SOERENSEN, and R. KATZENBEISSER (Dornier-Werke G.m.b.H., Friedrichshafen, West Germany) Feb. 1987 110 p
(Contract ESA-6029/84)
(TL-2699-ISS-1; ESA-CR(P)-2445; ETN-88-91142) Avail: NTIS HC A06/MF A01

The feasibility with state of the art technology of an on-board expert system for management of an autonomous spacecraft was assessed. Requirements for the design, development and test of the expert system were specified. Fault management functions

were selected and knowledge about them was detailed for power and on-board data handling. The definition of such domain knowledge was supported by a knowledge specification formalism proposed by the knowledge engineers to the domain experts for the preliminary acquisition of all the information considered useful and necessary for the creation of the knowledge base. The development environment, and approaches for the testing, evaluation and validation of the prototype fault management system were studied. The impact of the use of on-board expert systems on ground/spacecraft communication protocols and on board complexity was assessed. ESA

N88-15930*# TRW, Inc., Redondo Beach, Calif.
SAMSS: AN IN-PROGRESS REVIEW OF THE SPACECRAFT ASSEMBLY, MAINTENANCE, AND SERVICING STUDY
WILLIAM W. BURT *In* NASA. Lewis Research Center, Cleveland, Ohio. Cryogenic Fluid Management Technology Workshop. Volume 1: Presentation Material and Discussion p 117-137 Sep. 1987
(Contract F04701-86-C-0032)
Avail: NTIS HC A17/MF A01 CSCL 20D

The Spacecraft Assembly, Maintenance, and Servicing Study (SAMSS) is an effort to define and verify the most cost effective approach to spacecraft servicing, as a alternative to replacement, in the 1990's and beyond. The intent of the study is to assess the servicing of satellites in all orbit regimes. Elements of a space servicing infrastructure are developed and cost estimates are generated. Readiness is assessed and proof of concept demonstrations are identified. Cryogenic fuel resupply is discussed. Author

N88-15932*# General Dynamics Corp., San Diego, Calif. Space Systems Div.
LARGE CAPACITY CRYOPROPELLANT ORBITAL STORAGE FACILITY
J. R. SCHUSTER *In* NASA. Lewis Research Center, Cleveland, Ohio. Cryogenic Fluid Management Technology Workshop. Volume 1: Presentation Material and Discussion p 151-174 Sep. 1987
Avail: NTIS HC A17/MF A01 CSCL 21I

A comprehensive study was performed to develop the major features of a large capacity orbital propellant storage facility for the space-based cryogenic orbital transfer vehicle. Projected propellant usage and delivery schedules can be accommodated by two orbital tank sets of 100,000 lb storage capacity, with advanced missions expected to require increased capacity. Information is given on tank pressurization schemes, propellant transfer configurations, pump specifications, the refrigeration system, and flight tests. R.J.F.

N88-16372*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
MTK: AN AI TOOL FOR MODEL-BASED REASONING Abstract Only
WILLIAM K. ERICKSON and MARY R. SCHWARTZ *In* NASA. Marshall Space Flight Center, Third Conference on Artificial Intelligence for Space Applications, Part 1 p 79 Nov. 1987
Avail: NTIS HC A18/MF A01 CSCL 09B

A 1988 goal for the Systems Autonomy Demonstration Project Office of the NASA Ames Research Center is to apply model-based representation and reasoning techniques in a knowledge-based system that will provide monitoring, fault diagnosis, control and trend analysis of the space station Thermal Management System (TMS). A number of issues raised during the development of the first prototype system inspired the design and construction of a model-based reasoning tool called MTK, which was used in the building of the second prototype. These issues are outlined, along with examples from the thermal system to highlight the motivating factors behind them. An overview of the capabilities of MTK is given. Author

N88-16417*# Auburn Univ., Ala. Dept. of Computer Science and Engineering.
PLANNING ACTIVITIES IN SPACE
KAI-HSIUNG CHANG *In* NASA. Marshall Space Flight Center, Third Conference on Artificial Intelligence for Space Applications, Part 1 p 315-319 Nov. 1987
Avail: NTIS HC A18/MF A01 CSCL 09B

Three aspects of planning activities in space are presented. These include generating plans efficiently, coordinating actions among multiple agents, and recovering from plan execution errors. Each aspect is discussed separately. Author

N88-16792* Rockwell International Corp., Downey, Calif. Space Station Systems Div.
SPACE STATION STRUCTURES DEVELOPMENT
V. B. TELLER Oct. 1986 332 p
(Contract NAS8-36421)
(NASA-CR-179261; NAS 1.26:179261; SSS-86-0133) Avail: NTIS HC A15 CSCL 22B

A study of three interrelated tasks focusing on deployable Space Station truss structures is discussed. Task 1, the development of an alternate deployment system for linear truss, resulted in the preliminary design of an in-space reloadable linear motor deployer. Task 2, advanced composites deployable truss development, resulted in the testing and evaluation of composite materials for struts used in a deployable linear truss. Task 3, assembly of structures in space/erectable structures, resulted in the preliminary design of Space Station pressurized module support structures. An independent, redundant support system was developed for the common United States modules. Author

N88-17710*# Norfolk Public Schools, Va. Science and Technology Advanced Research.
THE NORSTAR PROGRAM: SPACE SHUTTLE TO SPACE STATION
RONALD C. FORTUNATO *In* NASA. Goddard Space Flight Center, The 1987 Get Away Special Experimenter's Symposium p 133-140 Feb. 1988
Avail: NTIS HC A08/MF A01 CSCL 22A

The development of G-325, the first high school student-run space flight project, is updated. An overview is presented of a new international program, which involves students from space station countries who will be utilizing Get Away Special technology to cooperatively develop a prototype experiment for controlling a space station research module environment. Author

N88-17713# National Defense Univ., Washington, D. C.
AMERICA PLANS FOR SPACE
1986 201 p
(AD-A187465) Avail: NTIS HC A10/MF A01 CSCL 22A

A report on America's future plans for space exploration contains the following: Pursuing a Balanced Space Program; The Space Defense Initiative; Warfare in Space; The Lunar Laboratory; The Role of Space in Preserving the Peace; Living off the Land-the Use of Resources in Space for Future Civilian Space Operations; The Military Uses of Space; C3I(Command Control Communications and Intelligence); Aspects of Space Technology; Arms Control in Space: Preserving Critical Strategic Space Systems Without Weapons in Space; Space and Arms Control: A Skeptical View; Options for Space Arms Control; Space Arms Control. GRA

N88-18608*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ASSESSMENT OF MIXED FLEET POTENTIAL FOR SPACE STATION LAUNCH AND ASSEMBLY
L. J. DERYDER, ed. Dec. 1987 134 p
(NASA-TM-100550; NAS 1.15:100550) Avail: NTIS HC A07/MF A01 CSCL 22B

Reductions in expected STS flight rates of the Space Shuttle since the 51-L accident raise concerns about the ability of available launch capacity to meet both payload-to-orbit and crew rotation requirements for the Space Station. In addition, it is believed that some phases of Station build-up could be expedited using unmanned launch systems with significantly greater lift capacity than the STS. Examined is the potential use of expendable launch vehicles (ELVs), yet-to-be-developed unmanned shuttle-derived vehicles (SDVs), and international launch vehicles for meeting

overall launch requirements to meet Space Station program objectives as defined by the 1986 Critical Evaluation Task Force (CETF). The study concludes that use of non-STS transportation can help meet several important program objectives as well as reduce the total number of STS flights. It also finds, however, that reduction of Space Station-dedicated STS flights below 8 per year forces a reduction in Station crew size assuming the CETF 90 day crew stay time baseline and seriously impairs scientific utilization of the Station. Author

N88-19492# MATRA Espace, Toulouse (France).
ASSEMBLY AND SERVICING OF A EUROPEAN SPACE STATION
C. COUGNET *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 53-62 Nov. 1987
Avail: NTIS HC A21/MF A01

The implementation of a European manned space infrastructure as a follow-on to Columbus is discussed. The types of in orbit operations and the elements (vehicles, or other) required by the assembly and servicing of this Space Station are reviewed. Scenarios of construction are discussed with emphasis on the assembly of each Space Station element. The concept of a vehicle necessary for the transportation and assembly of the elements is featured. Analysis of the servicing scenarios highlights the types of servicing vehicle (Hermes, or logistics vehicle using an Ariane extended stage) maintenance operations, and manipulator systems. ESA

N88-19500# MATRA Espace, Toulouse (France).
UTILIZATION OF SMS AND EVA FOR THE SERVICING OF EUROPEAN SPACE STATION
C. COUGNET and T. BLAIS *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 127-137 Nov. 1987
Avail: NTIS HC A21/MF A01

It is shown how the service manipulator system (SMS) and extravehicular activity (EVA) can be used to perform servicing of a space station to succeed Columbus. Most of the external servicing tasks to be done on the Space Station consist of exchanging an orbital replacement unit; the others are related to refuelling, inspection, or repair. The alternative modes to perform these tasks and the problem of unloading the logistics vehicle are discussed. Alternative servicing modes: use of SMS alone, or astronaut in EVA supported by SMS are compared, and typical operation sequence, and modes of control command are reviewed. ESA

N88-19585*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
COST EFFECTIVE DEVELOPMENT OF A NATIONAL TEST BED
H. B. WAITES, V. L. JONES, and S. M. SELTZER (Control Dynamics Co., Huntsville, Ala.) Feb. 1988 18 p
(NASA-TM-100321; NAS 1.15:100321) Avail: NTIS HC A03/MF A01 CSCL 22B

For several years, the Marshall Space Flight Center has pursued the coordinated development of a Large Space Structures (LSS) National Test Bed for the investigation of numerous technical issues involved in the use of LSS in space. The origins of this development, the current status of the various test facilities and the plans laid down for the next five years' activities are described. Particular emphasis on the control and structural interaction issues has been paid so far; however, immediately emerging are user applications (such as the proposed pinhole occulter facility). In the immediate future, such emerging technologies as smart robots and multibody interactions will be studied. These areas are covered. Author

02

ANALYSIS AND DESIGN TECHNIQUES

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

A88-11793*# TRW, Inc., Redondo Beach, Calif.
ADVANCED PHOTOVOLTAIC SOLAR ARRAY DESIGN
RICHARD KURLAND (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) and PAUL STELLA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 103-114. refs
(Contract JPL-957358)

An ultralightweight flexible-blanket flatpack, foldout solar array design is defined. The design establishes a critical intermediate milestone of the NASA high-performance Advanced Photovoltaic Solar Array program through its primary objective of realistically demonstrating a solar array that can provide greater than 130 W/kg at beginning of life (BOL) and 100 W/kg at end of life for a 10-year geosynchronous 10-kW (BOL) space power system. This paper reviews the critical features of the preliminary design and the implications for long-term array technology development. Author

A88-12006*# Little (Arthur D.), Inc., Cambridge, Mass.
PERFORMANCE CHARACTERISTICS OF MOVING BELT RADIATORS
D. MCFADDEN and W. P. TEAGAN (Arthur D. Little, Inc., Cambridge, MA) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 4. New York, American Institute of Aeronautics and Astronautics, 1987, p. 2029-2033. NASA-supported research.

A design features and performance capabilities evaluation is made for a novel, 'hybrid belt radiator' spacecraft heat rejection system, which retains the excellent heat transfer capacity of liquid belt radiators but does not require the direct exposure of a free liquid surface to the space environment. Attention is given to the preliminary results of a computer model analyzing the dynamic behavior of the flexible belt structure due to spacecraft accelerations, as well as to the results of system studies determining size constraints on the radiator. Over the 300-700 K range of operating temperatures, Space Shuttle-stowable radiators with 10-200 MW thermal capacities can be designed. O.C.

A88-15960*# Cleveland State Univ., Ohio.
MODELLING THE PERFORMANCE OF THE MONOGROOVE WITH SCREEN HEAT PIPE FOR USE IN THE RADIATOR OF THE SOLAR DYNAMIC POWER SYSTEM OF THE NASA SPACE STATION
AUSTIN LEWIS EVANS (Cleveland State University, OH) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 8 p. refs
(Contract NCC3-50)
(IAF PAPER 87-238)

A computer code to model the steady-state performance of a monogroove heat pipe for the NASA Space Station is presented, including the effects on heat pipe performance of a screen in the evaporator section which deals with transient surges in the heat input. Errors in a previous code have been corrected, and the new code adds additional loss terms in order to model several different working fluids. Good agreement with existing performance curves is obtained. From a preliminary evaluation of several of the radiator design parameters it is found that an optimum fin width could be achieved but that structural considerations limit the thickness of the fin to a value above optimum. R.R.

A88-16293
MATHEMATICAL MODELS OF FLEXIBLE SPACECRAFT DYNAMICS - A SURVEY OF ORDER REDUCTION APPROACHES
P. TH. L. M. VAN WOERKOM (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 127-135. Research supported by the Nederlands Instituut voor Vliegtuigontwikkeling en Ruimtevaart. refs

Approaches to open loop model order reduction are evaluated with a view to the reduction of spacecraft mathematical dynamics model complexity. These approaches may be characterized as those of (1) parameter optimization, (2) aggregation, (3) singular perturbation, (4) modal dominance, (5) component cost analysis, and (6) internal balancing. The latter three approaches are judged to be the most significant, and are applied to the case of a long flexible beam in space that is controlled by two line torquers. O.C.

A88-17555
GEOMETRIC OPTIMIZATION AND DISCRETE VARIABLES OPTIMIZATION OF ANTENNA STRUCTURES
YUGENG ZENG, JINGSHENG LIU, and XIANGDONG XUE (Northwest Telecommunication Engineering Institute, Xian, People's Republic of China) IN: International Conference on Antennas and Propagation, 5th, York, England, Mar. 30-Apr. 2, 1987, Proceedings. Part 1. London, Institution of Electrical Engineers, 1987, p. 237-240. refs

A method for geometric optimization, minimization of the total weight, and improvement of the accuracy of antenna structures is proposed. Both the cross-sectional areas of the bars and the positions of the joints are treated as design variables in minimizing structural total weight. Having achieved the continuous optimal design point, a discrete optimization of the antenna is performed, with the rms taken as the objective function and the already minimized structural total weight taken as one of the main constraints. A method for transforming discrete variables into binary variables is proposed. R.R.

A88-19240#
DIRECT UPDATE OF DYNAMIC MATHEMATICAL MODELS FROM MODAL TEST DATA
BERND CAESAR (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) and JOERG PETER (Darmstadt, Technische Hochschule, Federal Republic of Germany) AIAA Journal (ISSN 0001-1452), vol. 25, Nov. 1987, p. 1494-1499. refs
(Contract ESA-5597/83/PB/SC)

Minimum required constraints derived from eigendynamic and force equilibrium conditions are obtained for two methods capable of directly updating mathematical models based on modal test data; the methods generate mass and stiffness matrices fitted exactly to the test data. While one method changes all coefficients of the mass with respect to the stiffness matrix, and minimizes solution effort through the algebraic elimination of Lagrangian multipliers, the other changes only those selected matrix coefficients that require additional solutions for the Lagrangian multipliers' numerical calculation. O.C.

A88-21642* Mitre Corp., Houston, Tex.
AN APPROACH TO DESIGN KNOWLEDGE CAPTURE FOR THE SPACE STATION
D. B. WECHSLER (Mitre Corp., Houston, TX) and K. R. CROUSE (NASA, Johnson Space Center, Houston, TX) IN: Space Station automation II; Proceedings of the Meeting, Cambridge, MA, Oct. 28-30, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 106-113. Previously announced in STAR as N87-12597. refs

The design of NASA's space station has begun. During the design cycle, and after activation of the space station, the reoccurring need will exist to access not only designs, but also deeper knowledge about the designs, which is only hinted in the design definition. Areas benefiting from this knowledge include training, fault management, and onboard automation. NASA's Artificial Intelligence Office at Johnson Space Center and The MITRE Corporation have conceptualized an approach for capture and storage of design knowledge. Author

A88-25979
THERMAL ENVIRONMENT SIMULATOR FOR VACUUM TESTING OF LARGE SPACECRAFT
T. S. MARSHALL (Martin Marietta Corp., Denver, CO) (Institute of Environmental Sciences and Aerospace Corp., Aerospace Testing Seminar, 10th, Los Angeles, CA, Mar. 10-12, 1987) Journal of Environmental Sciences (ISSN 0022-0906), vol. 31, Jan.-Feb. 1988, p. 29-32, 49.

A thermal environment simulator (TES) with 56 independently controllable temperature zones has been developed for Martin Marietta's Space Simulation Laboratory. This simulator is designed to test Shuttle payloads in a thermal vacuum chamber with liquid nitrogen cloud walls. The thermal environment simulator is an alternative to a 4.9-m (16-ft) diameter vertical beam solar simulator and two-axis gimbal system. The simulator can accommodate larger test articles at a lower cost. It provides complex heat flux distributions by surrounding the test articles with a multifaceted temperature environment. Issues resolved during initial operation included vacuum and cryogenic compatibility, control capabilities, instrumentation, calibration, heat flux uniformity, and reliability. Author

A88-27148
SYNTHESIS OF THE FLEXIBLE STRUCTURES OF COMPLEX SYSTEMS [SINTEZ GIBKIKH STRUKTUR SLOZHNYKH SISTEM]
M. A. MUZIUKIN and V. K. AKINFIEV IN: Methods for the optimization of complex systems. Moscow, Izdatel'stvo Nauka, 1987, p. 54-63. In Russian.

The problem of improving the structure and increasing the efficiency of globally distributed information/control systems is examined with particular reference to the automatic control systems of flight vehicles. The problem of the synthesis of the flexible structure of complex systems is formulated as a nonlinear mathematical programming problem. An optimization-simulation approach to the solution of such problems is proposed which involves the development of procedures using optimization and simulation or computational models for the synthesis of the optimal version of the structure. V.L.

A88-27781#
ABSORPTIVE TETHERS - A FIRST TEST IN SPACE
W. J. OCKELS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) ESA Journal (ISSN 0379-2285), vol. 11, no. 3, 1987, p. 355-358.

This paper preents a new concept for an absorptive tether (patent application in process) to be used for spaceborne proximity operations and positioning in general. The passive means by which friction is introduced facilitates certain operations in space, and makes them safer. An absorptive tether of the type described was flown on the German Spacelab D-1 mission in November 1985. Author

A88-28042#
OPTIMUM DESIGN OF STRUCTURES WITH MULTIPLE CONSTRAINTS
R. A. CANFIELD, V. B. VENKAYYA (USAF, Wright-Patterson AFB, OH), and R. V. GRANDHI (Wright State University, Dayton, OH) (Structures, Structural Dynamics, and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 1, p. 398-408) AIAA Journal (ISSN 0001-1452), vol. 26, Jan. 1988, p. 78-85. USAF-supported research. Previously cited in issue 18, p. 2617, Accession no. A86-38845. refs

A88-28043*# California Univ., Los Angeles.
CONTROL-AUGMENTED STRUCTURAL SYNTHESIS
R. V. LUST and L. A. SCHMIT (California, University, Los Angeles) AIAA Journal (ISSN 0001-1452), vol. 26, Jan. 1988,

p. 86-95. refs
(Contract NSG-1490)
(AIAA PAPER 86-1014)

A control-augmented structural synthesis methodology is presented in which the structural member sizes and active control system feedback gains are treated simultaneously as independent design variables. Multiple static and harmonic dynamic loading conditions are considered. Constraints are imposed on static displacements, natural frequencies, and the magnitudes of the steady-state dynamic displacements and actuator forces to ensure acceptable system behavior. Side constraints imposed on the design variables protect against the generation of unrealizable designs. Example problems are presented that demonstrate the method and underscore the importance of integrating the structural and active control system design process. Author

A88-31380#
DESIGN AND DEVELOPMENT OF THE TRUSS ASSEMBLY FIXTURE FOR SPACE STATION ASSEMBLY OPERATIONS
CHARLES SCOTT MACGILLIVRAY (Rockwell International Corp., Satellite and Space Electronics Div., Seal Beach, CA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 23-31.
(AIAA PAPER 88-2455)

This paper describes the Truss Assembly Fixture design evolution based on the state of on-orbit assembly technology and the Space Station design. The main design requirements and constraints are identified, and interfacing systems are discussed. The results of testing performed to date, including full-scale engineering mockup evaluations in both laboratory and underwater neutral buoyancy environments, are discussed. C.D.

A88-32190*# California Univ., Santa Barbara.
AN EFFICIENT MULTILEVEL OPTIMIZATION METHOD FOR ENGINEERING DESIGN
G. N. VANDERPLAATS, Y. J. YANG, and D. S. KIM (California, University, Santa Barbara) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 125-132. refs
(Contract NAG1-567)
(AIAA PAPER 88-2226)

An efficient multilevel design optimization technique is presented. The proposed method is based on the concept of providing linearized information between the system level and subsystem level optimization tasks. The advantages of the method are that it does not require optimum sensitivities, nonlinear equality constraints are not needed, and the method is relatively easy to use. The disadvantage is that the coupling between subsystems is not dealt with in a precise mathematical manner. Author

A88-32284#
OPTIMAL ON-LINE MEASUREMENT SYSTEM CONFIGURATION STRATEGIES
YAAKOV OSHMAN and DANIEL J. INMAN (New York, State University, Buffalo) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1048-1058. refs
(AIAA PAPER 88-2341)

This paper introduces a new measurement system optimization technique which can be implemented on-line in time-varying, continous-time systems. A case in which several measurement subsystems are available, each one of which may serve to drive a state estimation algorithm, is considered. However, due to practical implementation constraints, only one of these sybsystems can actually be used at a time. An algorithm is needed, by which the optimal measurement subsystem to be used at a certain time interval is selected at each measurement configuration epoch. The approach taken to solve this problem is based on using the square root continuous-time V-lambda filter as the underlying state estimation algorithm. This algorithm continously provides its user with the special factors of the estimation error covariance matrix, which are, in turn, used in this work as the basis for an on-line decision procedure by which the optimal measurement strategy is derived. A numerical example is presented, which demonstrates the performance of the new algorithm. Author

A88-32293*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MULTIPLE BOUNDARY CONDITION TEST (MBCT) - IDENTIFICATION WITH MODE SHAPES
C. P. KUO and B. K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1132-1142. refs
(AIAA PAPER 88-2353)

The multiple boundary condition test (MBCT) approach is a ground test method to test a class of large flexible structures which cannot be ground tested by state-of-the-art test methods due to the adverse terrestrial environment. The ultimate objective of a ground test is considered to be the validation and update of a mathematical model of the structure. The research to date has indicated the MBCT does work on numerical simulations and on experimental laboratory hardware. To date only the eigenvalue has been used in the model correlation/update by inclusion of the information in the nonlinear terms resulting from the difference between the analytical and measured eigenvectors. This paper presents the results of utilizing additional information, namely the difference in the analytical and the test eigenvectors, in the validation and update of the mathematical model. Author

A88-32355#
THE COMPONENT-MODE METHOD IN A PARALLEL COMPUTER ENVIRONMENT
DUC T. NGUYEN, JAE-SOO SHIM (Old Dominion University, Norfolk, VA), and YONGXING ZHANG IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1705-1710. refs
(AIAA PAPER 88-2438)

In this paper, a version of the component-mode technique is reexamined and a 'global-local' parallel procedure for eigenvalue analysis is presented. Parallel computation at the global level is achieved by using the component-mode method. At the local level, parallel computation is achieved by coupling the subspace iteration technique with a parallel version of the generalized Jacobi iteration technique. Numerical examples are provided to validate the proposed procedure. Author

A88-32356#
TORTURING RECURSIVE PARAMETER IDENTIFICATION ALGORITHMS WITH A GAP NONLINEARITY
ANDREAS VON FLOTOW (MIT, Cambridge, MA) and SCOTT E. SCHAFFER IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1711-1718. refs
(AIAA PAPER 88-2439)

This paper examines the performance of the recursive least squares (RLS) algorithm and a derivative, the recursive lattice least squares (RLLS) algorithm in matching a linear model to a simple nonlinear model. The response of a single degree of freedom mass-spring-dashpot system to continuous forcing is simulated, and estimates for the modal parameters are obtained. Nonlinearity is introduced by allowing the restoring spring to slide without friction in a gap of specified width. Such a nonlinearity is of interest since it is a simple model of the effect of loose joints in a deployable spacecraft structure. The RLS algorithm is found to be the most reliable. Author

N88-10387# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
A DMAP FOR UPDATING DYNAMIC MATHEMATICAL MODELS WITH MEASURED DATA
A. DEBOER and B. W. KOOI 11 Apr. 1986 25 p Presented at the MSC/NASTRAN European User's Conference, Munich, Fed. Republic of Germany
(Contract NIVR-1053)
(NLR-MP-86027-U; B8701064; ETN-87-90826) Avail: NTIS HC A03/MF A01

Two matrix correction methods are evaluated using a simple beam and a simple plate structure. Experimental data are obtained for the plate with an impact test and simulated in case of the beam. The structures were modelled with MSC/NASTRAN. To facilitate the comparison the Guyan reduction method was applied to calculate the natural frequencies and normal modes, and the position of the excitation points used in the tests coincide with the ASET. Both updating methods were programmed in DMAP. The results of the finite element calculation are obtained from the (old) problem tape and the experimental date are brought into the DMAP by bulk data cards. It is concluded that within MSC/NASTRAN the DMAP programming is a convenient facility to use for matrix correction methods. To guarantee the physical relevance of the updated matrices, the update methods have to be used with correlation methods. ESA

N88-12535 Virginia Polytechnic Inst. and State Univ., Blacksburg.
NEW FEEDBACK DESIGN METHODOLOGIES FOR LARGE SPACE STRUCTURES: A MULTI-CRITERION OPTIMIZATION APPROACH Ph.D. Thesis
DONG-WON REW 1987 228 p
Avail: Univ. Microfilms Order No. DA8719050

Three new feedback design algorithms are presented: (1) a generalized linear-quadratic regulator (LQR) formulation; (2) a generalized LQR formulation based on Lyapunov stability theorem; and (3) an eigenstructure assignment method using Sylvester's equation. In addition, a noniterative robust eigenstructure assignment algorithm via a projection method is introduced, which produces a fairly well-conditioned eigenvector matrix and provides an excellent starting solution for optimizations of various design criteria. Finally, two sets of numerical examples are adopted: 6th order mass-spring systems and various reduced order models of a flexible system. The numerical results confirm that the use of multi-criterion optimizations by using a minimum correction homotopy technique is a useful tool with significant potential for enhanced computer-aided design of control systems. The robust eigenstructure assignment algorithm is implemented and tested for a 24th reduced order model, which establishes the approach to be applicable to systems of at least moderate dimensionality. It is shown analytically and computationally that constraining closed-loop eigenvectors to equal open-loop eigenvectors generally does not lead to either optimal conditioning (robustness) of the closed-loop eigenvectors or minimum gain norm. Dissert. Abstr.

N88-13294# Brown Univ., Providence, R. I. Div. of Applied Mathematics.
COMPUTATIONAL METHODS FOR PROBLEMS IN AERODYNAMICS AND LARGE SPACE STRUCTURE USING PARALLEL AND VECTOR ARCHITECTURES Final Report
DAVID GOTTLIEB 1987 7 p
(Contract AF-AFOSR-85-0303; AF PROJ. 2304)
(AD-A185401; AFOSR-87-1189TR) Avail: NTIS HC A02/MF A01 CSCL 01C

One paper produced in this effort dealt with the importance of intermediate boundary conditions for approximate factorization schemes. A second paper derived stability results for spectral methods applied to initial-boundary value problems for hyperbolic systems. The paper demonstrates that one can bound certain weighted L2 spatial norms of the solution in terms of norms of the boundary data. A third paper deals with domain decomposition methods in the content of spectral techniques. Stability and convergence results are obtained for one and two dimensional cases. GRA

N88-13369*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DESIGN AND ASSEMBLY SEQUENCE ANALYSIS OF OPTION 3 FOR CETF REFERENCE SPACE STATION
L. BERNARD GARRETT, GREGORY C. ANDERSEN, JOHN B. HALL, JR., CHERYL L. ALLEN, A. D. SCOTT, JR., and KENNETH T. SO (Rockwell International Corp., Downey, Calif.) Nov. 1987 83 p
(NASA-TM-100503; NAS 1.15:100503) Avail: NTIS HC A05/MF A01 CSCL 22B

A design and assembly sequence was conducted on one option of the Dual Keel Space Station examined by a NASA Critical Evaluation Task Force to establish viability of several variations of that option. A goal of the study was to produce and analyze technical data to support Task Force decisions to either examine particular Option 3 variations in more depth or eliminate them from further consideration. An analysis of the phasing assembly showed that use of an Expendable Launch Vehicle in conjunction with the Space Transportation System (STS) can accelerate the buildup of the Station and ease the STS launch rate constraints. The study also showed that use of an Orbital Maneuvering Vehicle on the first flight can significantly benefit Station assembly and, by performing Station subsystem functions, can alleviate the need for operational control and reboost systems during the early flights. In addition to launch and assembly sequencing, the study assessed stability and control, and analyzed node-packaging options and the effects of keel removal on the structural dynamics of the Station. Results of these analyses are presented and discussed. Author

N88-13907*# Catholic Univ. of America, Washington, D.C. Dept. of Electrical Engineering.
OPTIMAL CONTROL OF LARGE SPACE STRUCTURES VIA GENERALIZED INVERSE MATRIX
CHARLES C. NGUYEN and XIAOWEN FANG 1987 5 p
(Contract NAG5-949)
(NASA-CR-182336; NAS 1.26:182336) Avail: NTIS HC A02/MF A01 CSCL 09B

Independent Modal Space Control (IMSC) is a control scheme that decouples the space structure into n independent second-order subsystems according to n controlled modes and controls each mode independently. It is well-known that the IMSC eliminates control and observation spillover caused when the conventional coupled modal control scheme is employed. The independent control of each mode requires that the number of actuators be equal to the number of modelled modes, which is very high for a faithful modeling of large space structures. A control scheme is proposed that allows one to use a reduced number of actuators to control all modeled modes suboptimally. In particular, the method of generalized inverse matrices is employed to implement the actuators such that the eigenvalues of the closed-loop system are as closed as possible to those specified by the optimal IMSC. Computer simulation of the proposed control scheme on a simply supported beam is given. Author

N88-14115*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
CONTINUUM MODELING OF LARGE LATTICE STRUCTURES: STATUS AND PROJECTIONS
AHMED K. NOOR and MARTIN M. MIKULAS, JR. Feb. 1988 79 p
(NASA-TP-2767; L-16360; NAS 1.60:2767) Avail: NTIS HC A05/MF A01 CSCL 22B

The status and some recent developments of continuum modeling for large repetitive lattice structures are summarized. Discussion focuses on a number of aspects including definition of an effective substitute continuum; characterization of the continuum model; and the different approaches for generating the properties of the continuum, namely, the constitutive matrix, the matrix of mass densities, and the matrix of thermal coefficients. Also, a

simple approach is presented for generating the continuum properties. The approach can be used to generate analytic and/or numerical values of the continuum properties. Author

N88-15000# Army Construction Engineering Research Lab., Champaign, Ill.
INVESTIGATION OF DESIGN CONCEPTS FOR LARGE SPACE STRUCTURES TO SUPPORT MILITARY APPLICATIONS Final Report
R. A. EUBANKS and ALVIN SMITH Sep. 1987 34 p
(AD-A186098; CERL-TR-M-87/16) Avail: NTIS HC A03/MF A01 CSCL 22B

Future exploration and enterprise in low-Earth orbit will most likely require space stations for support. In addition, promotion of the Strategic Defense Initiative is mandating research and development into technologies for building structures to serve military objectives in space. However, an assessment of the state of the art for space construction technology has revealed that the field is immature, with little conceptual and experimental research completed. The U.S. Army Construction Engineering Research Laboratory (USA-CERL) has collected information on existing technologies for possible application in designing large space structures (LSS) for military support. This work is part of an effort to ensure mission-responsiveness in anticipation of a role in space construction. Military structures will require design criteria much different from those of experimental space stations. Proposed conceptual criteria for both types of structures are compared and differences are noted. Much R and D is needed before any of these structures can be developed in space. To serve as background for future studies, a literature critique is included in this report. GRA

N88-16812*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
EMULATING A FLEXIBLE SPACE STRUCTURE: MODELING
H. B. WAITES, S. C. RICE, and V. L. JONES (Control Dynamics Co., Huntsville, Ala.) Feb. 1988 22 p
(NASA-TM-100320; NAS 1.15:100320) Avail: NTIS HC A03/MF A01 CSCL 22B

Control Dynamics, in conjunction with Marshall Space Flight Center, has participated in the modeling and testing of Flexible Space Structures. Through the series of configurations tested and the many techniques used for collecting, analyzing, and modeling the data, many valuable insights have been gained and important lessons learned. This paper discusses the background of the Large Space Structure program, Control Dynamics' involvement in testing and modeling of the configurations (especially the Active Control Technique Evaluation for Spacecraft (ACES) configuration), the results from these two processes, and insights gained from this work. Author

N88-17106# British Aerospace Dynamics Group, Bristol (England). Space and Communications Div.
STUDY OF LARGE SOLAR ARRAYS (SOLA), PHASE 2A Final Report
J. POPE, comp., C. P. LEE, R. K. BRADFORD, E. WINTER, H. BEBERMEIER, G. BEHRENS, W. SCHMITT, and H. AKISTER (Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost.) Paris, France ESA Jul. 1983 54 p
(Contract ESA-4903/81-NL-JS(SC))
(BAE-SS/1109; ESA-CR(P)-1819-VOL-1; ETN-87-90511) Avail: NTIS HC A04/MF A01

It is shown that it is feasible to manufacture a basic module from which arrays of various sizes can be constructed within acceptable limits defined by power losses and power to weight criteria in the range from 15 to 30 kW, in steps of 2 kW, with a choice of low (52 V) or high (156 V) operating voltage levels. This modular design can be extended to provide array system powers up to 60 kW, although above 30 kW, only the high voltage operating level is practical, due to the high resistive power losses associated with the length of array, hence harness, required for such operating power levels. Operating levels are 30 W/kg at 15 kW and 42 W/kg at 30 kW. These levels could be increased by optimizing the design for specific operating power levels, but at the expense of modularity. It is unlikely that the 50 W/kg goal can be reached. Author (ESA)

N88-17730# National Aerospace Lab., Tokyo (Japan).
FORMULATION METHODS OF RIGID MULTIBODY SYSTEMS FOR LARGE SPACE STRUCTURES AND SOME RESULTS OF COMPUTER SIMULATION
YOSHIAKI OHKAMI, OSAMU OKAMOTO, TAKASHI KIDA, ISAO YAMAGUCHI, KATSUHIKO YAMADA, and KAZUO TSUCHIYA Aug. 1987 19 p In JAPANESE; ENGLISH summary
(NAL-TR-942; ISSN-0389-4010) Avail: NTIS HC A03/MF A01

A comparative study of the simulation algorithms for dynamics of large space structures modeled as a collection of rigid multibodies connected by hinges is described. Two algorithms have been independently developed at two research institutes. One method is based upon the well-known Euler Newton formulation and the unified matrix approach. The unified matrix approach solves the dynamical equation for the derivatives of the non-holonomic velocities and the internal torques and forces simultaneously, hence permitting us to deal with an arbitrary large space structure (LSS) configuration. The other method provides for an efficient and fast algorithm based on Kane's method with modification in the inertia dyadic and other quantities. Both methods have been applied to two typical examples: the first is a satellite with four-link manipulator as a model of a chain structure, and the second is a satellite with a closed loop deployment mechanism. The results coincide satisfactorily and the validity of the two methods has been proven perfectly. The numerical values given in this report will be useful as a reference in other simulations. Author

N88-19493# Erno Raumfahrttechnik G.m.b.H., Bremen (West Germany).
AUTOMATIC IN-ORBIT PAYLOAD DEPLOYMENT MECHANISMS, LOGISTIC OPERATIONS AND TRANSPORT VEHICLE DESIGN COMPATIBILITIES
S. GRAUL *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 63-70 Nov. 1987
Avail: NTIS HC A21/MF A01

Three in-orbit deployment and loading mechanisms integrated into an advanced space transport system called LART are presented. The design parameters are the reduction of operation costs for payload loading and deployment and the reduction of the complexity of the mechanism. The influence of both parameters leads to a telescope mechanism as well as to two advanced long-term concepts, which are a tethered end effector and an autonomous operating payload container. For the telescope mechanism structural and dynamical aspects are outlined. ESA

N88-19532# National Aerospace Lab., Amsterdam (Netherlands).
DEFINITION OF THE EUROSIM SIMULATION SUBSYSTEM
C. N. A. PRONK, E. ERSUE, A. L. LIPPAY, and A. ELFVING (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 421-429 Nov. 1987
Avail: NTIS HC A21/MF A01

Requirements for the simulation software of the European Robotics Operations Simulator (EUROSIM) are discussed. A detailed complete specification of the simulation software is not possible due to the wide scope of EUROSIM. Therefore, detailed specifications were given for the kernel model software, i.e., the manipulator models, and high level descriptions for the related models and the simulation definition and control support software. From the study results it should be possible to define a conceptual design of the system/software architecture. With that design and the baseline requirements detailed software requirements can be specified. The various software elements, identified to be part of the simulation subsystem, were specified and development and cost estimates were given in order to arrive at the basic non real-time and real-time operational capabilities. ESA

03

STRUCTURAL CONCEPTS

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

A88-15967#
A GENERAL TRUSS SYSTEM FOR VERY LARGE SPACE BASE FOUNDATIONS, WITH APPLICATION TO THE SOLAR POWER SATELLITE
ANTHONY P. COPPA (General Electric Co., Astro Space Div., Philadelphia, PA) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 11 p. refs
(IAF PAPER 87-248)

The paper presents a general three-dimensional truss system (COPPATRUSS) that appears uniquely capable of satisfying the requirements for very large foundation structures in space. The currently patented system obtains perhaps the highest structural efficiency (strength/mass and stiffness/mass) possible in a general space truss. In addition it offers great architectural variety, modularity, fabrication economy, low package volume for launch, and rapid, principally automated, assembly in space. An example of an application to the Solar Power Satellite is discussed. Author

A88-16017#
TWO-DIMENSIONALLY DEPLOYABLE 'SHDF' TRUSS
JUNJIRO ONODA, NAOYUKI WATANABE, KAZUO ICHIDA (Tokyo, University, Japan), and HISASHI SAITO (Saito Co., Ltd., Tokyo, Japan) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 9 p. refs
(IAF PAPER 87-319)

The present paper describes a newly invented two-dimensionally deployable truss structure named SHDF, which has no articulated members. The most significant feature of SHDF truss is the very small number of the mechanisms to be actuated and locked at the deployment. A globally flat functional model actuated by tiny electromagnetic motors was designed and fabricated. The model demonstrated its practicality and virtually synchronized smooth motion in deploy/fold tests. Subsequently, the model was reformed into a globally parabolic configuration and combined with a one-dimensionally deployable truss named SHSF, which is also newly invented. Further deploy/fold tests similarly demonstrated the practicality of parabolic SHDF truss structure and the compatibility of SHDF with SHSF. Author

A88-16996* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
LARGE SPACE STRUCTURES TESTING
HENRY WAITES (NASA, Marshall Space Flight Center, Huntsville, AL) and H. EUGENE WORLEY (Control Dynamics Co., Huntsville, AL) IN: Guidance and control 1987; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 31-Feb. 4, 1987. San Diego, CA, Univelt, Inc., 1987, p. 353-370. Previously announced in STAR as N87-24520.
(AAS PAPER 87-036)

There is considerable interest in the development of testing concepts and facilities that accurately simulate the pathologies believed to exist in future spacecraft. Both the Government and Industry have participated in the development of facilities over the past several years. The progress and problems associated with the development of the Large Space Structure Test Facility at the Marshall Flight Center are presented. This facility was in existence for a number of years and its utilization has run the gamut from total in-house involvement, third party contractor testing, to the mutual participation of other goverment agencies in joint endeavors. Author

A88-18637*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
VERIFICATION OF LARGE BEAM-TYPE SPACE STRUCTURES
CHOON-FOO SHIH (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 1, p. 78-84) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Sept.-Oct. 1987, p. 469-473. Previously cited in issue 18, p. 2654, Accession no. A86-38809. refs

A88-22345*# LTV Missiles and Electronics Group, Dallas, Tex.
SPACE ERECTABLE RADIATOR SYSTEM DEVELOPMENT
J. A. OREN (LTV Corp., Missiles Div., Dallas, TX) and H. R. HOLMES (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 14 p. refs
(Contract NAS9-17495)
(AIAA PAPER 88-0469)

The NASA Space Station's Space Erectable Radiator System features modular radiator panels with high-capacity tapered artery heat pipes bonded within their aluminum honeycomb structures. Simple, dry aluminum-to-aluminum thermal contact surfaces are used for the connections, thereby requiring no fluid joints; a uniformly distributed clamping force at the radiator panel-to-thermal transport loop interface heat exchange surface yields high thermal contact conductance as well as minimum area and weight for the requisite performance. The design has been optimized for weight and cost. O.C.

A88-27743
DEPLOYABLE UMBRELLA REFLECTOR ANTENNAS [RAZVERTYVAEMYE ZERKAL'NYE ANTENNY ZONTICHNOGO TIPA]
MIKHAIL VASIL'EVICH GRIANIK and VLADIMIR IVANOVICH LOMAN Moscow, Izdatel'stvo Radio i Sviaz', 1987, 72 p. In Russian. refs

Aspects of the design of axisymmetric and axially asymmetric deployable umbrella reflector antennas are examined. An electrodynamic analysis of one-reflector and two-reflector umbrella antennas is presented; techniques for enhancing the efficiency of umbrella antennas are described; and the radiation characteristics of such antennas are calculated. B.J.

A88-27886#
NUMERICAL ANALYSIS OF INTERACTION OF A HIGH-VOLTAGE SOLAR ARRAY WITH IONOSPHERIC PLASMA
KYOICHI KURIKI (Tokyo, University, Japan) and HITOSHI KUNINAKA Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Nov.-Dec. 1987, p. 512-517. refs

Three-dimensional analysis of the solar array that exposes the surfaces at a relatively high potential and flies in the ionospheric plasma was conducted. For the standard ionospheric conditions, the drain power was calculated at about 0.3 percent of the solar generated power, which is rather insignificant. On the other hand, the ion forces were found to be enhanced by the large electric potential difference between the solar array and the plasma and must affect significantly the motion of spacecraft with the neutral particle drag. Author

A88-30320#
ROLL-OUT-FIN EXPANDABLE SPACE RADIATOR CONCEPT
R. PONNAPPAN (Universal Energy Systems, Inc., Dayton, OH), J. E. BEAM, and E. T. MAHEFKEY (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 2, Jan. 1988, p. 91-94. USAF-sponsored research. Previously cited in issue 18, p. 2621, Accession no. A86-39924. refs

A88-30999*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
LARGE SPACE STRUCTURES - STRUCTURAL CONCEPTS AND MATERIALS
CHARLES P. BLANKENSHIP and ROBERT J. HAYDUK (NASA, Langley Research Center, Hampton, VA) SAE, International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987. 30 p. refs
(SAE PAPER 872429)

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

A88-31377*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
STRUCTURES AND MATERIALS TECHNOLOGY FOR SPACE STATION
CHARLES P. BLANKENSHIP and JAMES C. YU (NASA, Langley Research Center, Hampton, VA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1-6. refs
(AIAA PAPER 88-2446)

This paper provides a brief overview of the NASA Langley structures and materials technology program for large space structures. Concepts developed for constructing large space truss structures such as space platforms and antennas are considered. The applications of the finding to the Space Station initiative are addressed. C.D.

A88-31383*# Texas A&M Univ., College Station.
NONDESTRUCTIVE CONSTRUCTION ERROR DETECTION IN LARGE SPACE STRUCTURES
NORRIS STUBBS (Texas A & M University, College Station), TAFT H. BROOME (Howard University, Washington, DC), and ROBERTO OSEGUEDA (Texas, University, El Paso) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 47-55. Research supported by Texas A & M University. refs
(Contract NAG1-383)
(AIAA PAPER 88-2460)

Continuum modeling of large space structures is extended to the problem of detecting construction errors in large space structures such as the proposed space station. First-order dynamic sensitivity equations for structures involving eigenfrequencies, modal masses, modal stiffnesses, and modal damping are presented. Matrix equations relating changes in element parameters to dynamic sensitivities are summarized. The sensitivity equations for the entire dynamical system are rearranged as a system of algebraic equations with unknowns of stiffness losses at selected locations. The feasibility of the formulation is numerically demonstrated on a simply-supported Euler-Bernouilli beam with simulated construction defects. The method is next extended to large space structures modelled as equivalent continua with simulated construction defects. Author

A88-31384#
DAMAGE DETECTION AND LOCATION IN LARGE SPACE TRUSSES
SCOTT L. HENDRICKS (Virginia Polytechnic Institute and State University, Blacksburg) and SUZANNE WEAVER SMITH IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 56-63. refs
(AIAA PAPER 88-2461)

Research toward the eventual construction of large space structures includes a considerable amount of work on the topic of damage. The focus of this work is detection and location of damage in large truss structures. A method has been developed which incorporates system identification techniques using dynamic response measurements with a damage location algorithm to pinpoint deleted members of a truss. Various damage cases are examined in simulations with two truss structures: a planar truss and a three dimensional orthogonal tetrahedral truss similar to that proposed for the Space Station. The simulation results show that damage can be located by using the response of a large truss structure. However, damage in certain members is difficult or impossible to locate with limited available data. Author

A88-31403
A COMPOSITE STRUCTURAL SYSTEM FOR A LARGE COLLAPSIBLE SPACE ANTENNA
L. HOLLAWAY and A. THORNE (Surrey, University, Guildford, England) IN: Composite structures 4; Proceedings of the Fourth International Conference, Paisley, Scotland, July 27-29, 1987. Volume 1. London and New York, Elsevier Applied Science, 1987, p. 1.30-1.44. Research sponsored by the Ministry of Defence. refs

An erectable reflector based on an extendable truss antenna is described which is deployed in earth orbit and then transported to geostationary orbit. A carbon fiber polyethersulfone material for building the reflector is suggested, and the manufacturing process is described. Compression and buckling tests on the mechanical properties of the composite after exposure to normal atmosphere and after degradation by temperature cycling in high vacuum are discussed. The temperature limits at present are found to be between +50 C and -95 C. The composite appears to be structurally satisfactory. C.D.

A88-32359#
MODEL ORDER REDUCTION TECHNIQUES IN LARGE SPACE STRUCTURE APPLICATIONS
HAGOP V. PANOSSIAN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1733-1741. USAF-supported research. refs
(AIAA PAPER 88-2467)

The advantages and disadvantages of various techniques of model order reduction for large space structure applications are discussed. Condensation methods such as the Guyan (1965) reduction basically reduce the order of the original large dimensional linear model by discarding some of the modal deflections called 'slave' degrees-of-freedom and retaining the remaining 'master' degrees-of-freedom. Other techniques considered include aggregation methods, the cost decomposition method, the balanced state-space representation, and optimal projection methods. An approach for generating optimal reduced order models for large-scale systems based on an appropriate performance index is presented. R.R.

N88-10340*# Old Dominion Univ., Norfolk, Va. Dept. of Mechanical Engineering and Mechanics.
ASSESSMENT OF THE COFSI/MAST I PROJECT Final Report, period ended 15 Sep. 1987
MENG-SANG CHEW Sep. 1987 16 p
(Contract NAS1-17993)
(NASA-CR-181366; NAS 1.26:181366; TA-75) Avail: NTIS HC A03/MF A01 CSCL 13I

The COFS (MAST I) deployer/retractor assembly (DRA) which has a cluster of mechanisms that constitute the collapsible/extensible Mast, contains mechanisms/linkages that

deploy and retract. The Mast is a flexible spatial (3D) linkage with hinges that lock into place during deployment to form a truss type structure. It is 60 meters long with repeating sections of two bays. Each bay has alternating diagonals. All joints are single degree-of-freedom hinges, arranged such that the Mast does not rotate during deployment/restow and that deformation energy is minimized. Mispan hinges are incorporated in the diagonals and half of the batten members. The various operational aspects and characteristics of the various mechanisms within the DRA are analyzed. In view of the disadvantages of statical in determinancy as well as the inefficiencies inherent in recirculating gear trains, it is recommended that the bevel gear trains and the bell-crank mechanisms be redesigned. Author

N88-10868*# Massachusetts Inst. of Tech., Cambridge. Space Systems Lab.
STRUCTURAL ASSEMBLY DEMONSTRATION EXPERIMENT (SADE) Final Report
DAVID L. AKIN, RAYMOND A. MILLS, and MARY L. BOWDEN 20 Jul. 1987 148 p
(Contract NAS8-34959)
(NASA-CR-179205; NAS 1.26:179205; SSL-16-87) Avail: NTIS HC A07/MF A01 CSCL 22B

The purpose of the Structural Assembly Demonstration Experiment (SADE) was to create a near-term Shuttle flight experiment focusing on the deployment and erection of structural truss elements. The activities of the MIT Space Systems Laboratory consist of three major areas: preparing and conducting neutral buoyancy simulation test series; producing a formal SADE Experiment plan; and studying the structural dynamics issues of the truss structure. Each of these areas is summarized. B.G.

N88-10874*# Teledyne Brown Engineering, Huntsville, Ala.
MISSION PECULIAR EQUIPMENT SUPPORT STRUCTURE: A PLATFORM FOR SPACE CONSTRUCTION
ROBERT HILL *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 55-66 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The Space Shuttle requires carriers to support payloads in the cargo bay. As a result, the Mission Peculiar Equipment Support Structure (MPESS) was designed to carry partial payloads aboard the shuttle. The efforts to customize the MPESS for the Experimental Assembly of Structure in EVA (EASE) and Assembly Concept for Construction of Erectable Space Structure (ACCESS) experiments are summarized. B.G.

N88-13388*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
POTENTIAL FOR ON-ORBIT MANUFACTURE OF LARGE SPACE STRUCTURES USING THE PULTRUSION PROCESS
MAYWOOD L. WILSON, IAN O. MACCONOCHIE, and GARY S. JOHNSON Dec. 1987 20 p Presented at the 46th Conference of Society of Allied Weight Engineers, Inc., Seattle, Wash., 18-20 May 1987
(NASA-TM-4016; L-16356; NAS 1.15:4016; SAWE-PAPER-1763)
Avail: NTIS HC A03/MF A01 CSCL 11D

On-orbit manufacture of lightweight, high-strength, advanced-composite structures using the pultrusion process is proposed. This process is adaptable to a zero-gravity environment by using preimpregnated graphite-fiber reinforcement systems. The reinforcement material is preimpregnated with a high-performance thermoplastic resin at a ground station, is coiled on spools for compact storage, and is transported into Earth orbit. A pultrusion machine is installed in the Shuttle cargo bay from which very long lengths of the desired structure is fabricated on-orbit. Potential structural profiles include rods, angles, channels, hat sections, tubes, honeycomb-cored panels, and T, H, and I beams. A potential pultrudable thermoplastic/graphite composite material is presented as a model for determining the effect on Earth-to-orbit package density of an on-orbit manufacture, the package density is increased by 132 percent, and payload volume requirement is decreased by 56.3 percent. The fabrication method has the potential for on-orbit manufacture of structural members for space platforms, large space antennas, and long tethers. Author

N88-16737# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Structures and Thermal Control Div.
WHY MECHANISMS ARE CRITICAL TO SPACECRAFT PERFORMANCE
H. M. BRISCOE *In its* ESA Bulletin No. 10 p 56-59 Aug. 1977
Avail: NTIS HC A05/MF A01

Spacecraft mechanisms used for deployment, momentum wheels, gyroscopes, despin mechanisms, solar array drives, antenna pointing mechanisms, tape recorders, scanning and slewing mechanisms, and spin-up and ejection mechanisms are discussed. The OTS bearing and power transfer assembly, and the GEOS boom system are described. Author (ESA)

N88-16807# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
MULTISURFACE CONTROL MECHANISM FOR A DEPLOYABLE ANTENNA: FAR INFRARED AND SUBMILLIMETER SPACE TELESCOPE (FIRST) TECHNOLOGY STUDY Final Report
Paris, France ESA Jan. 1987 113 p Prepared in cooperation with Sener SA, Madrid (Spain)
(Contract ESTEC-5994/84-NL-AN(SC))
(RP-FA-D003; ESA-CR(P)-2506; ETN-88-91300) Avail: NTIS HC A06/MF A01

Antenna control for the Far Infrared and Submillimeter Space Telescope 8 m, foldable dish was investigated. The best fit contour of the reflector must not deviate from the ideal paraboloid by greater than 8 microns rms throughout the operational temperature range between minus 107 and minus 185 C. The structural design leads to CFRP sandwich shell elements on self supporting CFRP frameworks. Aluminum and Kevlar cores were studied as to their effects on thermally induced contour errors, and an error budget was established. Mechanisms for fixing the stowed and unfolded configuration and for panel deployment were defined. Methods for in-orbit calibration were identified and an on-ground adjustment concept for antenna assembly was defined. A panel with CFRP cover sheets and an Al core was exposed to a thermal cycling test, proving manufacturing accuracy and insensitivity to thermal loads. The suitability of the surface coating is demonstrated by microwave reflectivity measurements. Breadboard models of adjustment mechanisms for in-orbit correction of the main dish contour were successfully tested. ESA

N88-18750# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
DEVELOPMENT OF THE EXTENDABLE AND RETRACTABLE MAST (ERM), DESIGN PHASE 2. VOLUME 1 Final Report
SPECHT, SCHMID, CHELLINGSWORTH, WISLEZ, BHATTI, and STENNE (Societe Anonyme Belge de Constructions Aeronautiques, Brussels, Belgium) Paris, France ESA 6 Mar. 1987 292 p Original contains color illustrations
(Contract ESTEC-5676/83-NL-AN(SC))
(RP-2010-0000-DS/09; ESA-CR(P)-2481; ETN-88-91697) Avail: NTIS HC A13/MF A01

An Extendable and Retractable Mast (ERM) for space applications such as deployment and retraction of high power rollable, foldable, or rigid solar arrays, large unfurlable antennas, and scientific payloads, was developed. The coverage of a large field of application requires a strong and stiff light-weight mast with good pointing accuracy allowing the adaptation of heavy tip masses as well as the fixation of line-loads to intermediate attachment points along the mast at the same time. The ERM payload capability is 40 kg on tip, plus 10 kg/m line load, plus 100N eccentric load. Deployed length is 40 m. The ERM is designed as a spindle-driven telescopic mast in carbon-fiber reinforced plastics (CFRP) technology. A 40 m solar array mast and a 20 m antenna mast were considered. The feasibility of a 60 m mast is also shown. Manufacturing and test of a breadboard model

hardware, and the detailed design of an engineering model mast are described. ESA

N88-18941*# Martin Marietta Aerospace, Denver, Colo.
THE INTEGRATION OF A MESH REFLECTOR TO A 15-FOOT BOX TRUSS STRUCTURE. TASK 3: BOX TRUSS ANALYSIS AND TECHNOLOGY DEVELOPMENT Final Report, Apr. 1985 - Nov. 1986
E. E. BACHTELL, W. F. THIEMET, and G. MOROSOW Mar. 1987 75 p
(Contract NAS1-17551)
(NASA-CR-178228; NAS 1.26:178228; MCR-86-669-TASK-3)
Avail: NTIS HC A04/MF A01 CSCL 20K

To demonstrate the design and integration of a reflective mesh surface to a deployable truss structure, a mesh reflector was installed on a 15 foot box truss cube. The specific features demonstrated include: (1) sewing seams in reflective mesh; (2) mesh stretching to desired preload; (3) installation of surface tie cords; (4) installation of reflective surface on truss; (5) setting of reflective surface; (6) verification of surface shape/accuracy; (7) storage and deployment; (8) repeatability of reflector surface; and (9) comparison of surface with predicted shape using analytical methods developed under a previous task. Author

N88-19568*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
PRELIMINARY INVESTIGATION OF STABILITY OF A FIN-STIFFENED SLENDER STRUT
MARK S. LAKE and K. CHAUNCEY WU Apr. 1988 24 p
(NASA-TM-4034; L-16411; NAS 1.15:4034) Avail: NTIS HC A03/MF A01 CSCL 22B

A fin-stiffened strut concept which possesses high bending stiffness and low packaged volume has been identified for use on large space structures. The concept incorporates three curved fins which deploy from a core tube to increase the effective cross-sectional moment of inertia, the buckling load, and the vibration frequency of the strut. A strut design incorporating welded fin connections provides an upper bound of the strut buckling load. A strut design which allows the individual fins and core to move independently in the strut axial direction provides a lower bound of the strut buckling load which is approximately 20 to 25 percent of the upper bound. A practical strut design, incorporating hinge assemblies which constrain the fins to move together but independently of the core tube in the strut axial direction, provides a buckling load which is 75 to 80 percent of the upper bound. Euler's equation can be used to accurately predict buckling loads for the bounding designs. Flat plate finite element models of all designs give results that agree to within 10 percent of the experimental values. Equivalent beam models of the strut give results which are slightly less accurate. Author

04

STRUCTURAL AND THERMAL ANALYSIS

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

A88-11734*# Mercer Univ., Macon, Ga.
SELF-SHADOWING EFFECTS ON THE THERMAL-STRUCTURAL RESPONSE OF ORBITING TRUSSES
JACK MAHANEY (Mercer University, Macon, GA) and EARL A. THORNTON (Old Dominion University, Norfolk, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, July-Aug. 1987, p. 342-348. Previously cited in issue 17, p. 2496, Accession no. A84-37491. refs

A88-11802#
OPTIMIZATION AND ANALYSIS OF LITHIUM HYDRIDE THERMAL ENERGY STORAGE DEVICE CONFIGURATIONS FOR SPACE POWER APPLICATIONS
MOSHE SIMAN-TOV, PAUL WILLIAMS, and MITCHELL OLSZEWSKI (Oak Ridge National Laboratory, TN) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 175-182. refs
(Contract DE-AC05-84OR-21400)

Most of the power required for space-based defense systems is needed during only a short period of the orbital cycle, raising the possibility that the radiator size and mass can be reduced by including a thermal energy storage (TES) component in the heat rejection system. This paper presents the results of thermal performance analysis and optimization of five heat sink TES configurations using LiH as the storage medium. System performance was calculated for a wide range of parameters, including the effects of the prespecified internal void, enhanced thermal conductivity, and internal fins. Masses of storage materials, encapsulating shells, and containment vessels were determined to give total system operational energy storage and power densities. The results show LiH-based TES systems can provide system energy and power densities ranging from 4 to 5 MJ/kg and 12 to 17 kW/kg, respectively. I.S.

A88-11803*# Los Alamos National Lab., N. Mex.
INTEGRATED HEAT PIPE-THERMAL STORAGE SYSTEM PERFORMANCE EVALUATION
E. KEDDY, J. T. SENA, M. MERRIGAN (Los Alamos National Laboratory, NM), and GARY HEIDENREICH (Sundstrand Corp., Rockford, IL) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 183-187. Research supported by the Sundstrand Corp.
(Contract NAS3-24666)

An integrated thermal energy storage (TES) system, developed as a part of an organic Rankine cycle solar dynamic power system is described, and the results of the performance verification tests of this TES system are presented. The integrated system consists of potassium heat-pipe elements that incorporate TES canisters within the vapor space, along with an organic fluid heater tube used as the condenser region of the heat pipe. The heat pipe assembly was operated through the range of design conditions from the nominal design input of 4.8 kW to a maximum of 5.7 kW. The performance verification tests show that the system meets the functional requirements of absorbing the solar energy reflected by the concentrator, transporting the energy to the organic Rankine heater, providing thermal storage for the eclipse phase, and allowing uniform discharge from the thermal storage to the heater. I.S.

A88-11806*# LTV Aerospace and Defense Co., Dallas, Tex.
RADIATOR SELECTION FOR SPACE STATION SOLAR DYNAMIC POWER SYSTEMS
MIKE FLEMING (LTV Corp., LTV Missiles and Electronics Group, Dallas, TX) and FRANK HOEHN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 208-213. NASA-supported research.

A study was conducted to define the best radiator for heat rejection of the Space Station Solar Dynamic Power System. Included in the study were radiators for both the Organic Rankine Cycle and Closed Brayton Cycle heat engines. A number of potential approaches were considered for the Organic Rankine Cycle and a constructable radiator was chosen. Detailed optimizations of this concept were conducted resulting in a baseline for inclusion into the ORC Preliminary Design. A number of approaches were also considered for the CBC radiator. For this

application a deployed pumped liquid radiator was selected which was also refined resulting in a baseline for the CBC preliminary design. This paper reports the results and methodology of these studies and describes the preliminary designs of the Space Station Solar Dynamic Power System radiators for both of the candidate heat engine cycles. Author

A88-11810#
AN EVALUATION OF HEAT PIPE RADIATORS INCORPORATING PUMPED LIQUID RETURN
KEITH A. WOLOSHUN and MICHAEL A. MERRIGAN (Los Alamos National Laboratory, NM) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 235-240. refs

The capillary power limit encountered in long heat pipes for high-power, high-temperature heat rejection by radiation to space may be exceeded by incorporating external electromagnetic force pumps for enhanced liquid return. The hydrodynamic performance of capillary pumped heat pipes is compared with externally pumped heat pipes. Practical problems incurred with pump utilization are discussed. It is concluded that heat pipe radiator performance could be enhanced through external pumping under certain conditions, but, in general, power throughput requirements could be more readily achieved by other design changes. Pump implementation problems, including the required additional mass of the pumps, increased required radiator surface area for pump attachment, pump control requirements and pump power supply, are also discussed and evaluated. Author

A88-15953#
COLLECTOR AND RECEIVER DESIGNS FOR HIGH TEMPERATURE BRAYTON CYCLE FOR SPACE APPLICATION
W. J. DENNER, A. FRITZSCHE, and G. HELWIG (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 16 p. refs
(IAF PAPER 87-228)

A West German Ministry for Research and Technology study has been conducted into the development status and comparative advantages of solar dynamic power systems for spacecraft applications. Solar reflector, receiver, and energy storage baseline configurations are discussed with a view to efficiency, mass, cost effectiveness, and ease of deployment in orbit (by either EVA or automated means). Both foldable-petal segment and hexagonal truss structure-supported collector configurations are assessed; receivers considered are of the cavity and block-receiver types. O.C.

A88-16018#
CAPABILITIES AND SPECIAL FEATURES CONCERNING STRUCTURAL OPTIMIZATION OF SPACECRAFT STRUCTURES
PETER MIKOLAJ (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 12 p. refs
(IAF PAPER 87-320)

The program architecture and implementation of the MBB-LAGRANGE program for the structural optimization of spacecraft structures are discussed. Several optimization algorithms are implemented which are capable of handling both large scale sizing problems and small scale geometry problems. The program uses the FEM for analysis and Mathematical Programming or Optimality Criteria for the optimization algorithms. The efficiency of the process is demonstrated with examples including a NASA plate-optimization problem, a satellite coolplate, and an Ariane 5/Eureka adaptor. R.R.

A88-17566
RADIATION CHARACTERISTICS OF OFFSET RADIAL RIB REFLECTOR ANTENNAS
D. LIZIUS and A. D. OLVER (Queen Mary College, London, England) IN: International Conference on Antennas and Propagation, 5th, York, England, Mar. 30-Apr. 2, 1987, Proceedings. Part 1. London, Institution of Electrical Engineers, 1987, p. 319-322.

This paper studies the radiation characteristics of offset radial rib reflector antennas. Consideration is given to the mathematical description of the reflector surface, phase error characterization, and the features of the radiation patterns. It is shown that the copolar pattern of an offset radial rib reflector is closely related to that of an axisymmetric radial rib reflector with a slighly scaled focal length. The qualitative effects of varying the diameter, the number of ribs, or the focal length on the pattern of a radial rib reflector are described. I.S.

A88-18632#
FINITE-ELEMENT MODEL FOR THE THERMOELASTIC ANALYSIS OF LARGE COMPOSITE SPACE STRUCTURES
J. D. LUTZ, D. H. ALLEN, and W. E. HAISLER (Texas A & M University, College Station) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 1, p. 96-102) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Sept.-Oct. 1987, p. 430-436. Previously cited in issue 18, p. 2616, Accession no. A86-38811. refs
(Contract F49620-83-C-0067)

A88-21083* Hughes Aircraft Co., Torrance, Calif.
HYBRID HONEYCOMB PANEL HEAT REJECTION SYSTEM
H. J. TANZER (Hughes Aircraft Co., Torrance, CA) and J. B. HALL, JR. (NASA, Langley Research Center, Hampton, VA) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 13 p. refs
(SAE PAPER 871419)

The evolution of a hybrid honeycomb panel heat rejection system concept for future high-power spacecraft is described. Performance evaluation of this heat pipe-based hybrid radiator is based on data and prediction models from a developmental component hardware testing program. The concept integrates three high-performance components into an optimized radiator system. These components are the sideflow heat pipe transport leg, honeycomb panel evaporator, and light-weight high-efficiency heat pipe fins. A 3.05 m (10 ft.) long hybrid radiator was designed considering remnant hardware available from other Hughes programs. The key performance objective for the hybrid radiator was to demonstrate high thermal transport capacity, increased radiating fin lengths, improved thermal efficiency across structural boundaries, and reduced weight. Analysis showed that 9000 W can be transported over a 3.05 m radiator and that finlengths of up to 1 m are possible. Author

A88-21085
ITDS - A PROGRAM FOR INTERACTIVE DESIGN AND ANALYSIS OF ADVANCED ACTIVE THERMAL CONTROL SYSTEMS
P. JEFF BERTSCH (McDonnell Douglas Astronautics Co., Houston, TX) and JOE P. CHAMBLISS (Lockheed Engineering and Management Services Co., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 22 p. refs
(SAE PAPER 871421)

The Interactive Thermal Design System (ITDS) is a new computer program developed specifically to support design and analysis of advanced spacecraft Active Thermal Control Subsystems (ATCSs). The program was developed for NASA/JSC during 1985 and 1986 to provide design and analytical support needed for projects such as the Space Station and space platforms. ITDS uses modern computing techniques, VAX computing machinery, and commercial database and graphics software to greatly improve the productivity of design and analytical efforts. The program uses interactive menus to control technical and supporting functions combined with graphical system representation to streamline the design and analysis process. The ITDS library of single and two-phase ATCS routines accommodates design

and analysis of single components or integrated systems. Supporting utilities provide units conversion, easily selected and accessed fluid property data for twenty ATCS fluids, and help data to assist the user with program functions. This paper describes the development of ITDS, the features it offers and examples of how it may be employed. Author

A88-21104
PUMPED TWO-PHASE AMMONIA THERMAL BUS TEST BED
MICHAEL P. MCHALE, STEVE D. GOO, and J. C. PIZZICHEMI (Boeing Aerospace Co., Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 6 p.
(SAE PAPER 871442)

Future large spacecraft such as the Space Station will have high power dissipations and long heat transport distances. The combination of these two requirements dictate the need for a new heat transport technology. NASA-JSC has developed the concept of a two phase thermal bus in which the working fluid is evaporated at the heat collection site and is condensed at the heat rejection site. This provides a nearly isothermal system at lower pumping powers than current single phase systems. Boeing has developed a two-phase thermal bus testbed using ammonia working fluid. This testbed uses a Sundstrand rotary fluid management device (RFMD) to provide fluid pumping and liquid-vapor phase management. Overall heat transport capacity is 25 kW. This internally funded testbed is being used for thermal bus heat exchanger characterization and critical component life tests in an ammonia environment. Currently, the testbed has been assembled, proof-pressure tested, leak tested, and checked out. Heat exchanger performance tests are underway. Author

A88-21129* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
DEVELOPMENT OF A THERMAL CONTROL COATING FOR SPACE SUITS
BERNADETTE SQUIRE and BRUCE WEBBON (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 11 p. refs
(SAE PAPER 871474)

Past space suits and the current Shuttle suit, which are constructed primarily from fabric, use the Integrated Thermal and Micrometeoroid Garment, which insulates the astronaut from his environment. The new generation of hard suits affords designers the opportunity to incorporate thermal control into the suit structure. Environmental influence on the suit temperature and heat flux can then be minimized with a high reflectance coating. Candidate coatings have been identified and ranked on the basis of thermophysical properties; wear, corrosion and atomic oxygen degradation resistance; and coating process and cost. Laboratory determination of properties, thermal cycling and wear resistance tests are underway to identify the optimum coating. A computer model is being developed to evaluate various environmental configurations. Preliminary results are presented here. Author

A88-21151* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
PRELIMINARY DESIGN OF THE SPACE STATION INTERNAL THERMAL CONTROL SYSTEM
MARK T. HERRIN, DAVID W. PATTERSON, and LARRY D. TURNER (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 13 p. refs
(SAE PAPER 871505)

The baseline preliminary design configuration of the Internal Thermal Control system (ITCS) of the U.S. Space Station pressurized elements (i.e., the Habitation and U.S. Laboratory modules, pressurized logistics carrier, and resources nodes) is defined. The ITCS is composed of both active and passive components. The subsystems which comprise the ITCS are identified and their functional descriptions are provided. The significant trades and analyses, which were performed during Phase B (i.e., the preliminary design phase) that resulted in the design described herein, are discussed. The ITCS interfaces with the station's central Heat Rejection and Transport System (HRTS), other systems, and externally attached pressurized payloads are described. Requirements on the ITCS with regard to redundancy and experiment support are also addressed. Author

A88-21153* LTV Missiles and Electronics Group, Dallas, Tex.
SPACE STATION BODY MOUNTED RADIATOR DESIGN
M. L. FLEMING and R. J. DUSCHATKO (LTV Corp., Missiles Div., Dallas, TX) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 8 p.
(Contract NAS8-36402)
(SAE PAPER 871507)

Consideration has been given to utilizing the external area of the Space Station common modules or resource nodes to provide heat rejection. A program was undertaken to define the best body mounted radiator design, to define and build a full size test article and to conduct testing to verify performance. Trade studies were conducted and a preferred design selected. The selected design employed high performance grooved heat pipes of an off-the-shelf design. Twenty panels, each about 1.2 m wide by 5.6 m long are installed on each module rejecting a total of about 12 kW. The radiators are interfaced with the module thermal control loop by use of a refrigerant 21 loop with an on-orbit operable disconnect at each panel. A one-panel test article has been designed and is currently being fabricated. Testing is scheduled to be conducted in June of 1987. Author

A88-21155* Grumman Aerospace Corp., Bethpage, N.Y.
HIGH THERMAL-TRANSPORT CAPACITY HEAT PIPES FOR SPACE RADIATORS
ALBERT W. CARLSON, ERIC GUSTAFSON, and SUSAN L. ROUKIS (Grumman Corp., Space Systems Div., Bethpage, NY) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 14 p. refs
(Contract NAS3-24665)
(SAE PAPER 871509)

This paper presents the results of performance tests of several dual-slot heat pipe test articles. The dual-slot configuration has a very high thermal transport capability and has been identified as a very promising candidate for the radiator system for the NASA Space Station solar dynamic power modules. Two six-foot long aluminum heat pipes were built and tested with ammonia and acetone. A 20-ft long heat pipe was also built and tested with ammonia. The test results have been compared with performance predictions. A thermal transport capacity of 2000 W at an adverse tilt of 1 in. and a 1000 W capacity at an adverse tilt of 2 in. were achieved on the 20-ft long heat pipe. These values are in close agreement with the predicted performance limits. Author

A88-22343*# LTV Missiles and Electronics Group, Dallas, Tex.
THERMAL CONTACT CONDUCTANCE OF PRESSURIZED SURFACES
FRED E. VOSS (LTV Corp., Missiles Div., Dallas, TX) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 7 p.
(Contract NAS9-17327)
(AIAA PAPER 88-0467)

Thermal vacuum testing has demonstrated the feasibility of the concept of pressurizing contact surfaces for the transfer of waste heat on the Space Station. Data show a thin inflatable bladder design to provide a greater contact conductance than an expandable bellows approach, with substantially less interface volume to transfer the same amount of heat. Extended vacuum testing of the Radiator-to-Thermal Bus assembly indicated a continual increase of conductance as the interface was maintained at 150 psi for a 100-hour period. R.R.

A88-22347*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
LARGE DEPLOYABLE REFLECTOR THERMAL CHARACTERISTICS IN LOW EARTH ORBITS

Y. C. WU and R. N. MIYAKE (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 10 p. refs
(AIAA PAPER 88-0471)

Preliminary results are presented from the development of a thermal analytical tool capable of analyzing the orbital thermal characteristics of a Large Deployable Reflector (LDR) spaceborne astronomical instrument for observations in the 30-micron to 1-mm range. This LDR thermal analytical tool is a 9X6-node reflector thermal model to be used in conjunction with the thermal analyzer program SINDA, as well as the orbital heat flux program TRASYS for the computation of solar and IR radiation and orbit-related input data. O.C.

A88-22349*# Lockheed Engineering and Management Services Co., Inc., Houston, Tex.
SPACE STATION ACTIVE THERMAL CONTROL SYSTEM MODELING
ABDUL HYE (Lockheed Engineering and Management Services Co., Inc., Houston, TX) and CHIN H. LIN (NASA, Johnson Space Center, Houston, TX) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 9 p. refs
(Contract NAS9-15800)
(AIAA PAPER 88-0473)

The Space Station Active Thermal Control System (ATCS) has been modeled using modified SINDA/SINFLO programs to solve two-phase Thermo-fluid problems. The modifications include changes in several subroutines to incorporate implicit solution which allows larger time step as compared to that for explicit solutions. Larger time step saves computer time but involves larger computational error. Several runs were made using various time steps for the ATCS model. It has been found that for a reasonable approach, three times larger time step as compared to that used in explicit method is a good value which will reduce the computer time by approximately 50 percent and still maintain the accuracy of the output data to within 90 percent of the explicit values.
Author

A88-25368
NEW RADIATOR SYSTEM DESIGNED FOR LARGE SPACECRAFT
Aerospace Engineering (ISSN 0736-2536), vol. 8, Jan. 1988, p. 52-56.

NASA has conducted intensive design investigations into the possible technologies and configurations of future high power spacecraft heat rejection systems, whose requirements will typically involve carrying 50-100 kW of heat over 10-20 m distances. Attention is presently given to a hybrid thermal rejection system employing a honeycomb panel evaporator, a sideflow heat pipe, and heat pipe panel radiator fins. The flattening of effective heat transfer area and the grooving of the condensation side of the common wall employed are found to substantially improve sideflow-to-fin element temperature drop. O.C.

A88-29725
STRUCTURAL TESTING ON THE MULTI-AXIS SIMULATOR - AN INNOVATIVE SIMULATION SYSTEM FOR SPACE-VEHICLE STRUCTURES
New-Tech News, no. 1, 1988, p. 28-30.

The multiaxis simulator presented is an innovative test apparatus for the verification of spacecraft structures' ability to withstand periods of high stress; it also ascertains where a structural system's design dimensions may be further reduced, in the interest of weight savings, without compromising the safety margins of structural integrity. The transient vibrations in six axes simulated with the apparatus correspond to forces acting on the spacecraft during launch and flight; the system is sufficiently ample to allow testing of major subcomponents of large structures. O.C.

A88-29819*# PRC Kentron, Inc., Hampton, Va.
AN APPLICATION OF MSC/NASTRAN IN THE INTERDISCIPLINARY ANALYSIS OF LARGE SPACE-BASED STRUCTURES
ALAN E. STOCKWELL, MARETA W. CHAMBERS (PRC Kentron, Inc., Hampton, VA), and PAUL A. COOPER (NASA, Langley Research Center, Hampton, VA) MSC World Users Conference, Los Angeles, CA, Mar. 21-25, 1988, Paper. 27 p.

The Integrated Multidisciplinary Analysis Tool (IMAT), a computer software system developed at NASA Langley to analyze and simulate the dynamics of space-structure/control-system interactions, is described, and its application to the MAST problem (a 60-m truss with fundamental frequency less than 200 mHz and equipped with linear proof-mass actuators, to be deployed from the Space Shuttle as part of COFS-I flight experiment) is demonstrated. Particular attention is given to the IMAT procedures which facilitate the use of the MCS/NASTRAN code to recover physical results from time-domain state-space solutions obtained with an FEM control-design code. Diagrams, drawings, and graphs are provided. T.K.

A88-31387#
SPACE STATION PROBABILITY OF NO PENETRATION DUE TO METEOROID AND ORBITAL DEBRIS IMPACT
M. A. WRIGHT, A. R. CORONADO, and P. H. STERN (Boeing Aerospace Co., Seattle, WA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 82-89. refs
(AIAA PAPER 88-2464)

An analysis technique and associated computer programs have been developed that predict the probability of no penetration of a spacecraft subject to meteoroid or man-made orbital debris impact. This technique accounts for the spacecraft's geometry, orientation, varying wall configuration and the varying density of the meteoroid and debris environment. Results are presented for a configuration similar to the proposed Space Station. These results show that the Space Station will require shields to obtain adequate safety levels. This shielding will be primarily designed by the debris threat. The results are sensitive to the environment definition and wall penetration function. Author

A88-32240*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SOLUTION OF STRUCTURAL ANALYSIS PROBLEMS ON A PARALLEL COMPUTER
OLAF STORAASLI, EUGENE POOLE (NASA, Langley Research Center, Hampton, VA), JAMES ORTEGA, ANDREW CLEARY (Virginia, University, Charlottesville), and COURTENAY VAUGHAN IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 596-605. refs
(AIAA PAPER 88-2287)

The problems of a blade-stiffened panel with a hole subjected to compression, and a deployable space mast subjected to tip loads, are treated through the application of FEM to model generation followed by the solution of a linear system of equations. Direct and iterative approaches to the solution of the linear systems are solved in turn; for the panel problems using varying numbers of processors, the incomplete Cholesky-conjugate gradient method was the fastest iterative method on all but two instances in which the number of processors was large. O.C.

N88-11738# Sandia National Labs., Albuquerque, N. Mex.
ESTIMATING PAYLOAD INTERNAL TEMPERATURES AND RADIATOR SIZE FOR MULTIMEGAWATT SPACE PLATFORMS
DEAN DOBRANICH Aug. 1987 74 p
(Contract DE-AC04-76DP-00789)
(DE88-000244; SAND-87-1216) Avail: NTIS HC A04/MF A01

A conceptual space platform consists of a payload, a power conditioning unit (PCU), and two radiators: the main radiator and a secondary radiator. A computer program was written to determine the required size of the two radiators and the temperatures of the PCU and payload for a given platform power level. An iterative approach is necessary because the required size of the main radiator depends on the size of the secondary radiator and vice

versa. Also, the temperatures of the payload and PCU depend on the size of the radiators. The program user can subdivide the two radiators into any number of nodes to increase the accuracy of the radiant heat transfer solution. The use of more nodes also allows better prediction of the nonlinear temperature drop that occurs across the radiators as the working fluid deposits the platform's waste heat in the radiator. View factor expressions are automatically calculated for different choices of the number of nodes. The user can also select different separation distances between the various platform structures. A model is included to couple the radiant and conduction heat transfer that occurs between the payload and its meteoroid shell and between the PCU and its shell. DOE

N88-11739# National Aerospace Lab., Amsterdam (Netherlands). Space Div.
CONSIDERATIONS CONCERNING A THERMAL JOINT FOR A DEPLOYABLE OR STEERABLE BATTERY RADIATOR FOR THE COLUMBUS POLAR PLATFORM
A. A. M. DELIL 6 Jun. 1986 41 p Sponsored in part by Fokker B.V.
(NLR-TR-86055-U; B8709830; ETN-87-91331) Avail: NTIS HC A03/MF A01

Concepts for a moveable thermal joint are discussed with respect to the applicability in a dedicated deployable or steerable heat pipe radiator system to handle the waste heat of the NiH batteries of the Polar Platform. Possible candidates for near-term deployable radiator development are: the flexible heat pipe; the low-melting-point alloy filled, grease filled, or low pressure helium gas filled (finned) heat exchanger; the braided conductor (having high mass and retraction torque); and the clamped contact. The flexible heat pipe is less attractive for steerable radiator applications. The braided conductor and the clamped contact are inadequate. The nonsolid material filled heat exchanger is the preferable joint if steerability is required. ESA

N88-12747*# Hughes Aircraft Co., Torrance, Calif. Electron Dynamics Div.
ADVANCED RADIATOR CONCEPTS UTILIZING HONEYCOMB PANEL HEAT PIPES Final Technical Report, Jun. 1982 - Jun. 1987
G. L. FLEISCHMAN, S. J. PECK, and H. J. TANZER Oct. 1987 107 p
(Contract NAS9-16581; NASA ORDER W-30746)
(NASA-CR-172017; NAS 1.26:172017) Avail: NTIS HC A06/MF A01 CSCL 20D

The feasibility of fabricating and processing moderate temperature range vapor chamber type heat pipes in a low mass honeycomb panel configuration for highly efficient radiator fins for potential use on the space station was investigated. A variety of honeycomb panel facesheet and core-ribbon wick concepts were evaluated within constraints dictated by existing manufacturing technology and equipment. Concepts evaluated include type of material, material and panel thickness, wick type and manufacturability, liquid and vapor communication among honeycomb cells, and liquid flow return from condenser to evaporator facesheet areas. A thin-wall all-welded stainless steel design with methanol as the working fluid was the initial prototype unit. It was found that an aluminum panel could not be fabricated in the same manner as a stainless steel panel due to diffusion bonding and resistance welding considerations. Therefore, a formed and welded design was developed. The prototype consists of ten panels welded together into a large panel 122 by 24 by 0.15 in., with a heat rejection capability of 1000 watts and a fin efficiency of essentially 1.0. Author

N88-13381# Sandia National Labs., Albuquerque, N. Mex.
THE EFFECT OF MAXIMUM-ALLOWABLE PAYLOAD TEMPERATURE ON THE MASS OF A MULTIMEGAWATT SPACE-BASED PLATFORM
D. DOBRANICH Aug. 1987 48 p
(Contract DE-AC04-76DP-00789)
(DE88-001921; SAND-87-1449) Avail: NTIS HC A03/MF A01

Calculations were performed to determine the mass of a space-based platform as a function of the maximum-allowed operating temperature of the electrical equipment within the platform payload. Two computer programs were used in conjunction to perform these calculations. The first program was used to determine the mass of the platform reactor, shield, and power conversion system. The second program was used to determine the mass of the main and secondary radiators of the platform. The main radiator removes the waste heat associated with the power conversion system and the secondary radiator removes the waste heat associated with the platform payload. These calculations were performed for both Brayton and Rankine cycle platforms with two different types of payload cooling systems: a pumped-loop system (a heat exchanger with a liquid coolant) and a refrigerator system. The results indicate that increases in the maximum-allowed payload temperature offer significant platform mass savings for both the Brayton and Rankine cycle platforms with either the pumped-loop or refrigerator payload cooling systems. Therefore, with respect to platform mass, the development of high temperature electrical equipment would be advantageous. DOE

N88-15823*# Georgia Inst. of Tech., Atlanta. School of Mechanical Engineering.
DEVELOPMENT OF AN EMULATION-SIMULATION THERMAL CONTROL MODEL FOR SPACE STATION APPLICATION Final Report
JAMES G. HARTLEY and GENE T. COLWELL Jan. 1988 88 p
(Contract NAG1-551)
(NASA-CR-182409; NAS 1.26:182409) Avail: NTIS HC A05/MF A01 CSCL 22B

The goal of this program is to develop an improved capability for comparing various techniques for thermal management in the space station. The work involves three major tasks: Develop a Technology Options Data Base (Task 1); Complete Development of a Space Station Thermal Control Technology Assessment Program (Task 2); and Develop and Evaluate Emulation Models (Task 3). Author

N88-15828# Fokker B.V., Amsterdam (Netherlands). Space Div.
THERMAL STRUCTURAL CONTROL MODELLING TECHNIQUES Final Report
J. J. WIJKER Paris, France ESA 12 Jun. 1986 110 p
(Contract ESTEC-5158/82-NL-PB(SC))
(FOK-TR-R-86-030; ESA-CR(P)-2496; ETN-88-91704) Avail: NTIS HC A06/MF A01

A link between the ASKA finite element program and the Dynamic and Control Analysis Package (DCAP) was developed. An interface software package called Interface DCAP (IFDCAP) was generated to transfer numerical data, describing the structural behavior of flexible bodies, between ASKA and DCAP. Ten test cases were defined in order to demonstrate the functioning of the interface program. Methodologies and links for data transfer between the System Improved Numerical Differencing Analyzer (SINDA) and ASKA were established. A temperature interpolation technique based on the prescribed average technique was developed. Using the finite element model of the structure with its conduction matrix, the thermal model temperatures are interpolate to obtain temperatures in all nodes of the structural model. software package called SINAS to transfer SINDA nod temperatures to the ASKA model nodes was written. Four te cases to demonstrate the functional performance of the interfa package SINAS were defined. E

N88-15925*# Air Force Astronautics Lab., Edwards AFB, C
AF CRYOGENIC AND FLUID MANAGEMENT SPACECRAF TECHNOLOGY PROGRAM
ROY SILVER *In* NASA. Lewis Research Center, Cleveland, Cryogenic Fluid Management Technology Workshop. Volu Presentation Material and Discussion p 7-20 Sep. 1987
Avail: NTIS HC A17/MF A01 CSCL 20D

Viewgraphs are given that outline the program objec long term cryogenic storage programs. Diagrams of t

transfer vehicle, thermal insulation blankets, cryogenic storage tanks, the advanced liquid feed experiment, and the acoustic measurement on satellite experiment are presented. The objectives, goals, and payoffs of the fluid management space experiment and the liquid droplet radiator are outlined. R.J.F.

05

STRUCTURAL DYNAMICS AND CONTROL

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

A88-10050
THEORETICAL PRINCIPLES OF THE OPTIMAL CONTROL OF FLEXIBLE SPACECRAFT [TEORETICHESKIE OSNOVY OPTIMAL'NOGO UPRAVLENIIA UPRUGIMI KOSMICHESKIMI APPARATAMI]
GENNADII LUKICH DEGTIAREV and TALGAT KASIMOVICH SIRAZETDINOV Moscow, Izdatel'stvo Mashinostroenie, 1986, 216 p. In Russian. refs

The principles of the mathematical description and synthesis of flexible spacecraft control are examined using an approach whereby a spacecraft is treated as a system with distributed parameters. Specific models of equations of motion and state for spacecraft are described, and methods are presented for the synthesis of optimal spacecraft control under conditions of incomplete information. Solutions to some control synthesis problems and results of numerical simulations are presented. An optimum control theory for stochastic systems with distributed parameters is presented which is based on the correlation theory of random processes. V.L.

A88-11736*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
BUNVIS-RG - EXACT FRAME BUCKLING AND VIBRATION PROGRAM, WITH REPETITIVE GEOMETRY AND SUBSTRUCTURING
M. S. ANDERSON (NASA, Langley Research Center, Hampton, VA) and F. W. WILLIAMS (University of Wales Institute of Science and Technology, Cardiff) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 2, p. 211-220) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, July-Aug. 1987, p. 353-361. SERC-supported research. Previously cited in issue 18, p. 2658, Accession no. A86-38903. refs
(Contract NCCW-000002)

A88-11829*# General Dynamics Corp., San Diego, Calif.
CONTROL CONSIDERATIONS FOR HIGH FREQUENCY, RESONANT, POWER PROCESSING EQUIPMENT USED IN LARGE SYSTEMS
J. W. MILDICE, K. E. SCHREINER (General Dynamics Corp., Space Systems Div., San Diego, CA), and F. WOLFF (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 350-355. Previously announced in STAR as N87-23690.

Addressed is a class of resonant power processing equipment designed to be used in an integrated high frequency (20 KHz domain), utility power system for large, multi-user spacecraft and other aerospace vehicles. It describes a hardware approach, which has been the basis for parametric and physical data used to justify the selection of high frequency ac as the PMAD baseline for the space station. This paper is part of a larger effort undertaken by NASA and General Dynamics to be sure that all potential space station contractors and other aerospace power system designers understand and can comfortably use this technology, which is now widely used in the commercial sector. In this paper, we will examine control requirements, stability, and operational modes; and their hardware impacts from an integrated system point of view. The current space station PMAD system will provide the overall requirements model to develop an understanding of the performance of this type of system with regard to: (1) regulation; (2) power bus stability and voltage control; (3) source impedance; (4) transient response; (5) power factor effects; and (6) limits and overloads. Author

A88-11908#
APPLICATION OF MAGNETIC BEARINGS TO HIGH-TORQUE, SATELLITE ATTITUDE CONTROL WHEELS
JAMES DOWNER, DAVID EISENHAURE, RICHARD HOCKNEY, and BRUCE JOHNSON (SatCon Technology Corp., Cambridge, MA) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 2. New York, American Institute of Aeronautics and Astronautics, 1987, p. 829-834. refs

The use of control moment gyros as slew actuators for large spacecraft or other payloads is considered, and an alternative magnetic bearing design employing a superconducting coil is proposed. In the present bearing design, a superconducting coil is used in order to eliminate the conventional magnetic cores and permanent magnets. A baseline superconducting magnetic bearing design is presented, and substantial improvements in mass and power consumption are realized in comparison with more conventional approaches. R.R.

A88-12289#
MODE LOCALIZATION PHENOMENA IN LARGE SPACE STRUCTURES
ODDVAR O. BENDIKSEN (Princeton University, NJ) (Structures, Structural Dynamics, and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 2, p. 325-335) AIAA Journal (ISSN 0001-1452), vol. 25, Sept. 1987, p. 1241-1248. Previously cited in issue 18, p. 2659, Accession no. A86-38914. refs

A88-12484
NON-LINEAR OSCILLATION OF ROTATING STRINGS
H. F. BAUER (Muenchen, Universitaet der Bundeswehr, Neubiberg, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 11, May-June 1987, p. 145-152. refs

The basic non-linear equations of motion of a rotating string along the axis of rotation or perpendicular to it are derived by assuming large deflections and a non-linear stress-strain relationship. The coupled non-linear partial differential equations are solved using the Ritz-Galerkin method. It is found that the non-linear stress-strain relationship may have a pronounced influence on the vibrational behavior of the string and that, depending on the magnitude of the prestress, it may either stiffen or soften the system. Backbone curves are presented for the various cases. Author

A88-12813* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
AN AMPLITUDE MODULATED LASER SYSTEM FOR DISTANCE AND DISPLACEMENT MEASUREMENT
ROBERT S. ROGOWSKI, JOSEPH S. HEYMAN (NASA, Langley Research Center, Hampton, VA), and MILFORD S. HOLBEN, JR. (PRC Kentron, Inc., Hampton, VA) IN: Laser radar technology and applications; Proceedings of the Meeting, Quebec, Canada, June 3-5, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 86-89.

A laser distance and displacement measurement system is being developed to monitor small displacements in large space structures for strain analysis and structural control. The reflected laser beam is focused on a detector and the detected signal is mixed with the reference. Small displacements are indicated by a change in modulation frequency which is adjusted to maintain quadrature between the received signal and the reference signal

from the voltage-controlled oscillator in a phase-locked loop. Measurement of absolute distance is accomplished by sweeping the modulation frequency from a quadrature lock point to an adjacent lock point. Author

A88-13929* Alabama Univ., Huntsville.
ROBUSTNESS OF ACTIVE MODAL DAMPING OF LARGE FLEXIBLE STRUCTURES
MICHAEL GREENE (Alabama, University, Huntsville) International Journal of Control (ISSN 0020-7179), vol. 46, Sept. 1987, p. 1009-1018. NASA-supported research. refs

The method of active modal damping (AMD) is reviewed, and the pinhole/occulter facility (P/OF) is presented as a design example. This system is a large space system composed of a flexible beam, a gimbal-pointing system, and an optical alignment system mounted in the Shuttle cargo bay and excited by typical Shuttle disturbances. The AMD system performance is compared with that of a series-compensated control system. C.D.

A88-13932* California Univ., Los Angeles.
DISTURBANCE AND VIBRATION ISOLATION IN SPACE STATIONS BY MEANS OF MECHANICAL DECOUPLING
P. K. C. WANG (California, University, Los Angeles) International Journal of Control (ISSN 0020-7179), vol. 46, Sept. 1987, p. 1061-1082. NASA-supported research. refs
(Contract NSF ECS-85-09145)

A decoupling approach to disturbance and vibration isolation in large space stations composed of modules interconnected by flexible members is proposed. A simplified mathematical model for the motion of the space station core and a laboratory module with both torsional vibration and translational motion decouplers is used in this study. The dynamic behavior of the model in the presence of decoupler friction is analyzed. Estimates for the maximum excursions of the laboratory module induced by various types of external disturbance are derived. The paper concludes with a simulation study involving the hard-docking of a space shuttle with a space station. Author

A88-14596#
FEEDBACK CONTROL FOR ATTITUDE CONTROL SYSTEM OF THE ELASTIC VEHICLE
XIAOYE YE and XIANGWEI HE (Beijing Information and Control Research Institute, People's Republic of China) Acta Automatica Sinica (ISSN 0254-4156), vol. 13, May 1987, p. 184-190. In Chinese, with abstract in English. refs

In this paper, the reduced-order model of attitude control systems for elastic space vehicles is discussed by virtue of the finite bandwidth property of the controller. A design method of the control system is proposed. Taking advantage of this method, all eigenmodes of the reduced-order model can be controlled and the relation between the parameters of the controller and the eigenvalues of the closed-loop system may become simple and obvious. Author

A88-15713*# Massachusetts Inst. of Tech., Cambridge.
USE OF PIEZOELECTRIC ACTUATORS AS ELEMENTS OF INTELLIGENT STRUCTURES
EDWARD F. CRAWLEY and JAVIER DE LUIS (MIT, Cambridge, MA) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 1, p. 116-124) AIAA Journal (ISSN 0001-1452), vol. 25, Oct. 1987, p. 1373-1385. Previously cited in issue 18, p. 2616, Accession no. A86-38813. refs
(Contract NAGW-21)

A88-15716#
SPACE FRAME OPTIMIZATION SUBJECT TO FREQUENCY CONSTRAINTS
TZE HSIN WOO (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 1, p. 103-115) AIAA Journal (ISSN 0001-1452), vol. 25, Oct. 1987, p. 1396-1404. Research supported by TRW Independent Research and Development Program. Previously cited in issue 18, p. 2616, Accession no. A86-38812. refs

A88-15804#
DEVELOPMENT EXPERIENCE OF THE ATTITUDE CONTROL SYSTEM USING SINGLE-AXIS CONTROL MOMENT GYROS FOR LONG-TERM ORBITING SPACE STATIONS
V. N. BRANETS, D. M. VAINBERG, V. P. VERESHCHAGIN, N. N. DANILOV-NITUSOV, V. P. LEGOSTAEV (AN SSSR, Sovet Interkosmos, Moscow, USSR) et al. IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 9 p.
(IAF PAPER 87-04)

Although single-axis control moment gyroscopes, or 'gyrodins', are slightly inferior to two-axis control moment gyros in mass and power characteristics, the reliability that is a consequence of their simplicity has become very attractive for long service life space station applications. Their application to attitude control systems, however, requires the solution of complex control theory problems. Attention is presently given to the geometric configuration and electromechanical implementation of a state-of-the-art space station-applicable gyrodin. O.C.

A88-15836*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
RECENT ADVANCES IN STRUCTURAL DYNAMICS OF LARGE SPACE STRUCTURES
LARRY D. PINSON (NASA, Langley Research Center, Hampton, VA) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 22 p. refs
(IAF PAPER 87-51)

Recent progress in the area of structural dynamics of large space structures is reviewed. Topics include system identification, large angle slewing of flexible structures, definition of scaling limitations in structural models, and recent results on a tension-stabilized antenna concept known as the hoop-column. Increasingly complex laboratory experiments guide most of the activities leading to realistic technological developments. Theoretical progress in system identification based on system realization theory resulting in unification of several methods is reviewed. Experimental results from implementation of a theoretical large-angle slewing control approach are shown. Status and results of the development of a research computer program for analysis of the transient dynamics of large angle motion of flexible structures are presented. Correlation of results from analysis and vibration tests of the hoop-column antenna concept are summarized. Author

A88-15974#
DEPLOYMENT DYNAMICS OF ACCORDIAN TYPE OF DEPLOYABLE SOLAR ARRAYS CONSIDERING FLEXIBILITY OF CLOSED CONTROL LOOPS
B. S. NATARAJU (Indian Space Research Organization, Satellite Centre, Bangalore, India) and A. VIDYASAGAR IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 10 p.
(IAF PAPER 87-256)

An accordian type of deployment mechanism is under development for the deployment of solar arrays of the Indian Remote Sensing Satellite. A mathematical model for studying the effect of flexibility of Closed Control Loops (CCLs) on the deployment dynamics of such arrays has been formulated using Lagrange's method. The mathematical model involving dynamically coupled nonlinear simultaneous equations has been solved numerically after decoupling the second order terms using matrix transformation. This model has been used to choose a suitable spring in the CCLs to obtain a near synchronous deployment of the yoke and panels. Further, the effects due to variation of coefficient of friction, temperature and medium in which the arrays are deployed have been incorporated in the model. Author

A88-16016#
STRUCTURAL DESIGN AND DECOUPLED CONTROL
ROBERT A. CALICO (USAF, Institute of Technology, Wright-Patterson AFB, OH) and FRANKLIN E. EASTEP (Dayton, University, OH) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 9 p. refs
(IAF PAPER 87-318)

The decoupled control of an optimally designed space structure is considered. The optimal structure is a derivative of the CSDL I model spacecraft. In particular, the effects of structural perturbations on the optimal design are considered. The stiffness matrix for the structure is perturbed by changing the areas of its rod members. A LQR controller with modal suppression is designed for the nominal system. The controller is used on the perturbed systems and the effects on modal suppression noted. The spillover into the suppressed modes due to perturbations is also quantified in terms of the change in the row and column space of the control and observation matrices, respectively. The results obtained are compared to those obtained for the nominal CSDL I model.
Author

A88-16019#
SENSITIVITY ANALYSIS AND OPTIMAL DESIGN FOR LARGE UNRESTRAINED STRUCTURES
N. V. BANICHUK and E. V. MAKEEV (AN SSSR, Institut Problem Mekhaniki, Moscow, USSR) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 12 p. refs
(IAF PAPER 87-321)

An efficient sensitivity analysis method is proposed for calculating basic functional variations depending on variations in mass and stiffness. The method, which is based on the use of adjoint variables and adjoint systems of equations, makes it possible to define domains in a structure where redesign should be most effective. To calculate the dynamic behavior of large unrestrained structures, use is made of the modal analysis method; the eigenfrequencies and eigenmodes of free vibrations are determined by the perturbation method and a subspace iteration technique taking into account the properties of sparse matrices. The problem of rational material distribution in large space structures is also discussed, and some numerical examples are presented. V.L.

A88-16020#
NUMERICAL AND NUMERICAL-ANALYTICAL INTERFACES IN STRUCTURAL THERMAL-DYNAMIC INTERACTIVE PROBLEMS
CARLO ARDUINI and UGO PONZI (Roma I, Universita, Rome, Italy) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 29 p.
(IAF PAPER 87-322)

The 'extrapolation' and 'interpolation' techniques necessary to interface models of very different phenomena for a global numerical simulation of large space systems are considered. Characteristics and limitations of the extrapolation method are first reviewed with reference to thermal-conductive models, and the technique is demonstrated with an example of conductive extrapolation. The interpolation technique is then discussed with reference to dynamic models and is illustrated with the example of the interpolating of modal information from a continuous to a discrete model. R.R.

A88-16038#
A UNIFIED MATRIX APPROACH APPLIED TO DYNAMIC FORMULATION OF COMPLEX SPACE STRUCTURES WITH NONLINEAR HINGE FORCES AND TORQUES
Y. OHKAMI, O. OKAMOTO, T. KIDA, and I. YAMAGUCHI (National Aerospace Laboratory, Chofu, Japan) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 10 p. refs
(IAF PAPER 87-348)

In the present approach to a dynamical modeling of nonlinear hinge forces and torques for complex space structures, using the unified matrix method, emphasis is placed on the precise expression of both the relative displacements and velocities and the internal forces and torques at the hinges connecting two adjacent bodies. A computer code has been developed by means of which realistic simulation models can be implemented without cumbersome manipulation of mathematical relations. Illustrative latch-up and limiter mechanisms are presented for a space structure manipulator. O.C.

A88-16039#
ANGULAR MOMENTUM MANAGEMENT FOR LEO PLATFORMS
R. C. ROGERS (British Aerospace, PLC, Space and Communications Div., Stevenage, England) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 8 p.
(IAF PAPER 87-349)

The paper reviews the disturbance torques which act on an orbiting platform in Low Earth Orbit. The dependence of momentum dumping requirements on platform orientation is described and the possibility of cancellation between different disturbance torques considered. An approach to momentum dumping using magnetorquers is described, of particular relevance to a platform in an inertially fixed orientation. Author

A88-16041# Howard Univ., Washington, D. C.
THE DYNAMICS AND CONTROL OF LARGE SPACE STRUCTURES AFTER THE ONSET OF THERMAL SHOCK
PETER M. BAINUM, N. HAMSATH, and R. KRISHNA (Howard University, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 11 p. Research supported by Howard University and NASA. refs
(IAF PAPER 87-351)

This paper considers the problem of predicting the open and closed loop dynamics of large space structures after the onset of thermal shock. The thermal gradients induced in space structures due to solar radiation heating result in thermal deformations. The temperature gradient time history, the related thermal deflection response, the moments acting on a thermally deflected beam, and the control effort required for different combinations of solar incidence angles and material properties are considered in this investigation. The analysis is performed for structures which are nominally inertially stabilized as well as gravity stabilized. For the case of basic orbiting structural elements, such as a free-free plate (modeled as a beam in-plane), depending on the orientation, and required pointing accuracy, it may be necessary to redesign control algorithms previously developed for models which exclude the thermal shock effects. Author

A88-16043#
DYNAMICS AND CONTROL DURING SLEWING MANEUVERS
H. W. MAH, V. J. MODI (British Columbia, University, Vancouver, Canada), Y. MORITA, and H. YOKOTA (Tokyo, University, Japan) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 38 p.
(Contract NSERC-G-1547)
(IAF PAPER 87-353)

The librational dynamics of a flexible platform for the support of a mobile base that is connected to a series of slewing, flexible appendages is presently studied in light of a general formulation applicable to missions requiring slew maneuvers for antennas, telescopes, observational instruments, and remote manipulators. The formulation's application is illustrated by a rigid-platform satellite with slewing rigid appendage, a flexible beam-type platform with a flexible slewing arm, and a configuration representing a Space Shuttle-based flexible beam with a rigid reflector at its end. The results obtained indicate system instability under critical combinations of inertia parameters, orbit geometries, and translational and slewing-time histories. O.C.

A88-16044#
MISSION FUNCTION CONTROL APPLIED TO SLEW MANEUVER
HIRONORI FUJII and SHINTARO ISHIJIMA (Tokyo Metropolitan Institute of Technology, Japan) IAF, International Astronautical

Congress, 38th, Brighton, England, Oct. 10-17, 1987. 6 p. refs (IAF PAPER 87-354)

A new control algorithm, named the mission function control, is introduced and applied to slew maneuver of a spacecraft with a flexible appendage. The control algorithm is a type of the Liapunov's method applied to a mechanical system combined with a control system and employs the concept of the generalized energy functions. The flexible appendage is modeled in terms of the partial differential equations which is believed to describe most precisely the distributed systems. Implementation of the control algorithm naturally results with physical meanings and it is shown that it is necessary to sense the shearing force and bending moment at the root of the flexible appendage. Results of numerical simulation show an excellent controlled behavior for the slew maneuver. Author

A88-16046#
REDUCED ORDER MODELS OF A LARGE FLEXIBLE SPACECRAFT
KAZUO TSUCHIYA, TOSHIO KASHIWASE, and KATSUHIKO YAMADA (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 5 p. refs (IAF PAPER 87-356)

Two reduced-order models of a large flexible spacecraft are proposed. The first one is expressed in terms of the modes of static deformation of the spacecraft and the normal modes of vibration of the spacecraft. The reduced-order model can express the dynamical behavior of the spacecraft accurately in a low frequency region with proper choice of the modes of static deformation of the spacecraft. The second one is suited for a class of spacecraft composed of the main body with subbodies. The reduced-order model is expressed in terms of two sets of the normal modes of vibration, the normal modes of the whole spacecraft and the normal modes of the subbodies. The reduced order model can easily cope with the change of the structures of the subbodies. These reduced order models are illustrated through application to a simple spacecraft model. Author

A88-16276
AUTOMATIC CONTROL IN SPACE 1985
J. P. CHRETIEN, ED. (Toulouse, Centre d'Etudes et de Recherches, France) Oxford and New York, Pergamon Press, 1986, 323 p. For individual items see A88-16277 to A88-16313.

The present conference on automatic control of space systems discusses topics in the fields of GEO satellite operations, highly instrumented scientific satellites, LEO satellite operations, flexible spacecraft systems, orbit and trajectory control, spacecraft component technology, and the control of platforms and manipulators. Attention is given to such specific issues as Italsat's antenna fine pointing system, solar sailing attitude control for a large GEO satellite, the Galileo attitude and articulation control system, and the attitude control system of a polar-orbiting meteorological satellite. Also discussed are the control of tethered satellite systems, autonomous satellite navigation using opticoinertial instruments, and the Hubble Space Telescope Rate Gyro assembly. O.C.

A88-16280
SOLAR SAILING ATTITUDE CONTROL OF LARGE GEOSTATIONARY SATELLITE
J. LIEVRE (Matra, S.A., Velizy-Villacoublay, France) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 29-32.

Solar pressure effects on GEO satellites can be harnessed by means of solar sails to furnish attitude control. In the case of the OTS2 satellite, two fixed solar sails are mounted on the solar arrays in order to improve control efficiency; disturbance-related torques are estimated by the ground station, and compensated for by solar array pointing angle, while control torques are achieved by low depointing of the solar arrays to angles that are computed onboard. The total required depointing of the solar arrays limits their efficiency loss to 1 percent. O.C.

A88-16281
EVALUATION OF CONTROL CONCEPTS FOR A LARGE GEOSTATIONARY DATA RELAY SATELLITE
M. CALDICHOURY (Matra, S.A., Velizy-Villacoublay, France) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 33-42. refs

This paper presents some results obtained during the investigation of attitude and antenna pointing control systems for a large geostationary Data Relay Satellite; due to high requirements in terms of pointing accuracy and admissible defocusing, the problem of interaction between the spacecraft structure and control has a considerable significance. The modelization of flexible substructures and liquid sloshing, and the derivation of linear and nonlinear models are described. A comparative study of several control concepts, with or without active control of flexible modes, is presented here for both normal and station-keeping modes. Simulation results and performance evaluations of selected control systems are shown. The study synthesis leads to point out some recommendations for further studies. Author

A88-16292
MODAL DAMPING MEASUREMENT OF MOS-1 SOLAR ARRAY PADDLE
Y. FUJIMORI (National Space Development Agency of Japan, Tokyo), J. KATO, S. MOTOHASHI, F. KUWAO, and S. SEKIMOTO (Toshiba Corp., Kawasaki, Japan) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 121-125. refs

Dynamic test on the MOS-1 satellite's paddle structure was conducted to measure damping coefficients of the lower three modes. Precautions against the effect of the gravity force, interface damping, suspension cable length and data processing software on the test results are carefully taken, so that the data survive severe technical scrutinies. The dynamic characteristics of the solar array drive and power transmission assembly in the torsional direction was examined separately in an open room. The experimental results of the damping coefficients are analytically extrapolated to the on-orbit values; 1.1, 0.4, and 0.45 percent for 1st, 2nd and 3rd modes, respectively. Author

A88-16296
APPLICATION OF ADAPTIVE OBSERVERS TO THE CONTROL OF FLEXIBLE SPACECRAFT
S. V. SALEHI (British Aerospace, PLC, Space and Communications Div., Bristol, England) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 167-174. refs (Contract ESA-5665/83)

A difficulty in the control of large flexible structures arises from model uncertainty of a deterministic nature. The modern state-space theory of quadratic regulators yields a robust feedback design, that is one that is relatively insensitive to uncertainty. However, the state estimator (i.e., asymptotic observer) limits the overall robustness of the controller. State estimation may be enhanced by using Kreisselmeier's (1982) continuous-time adaptive observer, modified to adapt on a small number of physically meaningful parameters. The above techniques are applied to the stationkeeping-mode attitude control of a possible growth version of Olympus having much larger solar arrays. No special test signal is used to force the convergence of the parameter identification loop. The controllers are evaluated in the presence of noise, thruster nonlinearity and unmodeled dynamics. The use of the adaptive observer is found to enhance the robustness of the controller, while maintaining the pointing within specification. The method shows promise for more general flexible space structures. Author

A88-16990
DEVELOPMENT OF THE MAST FLIGHT SYSTEM LINEAR DC MOTOR INERTIAL ACTUATOR
J. W. SHIPLEY, L. D. DAVIS, W. T. BURTON, and F. M. HAM (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: Guidance and control 1987; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO,

Jan. 31-Feb. 4, 1987. San Diego, CA, Univelt, Inc., 1987, p. 237-255.
(AAS PAPER 87-021)

A linear dc motor (LDCM) inertial actuator is being developed for use on the Mast Flight System. Both tip mounted and intermediate station mast actuators will employ this concept. Excitation, damping and structural control will be accomplished using these actuators. Performance goals have been established for the LDCM which will insure that the Mast Flight System will meet its objective as a test bed for development and verification of controls/structures interaction (CSI). The design goals involve force output, frequency response, waveform distortion, dynamic range, drift compensation and packaging. The present paper discusses the design and development of the LDCM. In particular, command and compensation strategy trades, sensor resolution requirements and motor commutation techniques are considered. Also development of a compound pendulum test bed which emulates low frequency dynamics of the Mast Flight System is reviewed, and test results are presented on excursion performance and baseline damping algorithm performance. Author

A88-16993
POINTING MOUNT WITH ACTIVE VIBRATION ISOLATION FOR LARGE PAYLOADS
BRIAN J. HAMILTON, JAMES H. ANDRUS, and DELANO R. CARTER (Honeywell, Inc., Sperry Aerospace and Marine, Phoenix, AZ) IN: Guidance and control 1987; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 31-Feb. 4, 1987. San Diego, CA, Univelt, Inc., 1987, p. 299-318. refs
(AAS PAPER 87-033)

The paper presents a single-axis brassboard model of a dual-mode pointing mount which provides the high performance active isolation of magnetic suspension technology without the limitations on articulation normally imposed by small magnetic gaps. The equipment was designed to provide fast feedforward positioning forces in excess of 1000 pounds while simultaneously offering -80 dB of isolation over a wide frequency range and allowing several inches of travel between the carrier and the suspended body. Comparison of brassboard performance to analysis revealed a thorough analytical understanding of the linear and nonlinear dynamics of the system actuators. K.K.

A88-16998
STABILITY ANALYSIS FOR ALTERNATIVE FORCE CONTROL SCHEMES AS APPLIED TO REMOTE SPACE TELEOPERATION
JIM D. CHAPEL and DALE A. LAWRENCE (Martin Marietta Corp., Denver, CO) IN: Guidance and control 1987; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 31-Feb. 4, 1987. San Diego, CA, Univelt, Inc., 1987, p. 399-415. refs
(AAS PAPER 87-043)

In an attempt to understand the observed behavior of force feedback teleoperation in tasks involving environmental interaction, consideration is given to a dynamic model of the system along a single Cartesian degree of freedom. A comparison made between the stability properties of this model and a full 6-DOF hardware implementation, using a software hand controller emulation, reveals the fidelity of this model along a single degree of freedom. It is found that an impedance control structure can provide substantial performance advantages especially when significant communication delays are present. K.K.

A88-16999* Stanford Univ., Calif.
EXPERIMENTS IN ADVANCED CONTROL CONCEPTS FOR SPACE ROBOTICS - AN OVERVIEW OF THE STANFORD AEROSPACE ROBOTICS LABORATORY
M. G. HOLLARS, R. H. CANNON, JR., H. L. ALEXANDER, and D. F. MORSE (Stanford, University, CA) IN: Guidance and control 1987; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 31-Feb. 4, 1987. San Diego, CA, Univelt, Inc., 1987, p. 417-434. NASA-supported research. refs
(Contract F49620-82-C-00092; F33615-85-C-5106; F33615-82-K-5108; MDA903-86-K-0037)
(AAS PAPER 87-044)

The Stanford University Aerospace Robotics Laboratory is actively developing and experimentally testing advanced robot control strategies for space robotic applications. Early experiments focused on control of very lightweight one-link manipulators and other flexible structures. The results are being extended to position and force control of mini-manipulators attached to flexible manipulators and multilink manipulators with flexible drive trains. Experimental results show that end-point sensing and careful dynamic modeling or adaptive control are key to the success of these control strategies. Free-flying space robot simulators that operate on an air cushion table have been built to test control strategies in which the dynamics of the base of the robot and the payload are important. Author

A88-18326#
ON THE DERIVATION OF SATELLITE DYNAMICS WITH MULTI-POINT CONNECTED FLEXIBLE APPENDAGES
MASAZUMI UEBA and KAZUO NAKAGAWA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 404, 1987, p. 417-424. In Japanese, with abstract in English. refs

Low-frequency natural vibrations of satellite communication antennas attached at more than one point to the main body are investigated analytically, with a focus on the coupling between the rigid motion and the vibration. Lagrange multipliers are employed, and it is shown that the coupling coefficients can be derived from the modal momentum and modal angular momentum for any number of connecting points. Numerical results are presented in graphs. T.K.

A88-20908
APPLICATION OF PERTURBATION TECHNIQUES TO FLEXIBLE MULTIBODY SYSTEM DYNAMICS
LU YOU FANG, A. A. SHABANA (Illinois, University, Chicago), and OM P. AGRAWAL (Southern Illinois, University, Carbondale, IL) Computers and Structures (ISSN 0045-7949), vol. 27, no. 5, 1987, p. 631-637. refs

In this paper, a matrix perturbation technique is developed for flexible bodies (substructures) that undergo large reference translational and rotational displacements. Although the governing dynamic equations of motion of such systems are highly nonlinear because of the large angular rotations and the resulting nonliner inertia coupling between the reference motion and the elastic deformation, a generalized linear eigenvalue problem that defines the deformation mode shapes of the body with respect to the selected body reference is identified. This eigenvalue problem is solved only once and the variations in the body stiffness and inertia properties due to a change in selected design parameters are evaluated by using perturbation analysis techniques. The main advantage of using the proposed technique is to avoid a new finite element discretization when some design parameters are changed. This, in turn, substantially reduces the computational time, especially when large scale flexible bodies with complex geometry are considered. A numerical example is presented in order to demonstrate the use of the perturbation techniques developed in this paper in the design of flexible multibody systems. Author

A88-21221
FORMULATION OF RIGID MULTIBODY SYSTEMS IN SPACE
KATSUHIKO YAMADA and KAZUO TSUCHIYA (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan) JSME International Journal (ISSN 0913-185X), vol. 30, Oct. 1987, p. 1667-1674. refs

The equations of motion of rigid multibody systems, such as space structures whose bases are free, are derived using the equations of motion of Kane et al. (1983). The equations of motion which set the position of the center mass of one body as generalized coordinates are first obtained. A technique for deriving

the equations of motion which set the position of the center of mass of the system as generalized coordinates is then proposed in which the orbital motion and the attitude motion are treated separately. The method is shown to be applicable not only for the tree configuration system, but also for the loop configuration system with cutting loops, using Lagrange's multipliers as constrained forces. R.R.

A88-21275* Rensselaer Polytechnic Inst., Troy, N.Y.
SUBOPTIMAL SHAPE CONTROL FOR QUASI-STATIC DISTRIBUTED-PARAMETER SYSTEMS
M. J. BALAS (Rensselaer Polytechnic Institute, Troy, NY) and L. A. SIEVERS Journal of Optimization Theory and Applications (ISSN 0022-3239), vol. 55, Dec. 1987, p. 403-416. refs
(Contract AF-AFOSR-83-0124; NAG1-515)

An on-line control approach which will adjust the steady-state shape of a large antenna arbitrarily close to any achievable desired profile is approached. The method makes use of distributed-parameter system theory and allows refocusing using a limited number of control actuators and sensors. The controller gains are calculated by approximating the solution to an infinite-dimensional optimal quasi-static control problem. The controller gain calculation is computationally simpler than that previously proposed. The Galerkin (finite element) approximation method is used for model reduction. It is proved that both gain and state convergence can be achieved by using the proposed approximation scheme. Author

A88-22501#
FEEDBACK CONTROL DESIGN FOR SMOOTH, NEAR MINIMUM TIME ROTATIONAL MANEUVERS OF FLEXIBLE SPACECRAFT
S. R. VADALI (Texas A & M University, College Station) and R. M. BYERS AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 11 p. Research supported by Martin Marietta Corp. refs
(Contract F49620-86-K-00014)
(AIAA PAPER 88-0671)

The single axis slewing of a flexible spacecraft using bounded torque in near minimum time with simultaneous suppression of vibration of elastic modes is considered. The Hyperbolic Tangent (tanh) function is used as a smooth approximation of the discontinuous sign function in the rigid body 'bang-bang' control. Variable structure control concepts are used to identify the necessary characteristics of the control switching line. Simulations of the rest-to-rest and tracking maneuvers indicate that the elastic energy can be reduced by several orders of magnitude with only a modest increase in the maneuver time. Author

A88-22502#
SPACE STATION ATTITUDE CONTROL MOMENTUM REQUIREMENTS
BRENT P. ROBERTSON and MICHAEL L. HECK (Analytical Mechanics Associates, Inc., Hampton, VA) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 15 p. refs
(AIAA PAPER 88-0672)

The relationship between attitude and angular momentum control requirements is derived for a fixed-attitude, earth-orbiting spacecraft with large area articulating appendages. Environmental effects such as gravity gradient, solar radiation pressure, and aerodynamic forces arising from a dynamic, rotating atmosphere are examined. It is shown that, in general, each environmental effect contributes to both cyclic and secular momentum requirements both within and perpendicular to the orbit plane. The gyroscopic contribution to the angular momentum control requirements resulting from the rotating, earth-oriented spacecraft is also discussed. Special conditions are described whereby one or more components of the angular momentum can be made to vanish, or become purely cyclic. Computer generated plots for a candidate Space Station configuration are presented to supplement the analytically derived results. Author

A88-22504#
A RELATIVELY GENERAL FORMULATION FOR STUDYING DYNAMICS OF THE SPACE STATION BASED MRMS WITH APPLICATIONS
H. W. MAH, V. J. MODI (British Columbia, University, Vancouver, Canada), and Y. MORITA (Tokyo, University, Japan) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 10 p.
(AIAA PAPER 88-0674)

The paper presents a relatively general formulation for studying librational dynamics of a flexible platform supporting a mobile base connected to a series of slewing, flexible appendages. It is applicable to missions requiring slew maneuvers of antennas, telescopes, scientific instruments, and in particular, the U.S. proposed Space Station's Mobile Remote Manipulator System (MRMS). The formulation is applied to the SCOLE configuration representing the Space Shuttle based flexible beam supporting a rigid reflector at its end. The analysis provides a useful insight into interactions between inertia parameters, orbit geometry, translational and slewing time histories, flexibility and initial conditions. Results suggest that under critical combinations of the parameters the system may become unstable. Author

A88-22505*# Howard Univ., Washington, D. C.
MINIMUM TIME ATTITUDE SLEWING MANEUVERS OF A RIGID SPACECRAFT
FEIYUE LI and PETER M. BAINUM (Howard University, Washington, DC) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 12 p. refs
(Contract NSG-1414)
(AIAA PAPER 88-0675)

The minimum time attitude slewing motion of a rigid spacecraft with its controls provided by torques and forces, which have their upper and lower limits prescribed, is considered. The two-point boundary-value problem is derived by applying the Pontriagin's Maximum Principle to the system and solved by using a quasi-linearization algorithm. The nominal solutions to the problem as well as the starting values of the total slewing time and the unknown initial costates for this algorithm are generated by using Euler's eigenaxis rotation theorem. It is pointed out that one of the four initial costates associated with the quaternions can be arbitrarily selected without affecting the optimal controls and, thus, simplifying the computation. The minimum slewing time is determined by shortening the total slewing time until at least one of the controls becomes a bang-bang type. Several numerical tests for the rigidized SCOLE model are presented to show the applications of the methods. Author

A88-22507*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TECHNIQUES FOR ASSESSMENT OF FLEXIBLE SPACE STRUCTURE CONTROL PERFORMANCE
LAWRENCE F. ROWELL (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 17 p. refs
(AIAA PAPER 88-0677)

Several multivariable concepts are presently applied to both the open-loop and closed-loop analysis of a wrap-rib antenna space structure. After evaluating the alternative placements of sensors and actuators by means of controllability, observability, and transmission-zero concepts, the linear quadratic gaussian/loop transfer recovery method is used to synthesize a control law for suppression of the transient vibrations that are typically encountered during maneuvers. The integration of these techniques and associated computer programs into a larger spacecraft design system is also discussed. O.C.

A88-22608#
DISTRIBUTED SYSTEMS APPROACH TO THE IDENTIFICATION OF FLEXIBLE STRUCTURES
K. Y. LEE (Pennsylvania State University, University Park) and S. A. HOSSAIN (TRW, Inc., TRW Space and Technology Group,

Redondo Beach, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Nov.-Dec. 1987, p. 540-548. refs

This paper presents a distributed parameter estimation scheme and investigates its computational merit for three idealized examples of the identification of large flexible structures. The method retains the distributed nature of the structure throughout the development of the algorithm and a finite-element approximation is used only to implement the algorithm. This approach eliminates many problems associated with the model truncation used in other methods of identification. The identification problem is formulated in Hilbert spaces and an optimal control technique is used to minimize a weighted least squares of error between the actual and the model data. A variational approach is used to solve the problem. A costate equation, gradients of parameter variations and conditions for optimal estimates are obtained. Computer simulation studies are conducted using flexible beam models as examples. Numerical results show a close match between the estimated and true values of the parameters.

Author

A88-22609#
DYNAMICS OF EARTH-ORBITING FLEXIBLE SATELLITES WITH MULTIBODY COMPONENTS

L. VU-QUOC and J. C. SIMO (Stanford University, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Nov.-Dec. 1987, p. 549-558. refs
(Contract AF-AFOSR-83-0361)

A novel approach to the dynamics of satellites with flexible multibody components is proposed. The property of invariance under superposed rigid-body motions of geometrically-exact structural theories is employed to refer the dynamics of motion directly to the inertial frame. To avoid numerical ill conditioning, the dynamics of the far field and the near field are treated separtely by introducing a rotationally-fixed floating frame, which is a parallel translate of the inertial frame. Constraint conditions to determine the orientation of floating frames proposed in the past are thus entirely bypassed. The proposed formulation can accommodate an unrestricted class of maneuvers under the action of follower forces and gravitational force, and is particularly suited for the dynamics of flexible multibody systems undergoing a broad range of deformations.

Author

A88-22932* Virginia Polytechnic Inst. and State Univ., Blacksburg.
MANEUVERING AND VIBRATION CONTROL OF FLEXIBLE SPACECRAFT

L. MEIROVITCH (Virginia Polytechnic Institute and State University, Blacksburg) and R. D. QUINN (Case Western Reserve University, Cleveland, OH) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 35, July-Sept. 1987, p. 301-328. refs
(Contract NAG1-225)

This paper is concerned with the problem of slewing a large structure in space and suppressing any vibration at the same time. The structure is assumed to undergo large rigid-body motions and small elastic deformations. A perturbation method permits a maneuver strategy independent of the vibration control. Optimal control and pole placement techniques, formulated to include first-order actuator dynamics, are used to suppress the vibration during maneuver. The theory is illustrated by simultaneous maneuvering and vibration control of the Spacecraft Control Laboratory Experiment (SCOLE) model in a space environment.

Author

A88-22933* Nevada Univ., Las Vegas.
ATTITUDE CONTROL OF A THREE ROTOR GYROSTAT IN THE PRESENCE OF UNCERTAINTY

SAHJENDRA N. SINGH (Nevada, University, Las Vegas) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 35, July-Sept. 1987, p. 329-345. refs
(Contract NAS1-17919)

A nonlinear control law for large angle rotational maneuvers of spacecraft using reaction wheels in the presence of uncertainty is presented. The derivation of this suboptimal control law does not require any information on the values of the system parameters and the disturbance torques acting on the spacecraft. The controller includes a dynamic system in the feedback path. The control law is a nonlinear function of the attitude error, the rate of the attitude error and the compensator state. Simulation results are presented to show that large angle rotational maneuvers can be performed in spite of the uncertainty in the system.

Author

A88-23982#
DECENTRALIZED/HIERARCHICAL CONTROL FOR LARGE FLEXIBLE SPACECRAFT

K. JANSCHEK and M. SURAUER (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IFAC, World Congress, 10th, Munich, Federal Republic of Germany, July 26-31, 1987, Paper. 9 p. refs
(MBB-UR-967-87)

A MIMO design procedure for flexible spacecraft and equipment modeling based on a well-known sequential design approach is described which permits the user to deal with robust stabilization of flexible structural modes, complex equipment dynamics, time delay due to measurement/control algorithm processing, hybrid continuous/discrete time control loops, and nonlinearities. The boundary conditions that must be observed for the selection of an appropriate control concept and the general tasks for the different control loops are summarized. Some typical sample results are given for a communication satellite configuration.

C.D.

A88-24281* Nevada Univ., Las Vegas.
FLEXIBLE SPACECRAFT MANEUVER - INVERSE ATTITUDE CONTROL AND MODAL STABILIZATION

SAHJENDRA N. SINGH (Nevada, University, Las Vegas) Acta Astronautica (ISSN 0094-5765), vol. 17, Jan. 1988, p. 1-9. NASA-supported research. refs

A control law is presented for three-axis rotational maneuvers of a spacecraft (orbiter)-beam-tip body (antenna or a reflector) configuration based on nonlinear inversion and modal velocity feedback. Using invertibility and functional reproducibility results, a decoupling attitude control law is presented such that, in the closed-loop system, the attitude angles of the spacecraft are independently controlled using the control moments acting on the space vehicle. This controller asymptotically decouples the flexible dynamics from the rigid one and also allows the decomposition of the elastic dynamics into two subsystems representing the transverse deflections of the beam in two orthogonal planes. These low-order subsystems are used for derivation of a modal velocity feedback stabilizer using the force and moment actuators at the end body. Simulation results are presented to show that, in the closed-loop system, attitude control and elastic mode stabilization are accomplished in spite of the parameter uncertainty and disturbance torque input in the system.

Author

A88-24506#
ROOT LOCUS METHOD FOR ACTIVE CONTROL OF FLEXIBLE SYSTEMS

NORIHIRO GOTO (Kyushu University, Fukuoka, Japan) and SHINJI HOKAMOTO Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 30, Nov. 1987, p. 150-161. refs

Precise attitude and shape control of flexible spacecraft requires active control of flexural vibrations. This work is concerned with the root locus method applied to active vibration control systems for a certain class of flexible bodies. A general characteristic equation is first derived for a feedback system to control flexural vibrations with arbitrary numbers of sensors and actuators. Then it is shown for the first time that the characteristic equation in a determinantal form may be reduced to a mathematically tractable form. It is also shown that under the condition of colocation of sensors and actuators the characteristic equation takes a form by which the significance of the condition can be readily appreciated. Finally the paper presents a numerical study to illustrate a practical procedure of applying the root locus method to flexural vibration control systems.

Author

A88-25797
OPTIMIZATION OF ACTIVELY CONTROLLED STRUCTURES USING GOAL PROGRAMMING TECHNIQUES
S. S. RAO (Purdue University, West Lafayette, IN), V. B. VENKAYYA, and N. S. KHOT (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 26, Jan. 1988, p. 183-197. USAF-sponsored research. refs

The problem of design of actively controlled structures subject to restrictions on the damping parameters of the closed-loop system is formulated and solved as a multiobjective optimization problem. The purpose of control is to effectively suppress structural vibrations due to initial excitation. The cross-sectional areas of the members are treated as design variables. The structural weight and the controlled system energy are considered as objective functions for minimization. The goal programming approach is used for the solution of the multiobjective optimization problems. The procedure is illustrated through numerical simulations using two-bar and twelve-bar truss structures. Author

A88-26356#
AN EXPERIMENTAL STUDY ON FLEXIBLE SPACECRAFT THREE-AXIS ATTITUDE CONTROL
TAKASHI KIDA, ISAO YAMAGUCHI, OSAMU OKAMOTO, YOSHIAKI OHKAMI, SHINICHIRO ICHIKAWA et al. Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 407, 1987, p. 569-576. In Japanese, with abstract in English. refs

This paper studies three-axis attitude-control problems of a class of flexible spacecraft having elastic appendages. A linear quadratic regulator (LQR) associated with a state estimator is designed to control its attitude and the appendage vibration, simultaneously. In order to evaluate and demonstrate the controller performance, ground-based control experiments are conducted, using an ETS-VI laboratory model supported on a single-axis air table. The evaluation is made concered mainly with (1) LQR realization by using a thruster and a reaction wheel, and (2) stability robustness against the truncated vibration modes of flexible appendages. Author

A88-27317* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADAPTIVE CONTROL FOR FLEXIBLE SPACE STRUCTURES WITH MEASUREMENT NOISE
DAVID S. BAYARD, CHE-HANG CHARLES IH, and SHYH JONG WANG (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1987, p. 368-379. refs

Simulation results are presented to address the problem of measurement noise in the design of adaptive controllers for large flexible space structures. In order to reduce the unrealistically high overall control demand resulting from the presence of leakage terms, a method has been developed for the introduction of noise filters into the adaptive controller while at the same time ensuring the global stability of the adaptive algorithm. A branch filter allows filtering of the output error without introducing phase lag into the adaptive loop. The technique is demonstrated in the simulation of an adaptive payload articulation control for a Space Station model. R.R.

A88-27319* Texas Univ., Austin.
A PARAMETER ROBUST LQG DESIGN SYNTHESIS WITH APPLICATIONS TO CONTROL OF FLEXIBLE STRUCTURES
MINJEA TAHK and JASON L. SPEYER (Texas, University, Austin) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1987, p. 386-392. NASA-supported research. refs
(Contract AF-AFOSR-84-0371)

An asymptotic LQG design synthesis technique is described which explicitly includes a class of structured plant uncertainties by viewing plant parameter variations as an internal feedback loop. A direct structural relationship between this class of parameter uncertainties and the weighting matrices in the design of the LQG compensator is exploited by an asymptotic procedure in which either the regulator or the filter become insensitive to parameter variations. This asymptotic approach represents a generalization of the LQG/LTR technique. Controllers designed by this new LQG method and LQG/LTR are compared by application to a mass-spring-damper system which approximates the dynamics of flexible structures. For both colocated and noncolocated sensors and actuators configurations, the LQG/LTR design is extremely sensitive to parameter variations whereas the new LQG design allows considerably improved parameter robustness. Author

A88-27325
ROBUST STABILIZATION UNDER MODE TRUNCATION AND PARAMETER VARIATIONS
RAMA K. YEDAVALLI (Toledo, University, OH) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1987, p. 490-495. refs
(Contract F33615-86-K-3611)

This paper addresses the issue of stability robustness under mode truncation and parameter variations with emphasis on Large Space Structures (LSS) models. The recent development of elemental (structured) upper bounds on the perturbation of an asymptotically stable linear system to maintain stability is extended to the problem of LSS control in which both mode truncation (model reduction) as well as parameter variations (uncertainty in modal frequencies, dampings, and mode shape slopes at actuator/sensor locations) are considered as perturbations acting on the control design model. A simple algorithm is proposed to design a robust controller, with vibration suppression as the control objective, for robust stability and acceptable nominal performance under mode truncation and parameter errors. The algorithm is such that it clearly delineates the trade off between the control effort needed for acceptable regulation and the number of modes one needs to control for robust stability. Author

A88-27355* Pennsylvania State Univ., University Park.
INFORMATION PRIORITIZATION FOR CONTROL AND AUTOMATION OF SPACE OPERATIONS
ASOCK RAY (Pennsylvania State University, University Park), SURESH M. JOSHI (NASA, Langley Research Center, Hampton, VA), CYNTHIA K. WHITNEY (Charles Stark Draper Laboratory, Inc., Cambridge, MA), and HONG N. JOW (Yankee Atomic Electric Co., Framingham, MA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 958-960. refs

The applicability of a real-time information prioritization technique to the development of a decision support system for control and automation of Space Station operations is considered. The steps involved in the technique are described, including the definition of abnormal scenarios and of attributes, measures of individual attributes, formulation and optimization of a cost function, simulation of test cases on the basis of the cost function, and examination of the simulation scenerios. A list is given comparing the intrinsic importances of various Space Station information data. C.D.

A88-27357
ACTIVE VIBRATION CONTROL ON THE OSU FLEXIBLE BEAM
UMIT OZGUNER and STEVE YURKOVICH (Ohio State University, Columbus) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 970-975. Research supported by Ohio State University. refs

The idea of actively damping vibrations in flexible structure systems has received much attention in recent years. Such systems present a particular problem in that there is no fixed frame of reference for actuation; actuators must then be mounted on the

structure itself. Currently at Ohio State a laboratory facility is being developed to study control of flexible structures; one specific configuration is a six foot free-free beam which is suspended from the ceiling. Such a beam can be controlled by applying torques about the bending axis or by applying transverse forces. Due to the size constraints of such a laboratory-scale experiment, a small structure with small actuators and sensing devices is utilized. Transverse actuators (developed in-house) were chosen for the experiment, and sensing is accomplished via several sets of strain gauges and accelerometers mounted on the structure. This paper discusses issues involved with the modeling of this structure, and presents a brief summary of the various control approaches, primarily from a decentralized viewpoint, which are currently being applied to the laboratory setup. Author

A88-27358
STRUCTURAL DECOMPOSITION APPROACH TO DESIGN OF ROBUST DECENTRALIZED CONTROLLERS FOR LARGE SCALE SYSTEMS
J. V. MEDANIC, H. S. THARP, and W. R. PERKINS (Illinois, University, Urbana) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 976-981. refs

This paper describes an integrated methodology for determining a decentralized control structure for LSS with corresponding low-order controllers. Structural decomposition is based on the use of the Generalized Hessenberg Representation (GHR). Controller design is accomplished by utilizing frequency weighting in the performance criterion, together with projective controls. The methodology is illustrated by a case study of a 40th-order space structure model. Author

A88-27359* Virginia Polytechnic Inst. and State Univ., Blacksburg.
A SURVEY OF DECENTRALIZED CONTROL TECHNIQUES FOR LARGE SPACE STRUCTURES
D. K. LINDNER and K. REICHARD (Virginia Polytechnic Institute and State University, Blacksburg) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 982-985. refs
(Contract NAS1-18106)

Preliminary results on the design of decentralized controllers for the COFS I Mast are reported. A nine mode finite element model is used along with second order model of the actuators. It is shown that without actuator dynamics, the system is stable with collocated rate feedback and has acceptable performace. However, when actuator dynamics are included, the system is unstable. Author

A88-27364* Nevada Univ., Las Vegas.
THREE AXIS ROTATIONAL MANEUVER AND VIBRATION STABILIZATION OF ELASTIC SPACECRAFT
SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1106-1111. NASA-supported research. refs

A control law for three-axis rotational maneuvers of a spacecraft beam-tip body configuration based on non-linear inversion and modal velocity feedback is presented. A decoupling attitude control law is presented such that in the closed-loop system the attitude angles of the spacecraft are independently controlled, using the control moments acting on the space vehicle. This controller asymptotically decouples the flexible dynamics from the rigid one and also allows the decomposition of the elastic dynamics into two subsystems representing the transverse deflections of the beam in two orthogonal planes. These low-order subsystems are used for the derivation of a modal velocity feedback stabilizer using the force and moment actuators at the end body. Simulation results are presented to show the capability of the controller. Author

A88-27367* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DESIGN OF ROBUST LINE-OF-SIGHT POINTING CONTROL SYSTEM FOR THE SCOLE CONFIGURATION
S. M. JOSHI and E. S. ARMSTRONG (NASA, Langley Research Center, Hampton, VA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1125-1127. refs

Robust compensator design for attitude control of the Spacecraft Control Laboratory Experiment (SCOLE) configuration is considered. A loop-shaping procedure similar to that used in the LQG/LTR method is used to iteratively design the compensator. A satisfactory compensator is obtained by including the rigid modes and three elastic modes in the design model. C.D.

A88-27377
CONTROL OF DISTRIBUTED PARAMETER SYSTEMS WITH SPILLOVER USING AN AUGMENTED OBSERVER
YOSSI CHAIT and CLARK J. RADCLIFFE (Michigan State University, East Lansing) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1193-1198. refs

Modern modal control methods for flexible structures, based on a truncated model of the structure's dynamics, have control and observation spillover which can reduce the stability margin of the controlled structure. Here, a standard model formulation of a distributed-parameter system is presented along with conventional control methods. The spillover phenomenon is defined, and the advantages and disadvantages of sensor output filtering are examined. A new design for a modern modal control system with an output filter augmented into the observer is developed. A comparison between the different control methods is made using a numerical example. C.D.

A88-27393* Systems Engineering Labs., Inc., Greenbelt, Md.
ROBUSTNESS ISSUES IN BOUNDARY FEEDBACK OF FLEXIBLE STRUCTURES
W. H. BENNETT, H. G. KWATNY, and J. S. BARAS (Systems Engineering, Inc., Greenbelt, MD) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1307-1313. refs
(Contract NAS1-18209)

Transfer function models for basic structural elements with boundary control reveal certain inherent properties relevant to questions of control system realization, design, and analysis of robustness. The transfer functions involved are not strictly proper, may be nonminimum phase (except for the special case of colocated actuation and sensing), and often have large number of poles on the imaginary axis. In this paper these basic questions are considered in terms of modeling and control system design for robustness. The application of algebraic methods for computing stabilizing control, based on certain exact, irrational transfer functions is investigated. Boundary control of the wave equation is considered and extension of the method to more general problems is suggested. Special attention is given to implementation issues associated with a class of infinite dimensional control laws. Author

A88-27395
ACTIVE MODIFICATION OF WAVE REFLECTION AND TRANSMISSION IN FLEXIBLE STRUCTURES
DAVID W. MILLER, ANDREAS VON FLOTOW, and STEVEN R. HALL (MIT, Cambridge, MA) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1318-1324. refs

A theory for active control of elastic wave propagation in structures is developed. Attention is focused on active modification of the scattering behavior of discrete locations in a structural network. The wave mode input/output relation at a structural

junction containing control actuators can be altered in two ways. First, the closed loop reflection and transmission coefficients can be specified, and the necessary feedback to achieve these coefficients determined. Second, an optimal wave controller can be formulated which maximizes the average power dissipation at a junction. If the open loop structure is stable, then the optimal control guarantees stability, since energy is actively dissipated at the junction. Sample controllers are derived and simulated for a free-free beam to demonstrate the techniques and indicate the achievable performance. Author

A88-27397
SENSOR AND ACTUATOR SELECTION FOR OPTIMAL CLOSED-LOOP PERFORMANCE IN THE PRESENCE OF CORRELATED NOISE
G. A. NORRIS and R. E. SKELTON (Purdue University, West Lafayette, IN) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1337-1341. refs

A method is presented for the selection of sensors and actuators whose outputs may contain correlated noise. A generalization of the earlier results of Closed-Loop Input/Output Cost Analysis (CIOCA) is provided which utilizes decompositions of the closed-loop quadratic cost function into contributions from each stochastic noise input and each weighted output. It is shown that under certain circumstances the elimination of a correlated noise input may degrade performance. Application to a flexible space structure demonstrates the generalized method for sensor and actuator selection. Author

A88-27401
A HOMOTOPY ALGORITHM FOR SOLVING THE OPTIMAL PROJECTION EQUATIONS FOR FIXED-ORDER DYNAMIC COMPENSATION - EXISTENCE, CONVERGENCE AND GLOBAL OPTIMALITY
STEPHEN RICHTER (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1527-1531. refs
(Contract F49620-86-C-0038)

A homotopy algorithm for solving the optimal projection equations (OPEs), relevant to the problem of vibration suppression in large flexible space structures, is presented. The existence and the number of solutions are investigated. It is shown that the number of stabilizing solutions to the OPEs can be determined and that all solutions can be computed via a homotopic continuation from a simple problem. For an important special case, where the number of inputs or outputs to the system is less than or equal to the dimension of the compensator, there is only one solution to the OPE, guaranteeing that globally optimum reduced order controller can be computed. C.D.

A88-27402
(M,N)-APPROXIMATION - A SYSTEM SIMPLIFICATION METHOD
A. YOUSUFF (Drexel University, Philadelphia, PA), T. E. MCQUADE, and S. S. BANDA (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1534-1536. refs
(Contract F49620-85-C-0013)

The need for approximation of model systems has increased since the realization of large space structures and high-speed and supermaneuverable aircraft that undergo rapid dynamic changes. This paper presents a method for simplifying systems made up of N interconnected subsystems by approximating only M of the N subsystems. Each of the M subsystems is reduced while all interactions are active, and the identities of all subsystems in the overall approximation are preserved. A new version of balanced controllers is shown to be generated by this method. A numerical example is included which compares the new method with other balancing methods, and the results are shown to favor the new method. C.D.

A88-27404* Texas Univ., Arlington.
LYAPUNOV FUNCTION GRADIENT GENERATED ROBUST CONTROL IN THE ABSENCE OF THE NOMINAL STABILIZING CONTROL
C. C. BLACKWELL (Texas, University, Arlington) IN: 1987 American Control Conference, 6th, Minneapolis, MN, June 10-12, 1987, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1987, p. 1595-1600. refs
(Contract JPL-957451)

A relevant facet of the application of Lyapunov gradient-generated robust control to unstable linear autonomous plants is explored. It is demonstrated that if the plant, the output, and the nominal stabilizing control satisfy certain conditions, then the robust component alone stabilizes the nominal plant. An example characterized by two zero eigenvalues and two negative real value poles is presented. These results assure that the robust component will fulfill the role of nominal stabilization successfully so long as the possible magnitude of the robust component can overcome the contribution of the instability to positiveness of the Lyapunov rate. C.D.

A88-27768
IDENTIFICATION AND CONTROL OF FLEXIBLE STRUCTURES [IDENTIFICATION ET COMMANDE DES STRUCTURES FLEXIBLES]
J. P. CHRETIEN, G. HARDIER, and J. L. PAC (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) IN: Automatic systems in aeronautics; National Colloquium, Paris, France, Mar. 17-19, 1986, Proceedings. Toulouse, Cepadues-Editions, 1986, p. 455-493. In French. refs

Techniques for the active control of flexible structures and for modeling their behavior in the frequency and time domains are reviewed. The advantages of the frequency-domain approach are pointed out, and it is shown how processing of input signals and noise in the time-domain can lead to an equivalent collection of data in the frequency domain. The method is applied to the problem of the computer-aided analysis of transport aircraft flutter. The model is minimized to permit the obtaining of control laws. Canonical models are developed to solve the control problem. It is pointed out that the critical parameter of absolute damping is manifested at the level of the reduction of dimensionality, at the level of control filtering, and at the level of positive control. R.R.

A88-28253#
MOMENTUM MANAGEMENT AND ATTITUDE CONTROL DESIGN FOR A SPACE STATION
HENRY H. WOO, HENLEY D. MORGAN, and ERIC T. FALANGAS (Rockwell International Corp., Downey, CA) (Guidance, Navigation and Control Conference, Williamsburg, VA, Aug. 18-20, 1986, Technical Papers, p. 277-286) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Jan.-Feb. 1988, p. 19-25. Research supported by Rockwell International Corp. Previously cited in issue 23, p. 3426, Accession no. A86-47430. refs

A88-28509#
DYNAMICS OF LARGE CONSTRAINED FLEXIBLE STRUCTURES
F. M. L. AMIROUCHE (Illinois, University, Chicago) and R. L. HUSTON (Cincinnati, University, OH) ASME, Transactions, Journal of Dynamic Systems, Measurement and Control (ISSN 0022-0434), vol. 110, March 1988, p. 78-83. refs

This paper presents an automated procedure useful in the study of large constrained flexible structures, undergoing large specified motions. The structure is looked upon as a 'partially open tree' system, containing closed loops in some of the branches. The governing equations are developed using Kane's equations as formulated by Huston et al. The accommodation of the constraint equations is based on the use of orthogonal complement arrays. The flexibility and oscillations of the bodies is modeled using finite

segment modeling, structure analysis, and scaling techniques. The procedures developed are expected to be useful in applications including robotics, space structures, and biosystems. Author

A88-29245#
ON LOCAL STATE FEEDBACK AND STABILITY DOMAIN ESTIMATION OF NONLINEAR LARGE SCALE SYSTEMS
RUNYI YU and WEIBING GAO (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 8, Nov. 1987, p. A 597-A 604. In Chinese, with abstract in English. refs

In this paper, a linear quadratic design and a technique to define a quadratic Lyapunov function from the positive solution of N decoupled Riccati algebraic eqautions are used to stabilize nonlinear, time-invariant, large-scale systems by local state feedback and to determine the stability domain. For 'minimal strongly connected systems' and other systems with similar properties, the method is quite effective and the procedure is simple. The method gives better results than others with regard to the decentralized stabilization of a large-scale telescope. C.D.

A88-29474
INTEGRATED CONTROL OF LARGE FLEXIBLE STRUCTURES
GLORIA CAPITANI and MARCO TIBALDI (Bologna, Universita, Italy) International Journal of Control (ISSN 0020-7179), vol. 47, Feb. 1988, p. 569-580. refs

A procedure for the design of algebraic feedback that aims to improve the stability of flexible structures is presented. This algebraic controller design can be integrated into the design of a reduced-order dynamic controller. The algebraic feedback design is developed and improved from earlier works. An application to the solar optical telescope (SOT) model is shown. Author

A88-29698
DYNAMIC RESPONSES OF ORTHOTROPIC PLATES UNDER MOVING MASSES
O. P. AGRAWAL (Southern Illinois University, Carbondale, IL), S. SAIGAL (Worcester Polytechnic Institute, MA), and M. M. STANISIC Ingenieur-Archiv (ISSN 0020-1154), vol. 58, no. 1, 1988, p. 9-14. refs

The problem considered is that of heavy masses moving on lightweight rectangular plates of orthotropic materials, slated for use in space structures. The dynamic equation of motion for orthotropic plates which contains singularities in both space and time variables is first presented. The response is expressed as a summation of double series of eigenfunctions. The equation of motion is transformed into an integrodifferential equation for modal amplitudes using the Green's function. The Green's function is chosen to satisfy the initial conditions, the boundary conditions, and the transient conditions due to the moving masses. The solution series exhibits a good convergence. The effect of orthotropicity on natural frequencies and dynamic responses is demonstrated. Author

A88-29720
A CRITERION FOR SHAPE CONTROL ROBUSTNESS OF SPACE STRUCTURES
MENAHEM BARUCH (Technion - Israel Institute of Technology, Haifa) Zeitschrift fuer angewandte Mathematik und Physik (ISSN 0044-2275), vol. 39, Jan. 1988, p. 84-95. Research supported by Technion - Israel Institute of Technology. refs

The procedure proposed by Baruch (1985) for designing space-structure static-deformation controls without knowledge of the structure mass is rederived, and a robustness criterion for such shape controls is developed analytically. The robustness criterion is defined in terms of the spectral condition number with respect to inversion (Wilkinson, 1965) of the basic matrix A; its usefulness is demonstrated in a numerical example involving a free beam modeled as a 5-DOF discrete structure. T.K.

A88-29815*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SOME EXPERIENCES WITH THE EIGENSYSTEM REALIZATION ALGORITHM
RICHARD S. PAPPA and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) Union College and SEM, International Modal Analysis Conference, 6th, Orlando, FL, Feb. 1-4, 1988, Paper. 8 p. refs

The Eigensystem Realization Algorithm (ERA) is a multiinput/multioutput time-domain algorithm for minimum-order system realization and modal parameter identification. It has been used for structural dynamics data analysis at the Langley Research Center for several years. Some of the practical experiences encountered in these projects are discussed in this paper. Three examples are used: the Galileo spacecraft, the Solar Array Flight Experiment, and a laboratory space-truss model. Several techniques for assessing identification accuracy are illustrated. Author

A88-30115
ROTATION STABILITY OF A DEFORMABLE FLIGHT VEHICLE [OB USTOICHIVOSTI VRASHCHENIIA DEFORMIRUEMOGO LETATEL'NOGO APPARATA]
L. V. DOKUCHAEV Prikladnaia Matematika i Mekhanika (ISSN 0032-8235), vol. 52, Jan.-Feb. 1988, p. 25-33. In Russian. refs

The Lur'e (1961) approach and the Kane (1980) method are used to obtain general equations describing the motion of a liquid-filled elastic flight vehicle in orbit. By generalizing results of earlier studies, conditions are obtained for the asymptotic stability of the rotation of a flight vehicle with allowance for damping. The analysis is illustrated by an example. V.L.

A88-31378#
MEASUREMENT AND MODELING OF JOINT DAMPING IN SPACE STRUCTURES
STEVEN L. FOLKMAN and FRANK J. REDD (Utah State University, Logan) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 7-13. refs
(AIAA PAPER 88-2449)

An area of concern for the design of large space structures is the amount of structural damping which will be present. The joints used to assemble a large, light weight structure like the Space Station will provide some damping; however, an accepted methodology for predicting joint damping is yet to be established. This paper documents a research effort at Utah State University to better understand joint damping in large space structures. A miniature tetrahedral truss was constructed which used pinned joints. A large tip mass was attached to the truss to lower the natural frequency to a range associated with the space station. Considerable ground testing has been conducted to characterize the damping of the truss in a 1-g environment in different orientations and in a vacuum. These experiments show that gravity can dramatically influence the damping produced. Author

A88-31393*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
SPILLOVER STABILIZATION OF LARGE SPACE STRUCTURES
EVA A. CZAJKOWSKI, RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg), and ANDRE PREUMONT (Bruxelles, Universite Libre, Brussels, Belgium) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 131-143. refs
(Contract NAG1-603)
(AIAA PAPER 88-2484)

Active control of large flexible space structures is typically implemented to control only a few known elastic modes. This paper considers the stabilization of the neglected dynamics of the higher modes of vibration. An attempt is made to design modal

controllers with improved spillover stability properties. Two formulations for designing the observer to improve spillover stability with minimum performance loss are proposed. One optimizes the noise statistics used in the design of the Kalman-Bucy Filter (KBF), while the other directly optimizes the the gain matrix of the KBF. C.D.

A88-31394*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DYNAMICS AND CONTROL CHARACTERISTICS OF A REFERENCE SPACE STATION CONFIGURATION
THOMAS R. SUTTER, PAUL A. COOPER, and JOHN W. YOUNG (NASA, Langley Research Center, Hampton, VA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 144-154.
(AIAA PAPER 88-2485)

This paper describes the structural dynamic characteristics of a NASA reference space station configuration as defined in the November 1987 Space Station Program - Systems Engineering and Integration Engineering Data Book. The modes and frequencies of the station below 2.0 Hz were obtained and selected results along with rigid body properties are presented. A three-axis attitude control system using control moment gyros responding to attitude and attitude rate signals is used to regulate the orientation of the station. The stability of the control system with non-collocated sensors is investigated for both compensated and uncompensated control signals. Results from a closed-loop simulation of a commanded attitude change about three axes, and from a closed-loop simulation of the response of the station to an externally applied unit force impulse at the docking port are presented. These simulation results are used to evaluate the possible degree of control/structures interaction which could occur during normal operation of the station. Author

A88-31427
RECENT ADVANCES IN DYNAMICS OF COMPOSITE STRUCTURES
CHARLES W. BERT (Oklahoma, University, Norman) IN: Composite structures 4; Proceedings of the Fourth International Conference, Paisley, Scotland, July 27-29, 1987. Volume 2. London and New York, Elsevier Applied Science, 1987, p. 2.1-2.17. refs

The present evaluation of the development status of composite structure dynamics gives attention to research completed since 1980. The fields addressed encompass the characterization of continuous and short fiber-reinforced composites' dynamic stiffness and damping, the vibratory response of composite beams, plates, and shells, low-velocity transverse impact effects in composite plates, and such dynamic instabilities as aeroelastic phenomena and nonlinear effects. The work reported ranges over experimental, analytical, and numerical investigations; suggestions for future research are presented. O.C.

A88-31556#
THE IMPROVEMENT OF COMPUTATIONAL METHOD FOR EIGENVALUE OF LARGE COMPLEX STRUCTURE SYSTEM
ZHAO-CHANG ZHENG, BAO-RONG CHENG, WU-ZHENG ZU (Tsinghua University, Beijing, People's Republic of China), and PEI-JUN LI (Hebei, Mechanic-Electrical Institute, People's Republic of China) IN: Modal testing and analysis; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 77-81. refs

The method of Ritz vectors is applied to the dynamic substructure and dynamic response analysis of large complex structure systems. The force vector is defined to automatically generate Ritz vectors without external loading for the eigensolutions. Conditions to generate complete base vectors are discussed. The computational accuracy can be increased in the response analysis of a given load if several modes do not participate in the response. It is noted that the first Ritz vector formed must contain all the lowest normal modes required in order to obtain the lower normal modes in the eigenvalue evaluation. R.R.

A88-31564*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
DYNAMICS AND CONTROL OF A PLANAR TRUSS ACTUATOR
V. D. LOVEJOY, H. H. ROBERTSHAW (Virginia Polytechnic Institute and State University, Blacksburg), W. N. PATTEN (Iowa, University, Iowa City), and G. C. HORNER (NASA, Langley Research Center, Hampton, VA) IN: Vibration control and active vibration suppression; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 47-55. refs
(Contract NAG1-570)

The concept of using an active truss actuator to control the vibration of a flexible (space) structure has been investigated. The actuator with a generic beam continuum cantilevered from it has been modeled using energy methods. A time-invariant optimal state feedback scheme was utilized for the control method. A digital simulation of the system dynamic response demonstrated the good vibration control possibilities for the (planar) truss actuator on a large flexible space structure. Author

A88-31565*# Texas A&M Univ., College Station.
ACTIVE VIBRATION CONTROL IN MICROGRAVITY ENVIRONMENT
C. H. GERHOLD (Texas A & M University, College Station) and R. ROCHA (NASA, Johnson Space Center, Houston, TX) IN: Vibration control and active vibration suppression; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 57-63. refs

An active control process to reduce vibration transmitted from the Space Station structure to the vibration sensitive payload is evaluated. A low-friction air-bearing table is used to approximate zero gravity in the horizontal plane. An analog control system is described which activates calibrated air jets when displacement of the test mass is sensed. The air jet control system is found to introduce an effective damping factor in controlling the oscillatory response. The air-jet control system is designed such that the thrust force produces less than 10 to the -5th g acceleration of the payload. An analytical model has verified the amount of damping in addition to flow parameters such as the pressure drop across the valve and the air flow rate. R.R.

A88-31567#
A RECURSIVE POLE PLACEMENT METHOD FOR LARGE FLEXIBLE STRUCTURES
H. BARUH (Rutgers University, New Brunswick, NJ) IN: Vibration control and active vibration suppression; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 79-84. refs

This paper presents a recursive method to accomplish pole placement for control of large-order vibrating systems. The pole placement is based on matrix perturbation theory, where the controls are considered as a first-order perturbation on the uncontrolled system. The difference between the open-loop poles and the desired closed-loop poles is divided into regions small enough to maintain validity of the perturbation assumption. Control gains are then calculated in each region, resulting in a stepwise design. The method presented here is also applicable to any linear, time-invariant system. Author

A88-31570*# Purdue Univ., West Lafayette, Ind.
CONVERGENCE PROPERTIES OF MODAL COSTS FOR CERTAIN DISTRIBUTED PARAMETER SYSTEMS
A. HU and R. E. SKELTON (Purdue University, West Lafayette, IN) IN: Vibration control and active vibration suppression; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York,

American Society of Mechanical Engineers, 1987, p. 107-114. refs
(Contract NAG1-642)

A complete modal cost analysis is presented for the vibration of various kinds of simple continua with different boundary conditions. Explicit formulas for the norm of the response (called the 'cost') are derived for these distributed parameter systems. The convergence theorems developed are useful in the model reduction of the equivalent continuum models of large space structures as well as in the selection of finite-element code for control design. Author

A88-31574#
DESIGN AND ANALYSIS OF PASSIVELY DAMPED LARGE SPACE STRUCTURES
D. R. MORGENTHALER (Martin Marietta Corp., Denver, CO) IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 1-8.

The design of passive damping into large space structures has gained increasing interest in the past several years due to the advantages inherent in a passive control design. These advantages include strict stability, high reliability, relatively low cost, and little or no power requirements. This paper includes examples of large space structures which will benefit from passive damping treatments, the design goals characteristic of these structures, and outlines a basic design approach to achieve the desired damping levels in actual hardware. The paper also shows the application of the design method to structures which have been fabricated and dynamically tested for damping performance under the Passive and Active Control of Space Structures program . Author

A88-31580#
MODAL COUPLING OF STRUCTURES WITH COMPLEX STORAGE MODULI
S. TIWARI (Martin Marietta Corp., Denver, CO) IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 49-52. refs
(Contract F33615-82-C-3222)

A modal coupling technique of a large system with complex storage moduli is presented in this paper. The natural modes of vibration of each substructure are calculated by fixing the interface degrees of freedom of that substructure. The motion of each substructure is then written with reference to the constraint modes and fixed constraint complex modes. A global transformation is then used to incorporate the common boundary degrees of freedom of two or more substructures leaving the fixed constraint generalized dynamic coordinates of each substructure intact. The technique is verified with a planar truss structure having 40 degrees of freedom. Author

A88-31586#
LARGE SPACE STRUCTURE DAMPING TREATMENT PERFORMANCE - ANALYTIC AND TEST RESULTS
R. N. GEHLING (Martin Marietta Corp., Denver, CO) IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 93-100. refs
(Contract F33615-82-C-3222)

Future Large Space Structures (LSSs) will require some means of vibration damping in order to meet system performance goals. The necessary vibration suppression may be achieved through a passive or active means or through a compined passive/active control approach. The Representative System Article (RSA), developed under the Air Force/Martin Marietta Passive and Active Control of Space Structures program, was designed as a generic LSS for analytic study of passive and active control approaches. A laboratory model of the RSA, referred to as the Dynamic Test Article (DTA), is being fabricated to demonstrate the design methods and performance of passive damping treatments and mechanisms. This paper presents the analytic and experimental test results for three DTA components on which modal surveys have been conducted. The results demonstrate that passive damping can be successfully designed and predicted in LSS-type structures using the modal strain energy method and viscoelastic materials. Author

A88-31589#
FRACTIONAL DERIVATIVES IN THE DESCRIPTION OF DAMPING MATERIALS AND PHENOMENA
P. J. TORVIK and D. L. BAGLEY (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 125-135. refs

The use of constitutive equations which involve generalized or fractional derivatives for the description and prediction of the time dependent behavior of materials of interest for damping applications is described. Such relationships, which have origins in observed tendencies towards power law behavior rather than exponential response, are shown to be effective descriptors of the dynamic behavior of real materials. Such models are shown to have a sound theoretical basis and to satisfy essential thermodynamic relationships. When used in structural analysis they lead to causal, analytic results. Examples of the use of such relationships to predict vibratory and creep responses are given. The models and associated techniques are suggested as being highly appropriate for use in predicting the transient motion of large space structures. Author

A88-31594#
VERY HIGH DAMPING IN LARGE SPACE STRUCTURES
J. F. WILSON and L. P. DAVIS (Honeywell, Inc., Sperry Space Systems Div., Phoenix, AZ) IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 167-171.

Applications of passive damping to large space structures using viscous fluid damping elements are discussed. A heritage space qualified isolation system is described in which a similar damping element was used. A potential manifestation of the concept which could be used as the basic building block for large space trusses is described, and a design process for obtaining optimum dynamic performance is outlined. Numerical estimates of the performance achievable in a large Space Station-type truss predict dramatic reductions in settling times. Another manifestation suitable for providing local or supplemental damping is described, design optimization techniques are discussed, and a proposed satellite application is presented. In this example a significant decrease in launch vibration loading without modifying the structural dynamics appears feasible. Author

A88-31596#
INVESTIGATION OF DAMPING FROM NONLINEAR SLEEVE JOINTS OF LARGE SPACE STRUCTURES
A. A. FERRI (Georgia Institute of Technology, Atlanta) IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 187-195. Research supported by Honeywell, Inc. refs

A nonlinear sleeve joint model which accounts for the presence of clearances, impact damping and dry (Coulombic) friction is developed. By studying the free and forced response of this model, it is seen that the overall damping appears to be predominantly viscouslike in nature. This is found to be true even for the cases studied where dry friction is the sole source of energy dissipation. The results are supported by the study of simplified joint models

which use one-way viscous dampers and purely linear viscous elements to emulate the effects of impact and frictional damping. Author

A88-31597*# Auburn Univ., Ala.
AN INVESTIGATION OF THE DAMPING PHENOMENA IN WIRE ROPE ISOLATORS
M. A. CUTCHINS, J. E. COCHRAN, JR. (Auburn University, AL), S. GUEST (NASA, Marshall Space Flight Center, Huntsville, AL), N. G. FITZ-COY, and M. L. TINKER IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 197-204. refs
(Contract NAG8-532)

Early investigations into analytically modeling the dynamics of wire rope vibration isolators are described. Results from both very simple and very complex models are shown. The dynamic model which has the best agreement to date with simple one-dimensional experiments is one which includes a Coulomb friction force which varies with frequency. There are many yet unexplained phenomena, however. The fundamentals which underly multistrand NASTRAN models are given, and some early results are shown. An application simulation is briefly described, as is ongoing research. Author

A88-32177*# 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) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1-8. refs
(Contract F49620-87-C-0074)
(AIAA PAPER 88-2206)

Structural tailoring provides an attractive method to optimize the performance of actively controlled space structures. However, the simultaneous optimization of control gains and structural properties often becomes prohibitively expensive for large systems and physical insight is often lost in the resulting control law. This paper presents a method for optimization of the closed loop structural system using only structural tailoring. Optimal Linear Quadratic Regulator (LQR) control theory is used with weighting matrices chosen based on physical considerations. The LQR control law depends only on two scalar gains and the structural properties. Hence, the closed loop-performance can be expressed in terms of the structural parameters. Results are given for a beam and a truss-beam to show the simplicity of the method and the importance of structural tailoring to increase dynamic performance and to reduce the control effort. Author

A88-32178*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
EXPERIMENTAL STUDIES OF ACTIVE MEMBERS IN CONTROL OF LARGE SPACE STRUCTURES
J. L. FANSON and J. A. GARBA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 9-17. refs
(Contract NAS7-918)
(AIAA PAPER 88-2207)

Intelligent structures for precision spacecraft applications are structural systems incorporating sensors, actuators, and built-in electronic logic that facilitate self-monitoring of structure responses to disturbances. Attention is presently given to adaptive structures, in which the electronic logic need not be integral to the structure. Active members are used to replace selected passive members of truss-type structures; the sensors employed allow measurement of the elastic strain and deformation experienced by the structure. Two struss-type testbed structures are described. O.C.

A88-32189#
ANALYTICAL AND EXPERIMENTAL INVESTIGATIONS FOR SATELLITE ANTENNA DEPLOYMENT MECHANISMS
MASAYOSHI MISAWA, TETSUO YASAKA (Nippon Telegraph and Telephone Public Corp., Radio Communication Systems Laboratories, Kanagawa, Japan), and SHOJIRO MIYAKE (Nippon Telegraph and Telephone Public Corp., Applied Electronics Laboratories, Tokyo, Japan) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 116-124. refs
(AIAA PAPER 88-2225)

This paper deals with the prediction of deployment dynamics, antenna vibration characteristics, and reliability evaluation related to an antenna deployment mechanism (ADM) necessary for large satellite antenna development. A statistical analysis is proposed to predict the deployment dynamics of an antenna based on the driving and friction torques of mechanical parts whose statistical distributions are fitted to normal distributions. The effect of ADM bending stiffness on antenna natural frequencies was studied analytically to establish a guideline for determination of the ADM bending stiffness. The first natural frequency of the antenna was lessened by 5 Hz due to the effect of ADM bending stiffness. A procedure is proposed to evaluate the reliability of the ADM. Author

A88-32193#
DYNAMIC CHARACTERIZATION OF STRUCTURES BY PULSE PROBING AND DECONVOLUTION
A. S. CARASSO and E. SIMIU (NBS, Gaithersburg, MD) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 147-157. Research supported by the U.S. Department of the Interior and USAF. refs
(AIAA PAPER 88-2230)

An account is given of the mathematical and computational basis of a procedure for the identification of linear structural systems from measurements of transient responses to specified pulses. The dynamic Green's functions fully characterize the dynamic behavior of such systems; these functions can be reconstructed by deconvolution from response measurements. The exponential growth of errors due to contamination of the response by noise is prevented by the regularization of the problem in order to minimize a Tikhonov functional. Attention is given to the properties of infinitely divisible pulses. O.C.

A88-32197*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
A FINITE ELEMENT METHOD FOR TIME VARYING GEOMETRY IN MULTIBODY STRUCTURES
J. M. HOUSNER (NASA, Langley Research Center, Hampton, VA), S. C. WU, and C. W. CHANG (COMTEK Co., Grafton, VA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 187-197. refs
(AIAA PAPER 88-2234)

A three-dimensional finite element formulation using convected coordinates is presented for the multibody dynamics of truss-like configurations. Unlike existing formulations, the present one does not superimpose nonlinear rigid body kinematics with linear structural mode shapes, an approach that has recently been shown to be grossly inaccurate under certain conditions. Instead, the finite element method is extended to treat large motions/deformations. The formulation is oriented toward joint dominated structures and places the generalized coordinates at the joints. For the planar spin-up of a flexible beam, results are compared with those derived from a commercially available computer program. The two programs predict nearly identical results. Author

A88-32226*# Florida Univ., Gainesville.
LOW AUTHORITY-THRESHOLD CONTROL FOR LARGE FLEXIBLE STRUCTURES
D. C. ZIMMERMAN (Florida, University, Gainesville), D. J. INMAN (New York, State University, Buffalo), and J.-N. JUANG (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 459-469. refs
(Contract NGT-33-183-801; NSF MEA-83-51807; AF-AFOSR-85-0220)
(AIAA PAPER 88-2270)

An improved active control strategy for the vibration control of large flexible structures is presented. A minimum force, low authority-threshold controller is developed to bring a system with or without known external disturbances back into an 'allowable' state manifold over a finite time interval. The concept of a constrained, or allowable feedback form of the controller is introduced that reflects practical hardware implementation concerns. The robustness properties of the control strategy are then assessed. Finally, examples are presented which highlight the key points made within the paper. Author

A88-32227#
ESTIMATION AND IDENTIFICATION OF NONLINEAR DYNAMIC SYSTEMS
D. JOSEPH MOOK (New York, State University, Buffalo) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 470-478. refs
(AIAA PAPER 88-2271)

A technique is presented for processing noisy state-observable time domain measurements of a nonlinear dynamic system in order to optimally estimate both the state vector trajectory and any model error which may be present. The model error estimate may be subsequently used to accurately identify the parameters in the differential equation model of the nonlinear dynamic system. The method is demonstrated by application to several examples and is shown to be accurate and robust with respect to: (1) large errors in the original assumed differential equation model, including an assumed linear model, (2) low measurement frequency, (3) low measurement accuracy (i.e., large measurement noise), and even (4) low total number of measurements. Author

A88-32228#
CONTROL FOR ENERGY DISSIPATION IN STRUCTURES
S. P. JOSHI, T. L. VINCENT (Arizona, University, Tucson), and Y. C. LIN IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 479-490. refs
(AIAA PAPER 88-2272)

Active vibration suppression of a large flexible space structure has been studied extensively in recent years. The studies include reduced-order modeling of structures with associated controller design. The main objectives of active control design are minimizing hardware and real-time computation while achieving efficient and robust control of the structure. Structure modeling and various control techniques are briefly discussed in this paper. Control designs based on state variable feedback are compared with an energy dissipation-based design. The effect of nonlinearities is considered by allowing saturation of the actuator control. The control design is experimentally implemented and compared with the numerical simulation. Critical issues related to experimental implementation are discussed. The energy dissipation control design is shown to be superior to others in light of the above-mentioned objectives. Author

A88-32229#
VIBRATION CONTROL OF TRUSS BEAM STRUCTURES USING AXIAL FORCE ACTUATORS
MICHIHIRO NATORI (Tokyo, University, Sagamihara, Japan), SHOICHI MOTOHASHI, KENICHI TAKAHARA, and FUMIHIRO KUWAO (Toshiba Corp., Kawasaki, Japan) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 491-499. refs
(AIAA PAPER 88-2273)

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

A88-32259*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
DISPERSION, DAMPING AND CONFINEMENT OF PROPAGATING PULSES IN LARGE SPACE STRUCTURES
MICHAIL ZAK (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 825-836.
(Contract NAS7-918)
(AIAA PAPER 88-2311)

Pulse propagations in large space structures caused by repeated pulse excitations are studied analytically (by using the Z-transforms) and numerically. It is found that resonance regimes can be generated not only by periodical, but also by non-periodical repeated pulses; the conditions for such regimes are derived. Special attention is paid to the dispersion of propagating pulses due to structural irregularities, to damping of pulses due to appropriate combination of elastic and viscous properties of joints between structural members, and to the protection of certain areas of Large Space Structures (LSS) from impacts provided by a pulse trapping effect. Author

A88-32264*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THE NONLINEAR BEHAVIOR OF A PASSIVE ZERO-SPRING-RATE SUSPENSION SYSTEM
STANLEY E. WOODARD and JERROLD M. HOUSNER (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 884-889.
(AIAA PAPER 88-2316)

Various concepts for advanced syspension systems have been proposed for counteracting gravity loads in ground vibration testing of large space structures. Approximating the flight modes of a low-frequency flexible structure in a ground test requires a very soft suspension system. The dynamic behavior of a passive zero-spring-rate mechanism, sometimes used for such ground testing, is analyzed. This mechanism reduces the stiffness inherent in suspending a test specimen by cables. However, the mechanism is shown to be sensitive to imperfections. Imperfections can initiate nonlinear behavior which becomes more pronounced at lower operating frequencies. Furthermore, large pendular motion of the suspension system couples with the vertical motion, producing additional nonlinearity. Author

A88-32283#
OPTIMAL RECONFIGURATION OF THERMALLY DISTORTED WIRE MESH REFLECTORS FOR LARGE SPACE ANTENNAS
A. M. JANISZEWSKI (USAF, Aeronautical Laboratories, Wright-Patterson AFB, OH) and E. N. KUZNETSOV (Illinois, University, Urbana) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988,

Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1041-1047. refs
(AIAA PAPER 88-2340)

The subject of this study is the structural implementation of a large parabolic space antenna in the form of a wire mesh. Being an underconstrained structural system, a wire mesh is inherently shapeless, with any particular geometirc configuration being a function of the applied load. This feature entails ultimate ease of control; geometric reconfiguration of the system can be purely kinematic (i.e., it does not have to involve elastic deformations). This work is an initial assessment of the kinematic reconfiguration of a thermally distorted wire mesh reflector, and of the efficiency of resulting reflector surfaces. Typical thermal patterns are applied, and the resulting changes in member lengths are calculated to serve as inputs to the procedure. The developed technique for optical kinematic reconfiguration employs mean-square distortion. The primary goal of parametric studies performed was to evaluate the efficiency of reconfiguration in relation to the mesh fineness. The results look promising and confirm the viability of the concept of statically controlled geometry in underconstrained structural systems. Author

A88-32292*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ON THE EIGENVALUE AND EIGENVECTOR DERIVATIVES OF A NON-DEFECTIVE MATRIX
JER-NAN JUANG, PEIMAN GHAEMMAGHAMI, and KYONG BEEN LIM (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1124-1131. refs
(AIAA PAPER 88-2352)

A novel approach is introduced to address the problem of existence of differentiable eigenvectors for a nondefective matrix which may have repeated eigenvalues. The existence of eigenvector derivatives for a unique set of continuous eigenvectors corresponding to a repeated eigenvalue is rigorously established for nondefective and analytic matrices. A numerically implementable method is then developed to compute the differentiable eigenvectors associated with repeated eigenvalues. The solutions of eigenvalue and eigenvector derivatives for repeated eigenvalues are then derived. An example is given to illustrate the validity of formulations developed in this paper. Author

A88-32294#
MODE SHAPE IDENTIFICATION AND ORTHOGONALIZATION
ALVAR M. KABE (Aerospace Corp., El Segundo, CA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1143-1150. refs
(AIAA PAPER 88-2354)

An identification procedure to improve the mass weighted orthogonality of measured mode shapes is introduced. The procedure takes into account the degree of mode isolation present during measurement. This is accomplished by establishing a set of new mode shapes, from the measured vectors, that satisfy cross-orthogonality constraints and are a minimum deviation from the measured data. A significant feature is that each measured mode, from which improved modes are identified, can be established using different excitation locations and force levels. This allows the procedure to improve the isolation of modes measured with multishaker, sine dwell testing techniques. Author

A88-32296#
A GENERAL APPROACH TO MODAL ANALYSIS FOR TIME-VARYING SYSTEMS
A. M. BROWDER and R. M. ALEXANDER (Texas A & M University, College Station) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1162-1168. refs
(AIAA PAPER 88-2356)

Methods to generalize modal response analysis for the case of linear time-varying mechanical systems are developed and compared with regard to accuracy, reliability, and ease of implementation. Previous attempts to use modal methods for these systems have failed to include various terms due to time-variation in the eigenvectors; these terms are in fact negligible only under the very restrictive assumption that the system configuration varies quasi-statically. The methods developed here preserve all time-varying characteristics of the modal transformation, and therefore represent completely general approaches to the analysis of linear time-varying mechanical systems. Author

A88-32300#
STRUCTURAL MODEL VERIFICATION WITH LQO THEORY
HELENE LAPIERRE (Spar Aerospace, Ltd., Sainte-Anne-de-Bellevue, Canada) and GERMAIN OSTIGUY (Montreal, Universite, Canada) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1194-1201. Sponsorship: Department of Supply and Services. refs
(Contract DSS-01ST-36100-6-4158)
(AIAA PAPER 88-2360)

A graphical tool is developed and validated for the verification and updating of large structure finite element models (FEM) for better correlation with modal test data. The elaborated Linear Quadratic Optimization (LQO) theory consists of a linearization and solution of the conventional matrix optimization problem which respects the connectivity of the structure and the symmetry of the stiffness matrix. The LQO theory is validated through a numerical and experimental sensitivity analysis. The results demonstrate the ability of the LQO algorithm to identify the regions of the structure and update the stiffness coefficients associated with the inappropriately modeled load paths. Author

A88-32301#
SYSTEM IDENTIFICATION OF FLEXIBLE STRUCTURES
K. Y. LEE (Pennsylvania State University, University Park), S. A. HOSSIAN (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA), and V. B. VENKAYYA (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1202-1209. refs
(AIAA PAPER 88-2361)

This paper presents a distributed parameter estimation scheme for flexible structures and investigates its computational merit for three generic problems. The distributed nature of the structure is retained throughout the development of the algorithm and a finite-element approximation is used only to implement the algorithm. This approach eliminates many problems associated with model truncation used in other methods of identification. The identification problem is formulated in infinite-dimensional spaces and an optimal control technique is used to minimize weighted least squares of error between the actual and the model data. Computer simulation studies are conducted using flexible beam models as examples. Numerical results show a close match between the estimated and true values of the parameters. Author

A88-32323*# 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 IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC,

American Institute of Aeronautics and Astronautics, 1988, p. 1401-1410. refs
(AIAA PAPER 88-2391)

The Lanczos (1950), multisectioning, and subspace iteration sequential methods for vibration analysis presently used as bases for three parallel algorithms are noted, in the aftermath of three example problems, to maintain reasonable accuracy in the computation of vibration frequencies. Significant computation time reductions are obtained as the number of processors increases. An analysis is made of the performance of each method, in order to characterize relative strengths and weaknesses as well as to identify those parameters that most strongly affect computation efficiency. O.C.

A88-32325*# Carnegie-Mellon Univ., Pittsburgh, Pa.
TRANSIENT RESPONSE OF JOINT DOMINATED SPACE STRUCTURES - A NEW LINEARIZATION TECHNIQUE
G. A. FOELSCHE, J. H. GRIFFIN, and J. BIELAK (Carnegie-Mellon University, Pittsburgh, PA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1423-1432. refs
(Contract NAG1-612)
(AIAA PAPER 88-2393)

The linearization method presented for calculating the transient responses of nonlinear systems due to initial disturbances is an extension of the 'describing function' approach, in which the system's steady-state response is calculated by representing such nonlinear elements as space structure joints with impedances that are functions of response amplitude. It is shown that, for the transient case, the steady-state impedances can be averaged over the range of responses in order to furnish equivalent values of stiffness and damping; these, for a given set of initial displacements, may be treated as constant during calculations of system response. O.C.

A88-32339*# Massachusetts Inst. of Tech., Cambridge.
EXPERIMENTAL COMPONENT MODE SYNTHESIS OF STRUCTURES WITH SLOPPY JOINTS
GARY H. BLACKWOOD and A. H. VON FLOTOW (MIT, Cambridge, MA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1565-1575. refs
(Contract NAGW-21; AF-AFOSR-87-0031)
(AIAA PAPER 88-2411)

The accuracy of component mode synthesis is investigated experimentally for substructures coupled by nonideal joints. The work is based upon a segmented experimental beam for which free-interface frequency response matrices are measured for each segment. These measurements are used directly in component mode synthesis to predict the behavior of the assembled structure; the segments are then physically joined, and the resulting frequency response of the superstructure is compared to the prediction. Rotational freeplay is then introduced into the connecting joint, and the new superstructure frequency response is compared to the original linear component mode synthesis prediction. The level of accuracy to be expected in component mode synthesis is discussed in terms of the degree of nonlinearity in the joints, mode number, and mode shapes. Author

A88-32340#
DYNAMIC STABILITY OF A RECTANGULAR PLATE WITH FOUR FREE EDGES SUBJECTED TO A FOLLOWER FORCE
KEN HIGUCHI and EARL H. DOWELL (Duke University, Durham, NC) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1576-1583. refs
(Contract DAAL03-87-K-0023)
(AIAA PAPER 88-2412)

The dynamic stability of a flexible rectangular plate, such as a plate-like large space structure, is analyzed. One of the four free edges of the plate is subjected to a tangential follower force. The plate shows both flutter and divergence instabilities. The flutter load and divergence load are obtained for various slenderness ratios of the rectangular plate by means of modal analysis. In the calculation, many weak instabilities were found. The flutter mechanism was studied in depth because the behavior of the flutter is fairly complicated with respect to variations in slenderness ratio. Moreover, it was determined that a smaller slenderness ratio is generally desirable to realize a high acceleration of the plate. Author

A88-32341#
DYNAMICS AND CONTROL OF SPACECRAFT WITH RETARGETTING FLEXIBLE ANTENNAS
LEONARD MEIROVITCH and MOON K. KWAK (Virginia Polytechnic Institute and State University, Blacksburg) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1584-1592. refs
(Contract F33615-86-C-3233)
(AIAA PAPER 88-2414)

This investigation is concerned with the dynamics and control of a spacecraft comprising a rigid platform and a given number of retargetting 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. The paper contains the derivation of the equations of motion by a Lagrangian approach using quasi-coordinates, as well as a procedure for designing the feedback controls. A numerical example involving a spacecraft consisting of a rigid platform and a single flexible antenna is presented. Author

A88-32343*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ON THE ANALYTICAL TREATMENT OF IMPACT IN FINITE ELEMENT MODELING
GLENDA L. JEFFREY and JERROLD M. HOUSNER (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1602-1610. refs
(AIAA PAPER 88-2417)

Two simplified impact models which could be used in conjunction with finite element modeling of impacted structures are considered. The two methods are: a previously developed localized finite element impulse-momentum procedure for nondissipative impacts, and a simple gap element consisting of a parallel linear spring and damper useful in dissipative impacts. Results are presented for axial impact of an initially stationary rod. Impulse-momentum theory used in conjunction with finite element modeling was found to result in energy variations unrelated to physical behavior; these variations are reduced as the finite element model is refined. Author

A88-32360*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PASSIVE DAMPING FOR SPACE TRUSS STRUCTURES
GUN-SHING CHEN and BEN K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1742-1749. refs
(AIAA PAPER 88-2469)

Theoretical and experimental studies of passive damping techniques in truss-type structures are presented, with emphasis on the use of viscoelastic damping in the parallel load path. The constraining member length is shown to be a convenient design variable for enhancing damping performance. Results are presented for integral damping members made of thin-wall aluminum tubes,

concentric constraining members, and viscoelastic materials in a six-bay truss structure at low frequency and low dynamic strain conditions. Integral members with graphite/epoxy constraining members exhibited relatively low damping values due to the possible polymer interaction during the cocure stage. R.R.

A88-32362*# Massachusetts Inst. of Tech., Cambridge.
EFFECT OF JOINT DAMPING AND JOINT NONLINEARITY ON THE DYNAMICS OF SPACE STRUCTURES
MARY BOWDEN and JOHN DUGUNDJI (MIT, Cambridge, MA) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1764-1773. Research supported by the McDonnell Douglas Astronautics Co. refs
(Contract NAGW-21)
(AIAA PAPER 88-2480)

Analyses of the effect of linear joint characteristics on the vibrations of a free-free, three-joint beam model show that increasing joint damping increases resonant frequencies and increases modal damping but only to the point where the joint gets 'locked up' by damping. This behavior is different from that predicted by modeling joint damping as proportional damping. Nonlinear analyses of the three-joint model with cubic springs at the joints show all the classical single DOF nonlinear response behavior at each resonance of the multiple DOF system: nondoubling of response for a doubling of forcing amplitude, multiple solutions, jump behavior, and resonant frequency shifts. These properties can be concisely quantified by characteristic backbone curves, which show the locus of resonant peaks for increasing forcing amplitude. Author

A88-32363#
ENHANCEMENT OF FREQUENCY AND DAMPING IN LARGE SPACE STRUCTURES WITH EXTENDABLE MEMBERS
C. T. SUN (Purdue University, West Lafayette, IN) and R. T. WANG IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1774-1780. refs
(AIAA PAPER 88-2482)

The objective of this paper is to investigate the effectiveness of using extendable truss members to tailor the vibrational characteristics of large space structures. In contrast to the conventional control of structures using actuators mounted externally on the structures, the use of extendable truss members makes it possible to vary the control force internally, and, thus, achieve a change in natural frequencies and damping factors. A truss beam is employed as an example to demonstrate the effect of this approach in structural control. Author

A88-32718
SURVEY OF PARAMETER ESTIMATION METHODS IN EXPERIMENTAL MODAL ANALYSIS
U. FUELLEKRUG (DFVLR, Institut fuer Aeroelastik, Goettingen, Federal Republic of Germany) (International Modal Analysis Conference, 5th, London, England, Apr. 1987) Society of Environmental Engineers, Journal (ISSN 0374-356X), vol. 27-1, March 1988, p. 31-36, 44. refs

Parameter estimation methods using modal test data are reviewed. Existing techniques and methods are first classified in terms of the required measurement data. A distinction is made between modal and direct parameter identification methods, straightforward and iterative procedures, and local and global approaches. K.K.

N88-10082*# North Carolina Univ., Charlotte. Dept. of Electrical Engineering.
DYNAMICS OF SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) SLEW MANEUVERS Interim Report
Y. P. KAKAD Washington NASA Oct. 1987 43 p
(Contract NAG1-535)
(NASA-CR-4098; NAS 1.26:4098) Avail: NTIS HC A03/MF A01 CSCL 22B

This is the first of two reports on the dynamics and control of slewing maneuvers of the NASA Spacecraft Control Laboratory Experiment (SCOLE). In this report, the dynamics of slewing maneuvers of SCOLE are developed in terms of an arbitrary maneuver about any given axis. The set of dynamical equations incorporate rigid-body slew maneuver and three-dimensional vibrations of the complete assembly comprising the rigid shuttle, the flexible beam, and the reflector with an offset mass. The analysis also includes kinematic nonlinearities of the entire assembly during the maneuver and the dynamics of the interaction between the rigid shuttle and the flexible appendage. The final set of dynamical equations obtained for slewing maneuvers is highly nonlinear and coupled in terms of the flexible modes and the rigid-body modes. The equations are further simplified and evaluated numerically to include the first ten flexible modes and the SCOLE data to yield a model for designing control systems to perform slew maneuvers. Author

N88-10099*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
ATTITUDE CONTROL WORKING GROUP REPORT
DANIEL F. REID (General Electric Co., Philadelphia, Pa.) and PHILLIP A. STUDER *In* NASA-Lewis Research Center, Spacecraft 2000 p 201-232 Jul. 1986
Avail: NTIS HC A11/MF A01 CSCL 22B

The goals were to establish the Attitude Control System (ACS) requirements, constraints, technology assessment, technology shortfalls, expected in the year 2000. These were based upon all missions, military and civil, for LEO and GEO. The critical ACS technology issues were identified and ACS programs developed to address these critical issues. B.G.

N88-10103*# Draper (Charles Stark) Lab., Inc., Cambridge, Mass.
EFFICIENT PLACEMENT OF STRUCTURAL DYNAMICS SENSORS ON THE SPACE STATION
JANET A. LEPANTO and G. DUDLEY SHEPARD 29 Sep. 1987 25 p
(Contract NAS9-17560)
(NASA-CR-172015; NAS 1.26:172015; CSDL-R-2012; UPN-906)
Avail: NTIS HC A03/MF A01 CSCL 22B

System identification of the space station dynamic model will require flight data from a finite number of judiciously placed sensors on it. The placement of structural dynamics sensors on the space station is a particularly challenging problem because the station will not be deployed in a single mission. Given that the build-up sequence and the final configuration for the space station are currently undetermined, a procedure for sensor placement was developed using the assembly flights 1 to 7 of the rephased dual keel space station as an example. The procedure presented approaches the problem of placing the sensors from an engineering, as opposed to a mathematical, point of view. In addition to locating a finite number of sensors, the procedure addresses the issues of unobserved structural modes, dominant structural modes, and the trade-offs involved in sensor placement for space station. This procedure for sensor placement will be applied to revised, and potentially more detailed, finite element models of the space station configuration and assembly sequence. Author

N88-10867*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
RECENT ADVANCES IN STRUCTURAL DYNAMICS OF LARGE SPACE STRUCTURES
LARRY D. PINSON Oct. 1987 23 p Presented at the 38th International Astronautical Federation Congress, Brighton, United Kingdom, 9-17 Oct. 1987
(NASA-TM-100513; NAS 1.15:100513) Avail: NTIS HC A03/MF A01 CSCL 22B

Recent progress in the area of structural dynamics of large space structures is reviewed. Topics include system identification,

large angle slewing of flexible structures, definition of scaling limitations in structural models, and recent results on a tension-stabilized antenna concept known as the hoop-column. Increasingly complex laboratory experiments guide most of the activities leading to realistic technological developments. Theoretical progress in system identification based on system realization theory resulting in unification of several methods is reviewed. Experimental results from implementation of a theoretical large-angle slewing control approach are shown. Status and results of the development of a research computer program for analysis of the transient dynamics of large angle motion of flexible structures are presented. Correlation of results from analysis and vibration tests of the hoop-column antenna concepts are summarized. Author

N88-11735*# Control Research Corp., Lexington, Mass.
CONTROL DESIGN CHALLENGES OF LARGE SPACE SYSTEMS AND SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) Final Report
JIGUAN GENE LIN Oct. 1987 71 p
(Contract NAS1-18185)
(NASA-CR-178392; NAS 1.26:178392) Avail: NTIS HC A04/MF A01 CSCL 22B

The quick suppression of the structural vibrations excited by bang-bang (BB) type time-optional slew maneuvers via modal-dashpot design of velocity output feedback control was investigated. Simulation studies were conducted, and modal dashpots were designed for the SCOLE flexible body dynamics. A two-stage approach was proposed for rapid slewing and precision pointing/retargeting of large, flexible space systems: (1) slew the whole system like a rigid body in a minimum time under specified limits on the control moments and forces, and (2) damp out the excited structural vibrations afterwards. This approach was found promising. High-power modal/dashpots can suppress very large vibrations, and can add a desirable amount of active damping to modeled modes. Unmodeled modes can also receive some concomitant active damping, as a benefit of spillover. Results also show that not all BB type rapid pointing maneuvers will excite large structural vibrations. When properly selected small forces (e.g., vernier thrusters) are used to complete the specified slew maneuver in the shortest time, even BB-type maneuvers will excite only small vibrations (e.g., 0.3 ft peak deflection for a 130 ft beam). Author

N88-11740# Tokyo Univ. (Japan). Inst. of Space and Astronautical Science.
ADAPTIVE CONTROL OF LARGE SPACE STRUCTURE (LSS)
YU SHAOHUA Mar. 1987 43 p
(ISAS-R-621; ISSN-0285-6808) Avail: NTIS HC A03/MF A01

A set of closely related topics concerning the methodology of an optimal attitude maneuver control of a satellite with flexible appendages is investigated, i.e., such as a mathematical model of coupled motion, pulse-mode control, optimal and programmed maneuvers, appendage vibration damping through adaptive control and conventional control, and an adaptive identification (deterministic and stochastic) algorithm of time-varying modal coordinate parameters. A distinctive feature of the research was that only the actuators of the central satellite attitude control system were assumed to perform both satellite attitude control and appendage deformation control. Some aspects of interaction between control system characteristics and structure/configuration design parameters are outlined. Author

N88-12030*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
WAVEFRONT ERROR SENSING
ELDRED F. TUBBS 15 Oct. 1986 15 p
(NASA-CR-181504; JPL-D-3722; NAS 1.26:181504; LDR-TM-86-2)
Avail: NTIS HC A03/MF A01 CSCL 20D

A two-step approach to wavefront sensing for the Large Deployable Reflector (LDR) was examined as part of an effort to define wavefront-sensing requirements and to determine particular areas for more detailed study. A Hartmann test for coarse alignment, particularly segment tilt, seems feasible if LDR can operate at 5 microns or less. The direct measurement of the point spread function in the diffraction limited region may be a way to determine piston error, but this can only be answered by a detailed software model of the optical system. The question of suitable astronomical sources for either test must also be addressed. M.G.

N88-12534 North Carolina State Univ., Raleigh.
NATURAL CONTROL OF FLEXIBLE SPACE STRUCTURES Ph.D. Thesis
MARK HARRISON MORTON 1987 145 p
Avail: Univ. Microfilms Order No. DA8718909

Families of structural control systems are characterized and the inherent properties that provide the essential motiviation behind the theory of Natural Control are revealed. First, the nature of Natural Control and the associated exponential stability characteristics of flexible space structures are described. Nest the dynamics of freely non-rotating flexible spacecraft are reviewed and tne results extended to rotating flexible spacecraft. Finally, the effect of using a limited number of forces to control the non-rotating spacecraft over the use of distributed control forces is characterized by a change in the magnitude of the control effort and a deterioration in the dynamic performance. Two numerical examples demonstrate the results. Dissert. Abstr.

N88-12817*# North Carolina Univ., Charlotte. Dept. of Electrical Engineering.
COMBINED PROBLEM OF SLEW MANEUVER CONTROL AND VIBRATION SUPPRESSION
Y. P. KAKAD 1987 11 p
(Contract NAG1-535)
(NASA-CR-181537; NAS 1.26:181537) Avail: NTIS HC A03/MF A01 CSCL 20K

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

N88-13376# Illinois Univ., Urbana. Decision and Control Lab.
DESIGN OF LOW ORDER CONTROLLERS FOR ROBUST DISTURBANCE REJECTION IN LARGE SPACE STRUCTURES M.S. Thesis
RUSSELL A. RAMAKER Sep. 1987 67 p
(Contract N00014-84-C-0149)
(AD-A185202; DC-97; UILU-ENG-87-2260) Avail: NTIS HC A04/MF A01 CSCL 09A

This thesis will investigate several issues relating to the objective of improving the disturbance rejection of a Large Space Structure (LSS) type system. Due to properties of LSS systems, the design of the controller must address three main issues: 1) improving of the disturbance rejection properties of the system; 2) insuring that the controller is robust to modeling uncertainty; and 3) implementing the design as a low order output feedback controller. The disturbance rejection of the system will be quantified using the H-norm. An arbitrary level of disturbance rejection will then be achieved through a Linear Quadratic (LQ) minimization. This LQ solution produces a state feedback controller which is robust to modeling uncertainty. In order to realize this design, a low order output feedback controller will be designed based on the LQ solution using projective controls. The method described in this thesis will then be applied to a 40th order LSS example. Using a decentralized approach, a controller will be designed which satisfies the issues discussed above. GRA

N88-13377# Stanford Univ., Calif. Dept. of Aeronautics and Astronautics.
MODELING AND CONTROL OF LARGE FLEXIBLE VEHICLES IN THE ATMOSPHERE AND SPACE Final Report, 15 Dec. 1981 - 14 Dec. 1986

HOLT ASHLEY 15 Jun. 1987 8 p
(Contract AF-AFOSR-82-0062; AF PROJ. 2302)
(AD-A185368; AFOSR-87-1171TR) Avail: NTIS HC A02/MF A01 CSCL 20K

Summary of major research findings in three topical areas: 1) traveling wave concepts in the dynamics and control of Large Space Structures, 2) passive damping in Large Space Structures Applications, and 3) active control of rigid and flexible Manipulator Arms. The traveling wave concepts for characterizing the dynamics of flexible structures have introduced an alternative to modal synthesis and established a basis for the development of new controls algorithms. Passive damping studies identified various types of damping mechanisms including thermoelastic, and electromagnetic, and quantified their relative contributions. The active control studies generated a number of algorithms and control strategies and demonstration applications. GRA

N88-13622*# Cincinnati Univ., Ohio. Dept. of Aerospace Engineering and Engineering Mechanics.
SIMULTANEOUS STRUCTURAL AND CONTROL OPTIMIZATION VIA LINEAR QUADRATIC REGULATOR EIGENSTRUCTURE ASSIGNMENT
G. A. BECUS, C. Y. LUI, V. B. VENKAYYA, and V. A. TISCHLER (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.) *In* NASA-Marshall Space Flight Center, The 58th Shock and Vibration Symposium, Volume 1 p 225-232 Oct. 1987
Avail: NTIS HC A21/MF A01 CSCL 20K

A method for simultaneous structural and control design of large flexible space structures (LFSS) to reduce vibration generated by disturbances is presented. Desired natural frequencies and damping ratios for the closed loop system are achieved by using a combination of linear quadratic regulator (LQR) synthesis and numerical optimization techniques. The state and control weighing matrices (Q and R) are expressed in terms of structural parameters such as mass and stiffness. The design parameters are selected by numerical optimization so as to minimize the weight of the structure and to achieve the desired closed-loop eigenvalues. An illustrative example of the design of a two bar truss is presented. Author

N88-13623*# Honeywell, Inc., Glendale, Ariz.
VISCOUS DAMPED SPACE STRUCTURE FOR REDUCED JITTER
JAMES F. WILSON and L. PORTER DAVIS *In* NASA-Marshall Space Flight Center, The 58th Shock and Vibration Symposium, Volume 1 p 233-243 Oct. 1987
Avail: NTIS HC A21/MF A01 CSCL 20K

A technique to provide modal vibration damping in high performance space structures was developed which uses less than one once of incompressible fluid. Up to 50 percent damping can be achieved which can reduce the settling times of the lowest structural mode by as much as 50 to 1. This concept allows the designers to reduce the weight of the structure while improving its dynamic performance. Damping by this technique is purely viscous and has been shown by test to be linear over 5 orders of input magnitude. Amplitudes as low as 0.2 microinch were demonstrated. Damping in the system is independent of stiffness and relatively insensitive to temperature. Author

N88-14067*# Honeywell, Inc., Clearwater, Fla. Space and Strategic Avionics Div.
APPROACHES AND POSSIBLE IMPROVEMENTS IN THE AREA OF MULTIBODY DYNAMICS MODELING
K. W. LIPS and R. SINGH (DYNACS Engineering Co., Inc., Clearwater, Fla.) 30 Oct. 1987 45 p
(Contract NAS8-34588)
(NASA-CR-179227; NAS 1.26:179227) Avail: NTIS HC A03/MF A01 CSCL 01A

A wide ranging look is taken at issues involved in the dynamic modeling of complex, multibodied orbiting space systems. Capabilities and limitations of two major codes (DISCOS, TREETOPS) are assessed and possible extensions to the CONTOPS software are outlined. In addition, recommendations are made concerning the direction future development should take in order to achieve higher fidelity, more computationally efficient multibody software solutions. Author

N88-14121# Rensselaer Polytechnic Inst., Troy, N.Y.
STUDIES OF THE STRUCTURAL DYNAMIC BEHAVIOR OF SATELLITE ANTENNA SYSTEM Final Report, 1 Sep. 1983 - 29 Jun. 1987
ROBERT G. LOEWY 29 Jun. 1987 28 p
(Contract AF-AFOSR-0348-83)
(AD-A185526; AFOSR-87-1167TR) Avail: NTIS HC A03/MF A01 CSCL 22B

A Transfer Matrix (TM) Analysis is formulated to predict the natural modes and frequencies of hoop-maypole type satellite antenna systems. Two directions of bending, axial extension/compression and torsion are represented as coupled by feed assemblies canted with respect to the mast, solar panels tilted out of the plane of the center structure and masses offset from the mast centerline. Shear deflections, large steady cable loads and large compressive loads are accounted for in appropriate members. Using properties chosen as representative of such structures, trends are predicted with variations in size and configuration for several simplified configurations; these include, (a) two-dimensional cable-suspended rigid bars on a flexible center body (mast), (b) T and H -shaped center body sub structures in two and three-dimensional vibrations and (c) cable-stiffened, planar polygonal hoop assemblies. In the last of these cyclic symmetry had to be invoked to avoid numerical difficulties. Some general conclusions are drawn regarding the free vibrations of such structures. The TM approach is seen as a viable alternative to FEM analyses, when structures are encountered which have major substructures with one dimension longer than its others. Full use of the TM analysis for hoop-maypole type structures must await a reformulation in which cyclic symmetry can be invoked, as in the plane hoop cases. GRA

N88-14866*# Texas A&M Univ., College Station. Dept. of Mechanical Engineering.
ACTIVE CONTROL OF FLEXURAL VIBRATIONS IN BEAMS Final Report
CARL H. GERHOLD *In* NASA. Lyndon B. Johnson Space Center, Houston, Tex. NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program, 1987. Volume 1 20 p Nov. 1987
Avail: NTIS HC A15/MF A01 CSCL 20K

The feasibility of using piezoelectric actuators to control the flexural oscillations of large structures in space is investigated. Flexural oscillations are excited by impulsive loads. The vibratory response can degrade the pointing accuracy of cameras and antennae, and can cause high stresses at structural node points. Piezoelectric actuators have the advantage of exerting localized bending moments. In this way, vibration is controlled without exciting rigid body modes. The actuators are used in collocated sensor/driver pairs to form a feedback control system. The sensor produces a voltage that is proportional to the dynamic stress at the sensor location, and the driver produces a force that is proportional to the voltage applied to it. The analog control system amplifies and phase shifts the sensor signal to produce the voltage signal that is applied to the driver. The feedback control is demonstrated to increase the first mode damping in a cantilever beam by up to 100 percent, depending on the amplifier gain. The damping efficiency of the control system when the piezoelectric are not optimally positioned at points of high stress in the be is evaluated. Aut

N88-14872*# Michigan Technological Univ., Houghton. D of Mechanical Engineering/Engineering Mechanics.
DYNAMICS FORMULATIONS FOR THE REAL-TIME SIMULATION OF CONSTRAINED MOTION Final Report
FREDERICK A. KELLY *In* NASA. Lyndon B. Johnson Center, Houston, Tex. NASA/American Society for Engi Education (ASEE) Summer Faculty Fellowship Program

Volume 1 20 p Nov. 1987
Avail: NTIS HC A15/MF A01 CSCL 20C

The Space Shuttle program has relied heavily on simulation throughout all phases of development and operation. Real-time, man-in-the-loop simulation has served the NASA manned space flight program by providing the means to evaluate systems design and integrated systems performance in a simulated flight environment as well as provide a means to train flight crews. New challenges are presented by the development and operation of a permanently manned space station. The assembly of the space station, the transferral of payloads and the use of the space station manipulator to berth the Orbiter are operations critical to the success of the space station. All these operations are examples of constrained motion among the bodies associated with the Orbiter and space station system. The state of the art of formulating the governing dynamical equations of motion for constrained systems are described. The uses of the two basic problems in multibody dynamics are discussed. The most efficient formulations of the equations of motion are addressed from the point of view of completeness. The issues surrounding incorporating the constraints into the equation of motion are presented. Author

N88-15001# WEA, Cambridge, Mass.
NATURAL FREQUENCIES AND STRUCTURAL INTEGRITY ASSESSMENT OF LARGE SPACE STRUCTURES Technical Report, 1 Sep. 1985 - 1 Apr. 1987
JAMES H. WILLIAMS, JR. and RAYMOND J. NAGEM 1 Apr. 1987 39 p
(Contract F49620-85-C-0148)
(AD-A186139; AFOSR-87-1290TR) Avail: NTIS HC A03/MF A01 CSCL 20K

In a previous report, transfer matrices and joint coupling matrices are used to compute natural frequencies of vibration of a five-bay planar lattice structure. In this report, the problem of detecting damage in the five-bay planar lattice structure is considered. Seven different states of damage are assumed. Each damage state corresponds to a disconnected or partially disconnected joint in the lattice. Transfer matrices and joint coupling matrices are used to compute natural frequencies associated with each damage state. The natural frequencies computed for each damage state are significantly different from the natural frequencies of the undamaged lattice; for example, the frequencies of the first flexible mode of the damaged lattice are 26 to 83 percent lower than the frequency of the first flexible node of the undamaged lattice. The results presented here demonstrate that measurement of natural frequencies is a potentially useful method for detecting damage in lattice structures, at least, for the types of damage considered here. However, it is also shown here that measurement of natural frequencies alone is not sufficient, in general, to determine the location of damage within the lattice structure. Thus, measurement of natural frequencies should be regarded as only a part of a complete nondestructive evaluation method. After the results obtained here are presented, some suggestions for NDE methods which may be capable of providing more quantitative measures of structural integrity. GRA

N88-15002# WEA, Cambridge, Mass.
WAVE PROPAGATION EXPERIMENTS ON 22-BAY LATTICE Technical Report, 1 Sep. 1985 - 1 Jun. 1987
JAMES H. WILLIAMS, JR. and JIA J. ZHANG 1 Jun. 1987 37 p
(Contract F49620-85-C-0148)
(AD-A186140; AFOSR-87-1289TR) Avail: NTIS HC A03/MF A01 CSCL 22B

Wave propagation characteristics of large space structures (LSS) affect their performance, integrity and the ability to nondestructively assess their integrity. In this study, wave propagation characteristics of an aluminum 22-bay planar lattice structure are determined experimentally. Two ultrasonic piezoceramic longitudinal transducers are mounted at various locations on the structure. Wave measurements are obtained by injecting an impulsive load via the transmitting transducer and recording the response via the receiving transducer. The waves injected into the structure are longitudinal waves, transverse to the surface, although a complex stress distribution which may be described by directivity functions is actually realized. The impulsive loading signal has a broad frequency spectrum containing frequencies greater than 0.5MHz. GRA

N88-15003# Harris Corp., Melbourne, Fla. Government Aerospace Systems Div.
MAXIMUM ENTROPY/OPTIMAL PROJECTION DESIGN SYNTHESIS FOR DECENTRALIZED CONTROL OF LARGE SPACE STRUCTURES Annual Report, Oct. 1986 - Apr. 1987
DAVID C. HYLAND and DENNIS S. BERNSTEIN May 1987 233 p
(Contract F49620-86-C-0038)
(AD-A186359; AFOSR-87-1196TR) Avail: NTIS HC A11/MF A01 CSCL 22A

The Maximum Entropy/Optical Projection (MEOP) methodology is a novel approach to designing implementable vibration-suppression controllers for large space systems. Two issues, in particular, have been addressed, namely, controller order (i.e. complexity) and systems robustness (i.e., insensitivity to plant variations). Extensions developed herein include generalizations to decentralized controller architectures and a new robustness analysis technique known as Majorant Robustness Analysis. GRA

N88-15830*# Howard Univ., Washington, D. C. Dept. of Mechanical Engineering.
THE DYNAMICS AND CONTROL OF LARGE-FLEXIBLE SPACE STRUCTURES, PART 10 Final Report
PETER M. BAINUM and A. S. S. R. REDDY Jan. 1988 199 p
(Contract NSG-1414)
(NASA-CR-182426; NAS 1.26:182426) Avail: NTIS HC A09/MF A01 CSCL 22B

A mathematical model is developed to predict the dynamics of the proposed orbiting Spacecraft Control Laboratory Experiment (SCOLE) during the station keeping phase. The equations of motion are derived using a Newton-Euler formulation. The model includes the effects of gravity, flexibility, and orbital dynamics. The control is assumed to be provided to the system through the Shuttle's three torquers, and through six actuators located by pairs at two points on the mast and at the mass center of the reflector. The modal shape functions are derived using the fourth order beam equation. The generic mode equations are derived to account for the effects of the control forces on the modal shape and frequencies. The equations are linearized about a nominal equilibrium position. The linear regulator theory is used to derive control laws for both the linear model of the rigidized SCOLE as well as that of the actual SCOLE including the first four flexible modes. The control strategy previously derived for the linear model of the rigidized SCOLE is applied to the nonlinear model of the same configuration of the system and preliminary single axis slewing maneuvers conducted. The results obtained confirm the applicability of the intuitive and appealing two-stage control strategy which would slew the SCOLE system, as if rigid to its desired position and then concentrate on damping out the residual flexible motions. Author

N88-16060*# Photon Research Associates, Inc., Cambridge, Mass.
LARGE-ANGLE SLEWING MANEUVERS FOR FLEXIBLE SPACECRAFT Final Report
HON M. CHUN and JAMES D. TURNER Washington NASA Feb. 1988 88 p
(Contract NAS1-18098)
(NASA-CR-4123; CR-R-016; NAS 1.26:4123) Avail: NTIS HC A05/MF A01 CSCL 22B

A new class of closed-form solutions for finite-time linear-quadratic optimal control problems is presented. The solutions involve Potter's solution for the differential matrix Riccati equation, which assumes the form of a steady-state plus transient term. Illustrative examples are presented which show that the new solutions are more computationally efficient than alternative

solutions based on the state transition matrix. As an application of the closed-form solutions, the neighboring extremal path problem is presented for a spacecraft retargeting maneuver where a perturbed plant with off-nominal boundary conditions now follows a neighboring optimal trajectory. The perturbation feedback approach is further applied to three-dimensional slewing maneuvers of large flexible spacecraft. For this problem, the nominal solution is the optimal three-dimensional rigid body slew. The perturbation feedback then limits the deviations from this nominal solution due to the flexible body effects. The use of frequency shaping in both the nominal and perturbation feedback formulations reduces the excitation of high-frequency unmodeled modes. A modified Kalman filter is presented for estimating the plant states. Author

N88-16803# Consulenze Generali Roma (Italy).
ANALYTICAL INTERACTIVE APPROACH FOR PHENOMENA INVOLVING STRUCTURES, THERMAL AND CONTROL ASPECTS. VOLUME 1: THEORY Final Report
C. ARDUINI, G. FUSCO, and S. SGUBINI Paris, France ESA Dec. 1985 347 p
(Contract ESTEC-5485/83-NL-PB(SC))
(ESA-CR(P)-2503-VOL-1; ETN-88-91205) Avail: NTIS HC A15/MF A01

The problem of producing comprehensive equations for describing the thermostructural fully interactive behavior of uni- and bi-dimensional elements (like beams, plates, shells) was studied. Ways of assembling these elements together, and with mechanical and thermal control devices were investigated. Conduction theory; radiative inputs (the shadow problem); elastic, inertial, and thermal loads; and interface constraints and assembly of elements are discussed. ESA

N88-16804# Consulenze Generali Roma (Italy).
ANALYTICAL INTERACTIVE APPROACH FOR PHENOMENA INVOLVING STRUCTURES, THERMAL, AND CONTROL ASPECTS. VOLUME 2: TOWARD THE SOLUTION Final Report
C. ARDUINI, G. FUSCO, and S. SGUBINI Paris, France ESA Dec. 1985 266 p
(Contract ESTEC-5485/83-NL-PB(SC))
(ESA-CR(P)-2503-VOL-2; ETN-88-91206) Avail: NTIS HC A12/MF A01

The problem of producing comprehensive equations for describing the thermostructural fully interactive behavior of uni and bidimensional elements (like beams, plates, shells) was studied. Ways of assembling these elements together, and with mechanical and thermal control devices were investigated. Methods for problems in the space domain of interactive problems are outlined. Examples of heat inputs and shadows; thermal problems; thermoelastic problems; and structure control interaction are shown. ESA

N88-16805# Consulenze Generali Roma (Italy).
ANALYTICAL INTERACTIVE APPROACH FOR PHENOMENA INVOLVING STRUCTURES, THERMAL, AND CONTROL ASPECTS. VOLUME 3: EXECUTIVE SUMMARY Final Report
C. ARDUINI, G. FUSCO, and S. SGUBINI Paris, France ESA Dec. 1985 67 p
(Contract ESTEC-5485/83-NL-PB(SC))
(ESA-CR(P)-2503-VOL-3; ETN-88-91211) Avail: NTIS HC A04/MF A01

The problem of producing comprehensive equations for describing the thermostructural fully interactive behavior of uni and bidimensional elements (like beams, plates, shells) was studied. Ways of assembling these elements together, and with mechanical and thermal control devices were investigated. ESA

N88-17067# RCA Astro-Electronics Div., Princeton, N. J.
OPTIMIZED STRUCTURE DESIGN USING REANALYSIS TECHNIQUES
F. H. CHU, T. E. POLLAK, and J. C. REUBEN *In* Shock and Vibration Information Center The Shock and Vibration Bulletin. Part 4: Structural Dynamics and Modal Test and Analysis p 47-50 Jan. 1987
Avail: NTIS HC A07/MF A01 CSCL 20K

A new approach for optimization of large structures with frequency constraint is presented. The REANALYSIS technique is used to iteratively evaluate feasible directions for achieving optimal solutions. Software was developed to implement this technique with the general purpose finite element NASTRAN analyser. An example of a space truss is given to illustrate the time savings and accuracy of this approach. Author

N88-17223*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
DEVELOPMENT OF A COUPLED EXPERT SYSTEM FOR THE SPACECRAFT ATTITUDE CONTROL PROBLEM
K. KAWAMURA, G. BEALE, J. SCHAFFER, B.-J. HSIEH, S. PADALKAR, J. RODRIGUEZMOSCOSO (Vanderbilt Univ., Nashville, Tenn.), F. VINZ, and K. FERNANDEZ *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 125-132 Oct. 1987
Avail: NTIS HC A23/MF A01 CSCL 22B

A majority of the current expert systems focus on the symbolic-oriented logic and inference mechanisms of artificial intelligence (AI). Common rule-based systems employ empirical associations and are not well suited to deal with problems often arising in engineering. Described is a prototype expert system which combines both symbolic and numeric computing. The expert system's configuration is presented and its application to a spacecraft attitude control problem is discussed. Author

N88-17683 Virginia Polytechnic Inst. and State Univ., Blacksburg.
SENSITIVITY OF ACTIVE VIBRATION CONTROL TO STRUCTURAL CHANGES AND MODEL REDUCTION Ph.D. Thesis
ZORAN NAUM MARTINOVIC 1987 123 p
Avail: Univ. Microfilms Order No. DA8721990

The analytical study presented is concerned with two types of sensitivity of active vibration control of large space structures (LSS). The first one required for assessing robustness, is the sensitivity of the performance and stability of the control system to changes in structure and to model reduction. The second type is the sensitivity of the optimum design of the control system to changes in the structure. This sensitivity is of interest in assessing the need for integrated structure/control design. Three direct rate feedback control techniques are studied for a laboratory structure which has characteristics of LSS and then compared to standard linear quadratic control. The baseline design of each control system is obtained first and then sensitivity analysis conducted.
Dissert. Abstr.

N88-18009# Colorado Univ., Boulder. Dept. of Electrical and Computer Engineering.
ROBUST CONTROLLER DESIGN FOR FLEXIBLE STRUCTURES
RENJENG SU and NASSIM M. ARBOUZ 1987 13 p
(Contract AF-AFOSR-0198-86)
(AD-A187217; AFOSR-87-1561TR) Avail: NTIS HC A03/MF A01 CSCL 20K

This document considers the problem of control of a beam which is moving in the x-y plane. It extends from x=0 to x=L. The left end at x=0 is clamped to an actuator which moves the beam along the v-axis. The control input is the force u(t) in y direction. While moving, the beam may vibrate. Let z(t) denote the displacement of the left from y=0, and w(t,x), the displacement of the beam from the line y=z(t) at position x and time t. Suppose a position sensor is placed on the beam and the sensing output is v(t, sub 0)=z(t) + w(t,x0), where 0 less than x sub 0 less than L is the sensor location. We are interested in the case when the flexure w(t,x) of the beam is significant. The problem is to synthesize a feedback control law which moves the beam from one position to another in a stable manner. It is well known that when the sensor and the actuator are colocated a simple lead compensator

suffices to produce a stable design. This result holds even when the beam dynamics are considered as a system with infinite zero-damping modes, and can be shown using root locus argument. This stabilization method may break down, however, when there is a positional gap between the sensor and actuator. In this case the classical compensation techniques are no longer effective. Time-domain optimization approaches based on state-space models have been applied to this problem. This article presents a case study of noncolocated beam control problem using frequency-domain optimization method proposed by Professor Kwakerna. GRA

N88-18616# Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).
CONSTRUCTION ASPECTS OF TESTBEDS FOR ATTITUDE CONTROL SYSTEMS SIMULATION OF ARTIFICIAL SATELLITES [ASPECTOS CONSTRUTIVOS DE BANCADAS PARA SIMULACAO DE SISTEMAS DE CONTROLE DE ATITUDE DE SATELITES ARTIFICAIS]
AGENOR T. FLEURY, PETRONIO NDESOUZA, and L. VICTOR C. CARDIERI Aug. 1987 6 p In PORTUGUESE; ENGLISH summary Presented at the 9th Brazilian Congress of Mechanical Engineering, Florianopolis, Santa Catarina, 7-11 Dec. 1987
(INPE-4283-PRE/1155) Avail: NTIS HC A02/MF A01

This work presents the basic aspects concerning the construction of two test beds for satellite Attitude and Orbit Control Systems (AOCS) hardware-in-the-loop tests. The main goal to be reached with these test beds is the fast accomplishment of laboratory results in the various phaess of an AOCS development, from its initial conceptual definition to a prequalification phase. The central equipment of these test beds consists of a one-degree-of-freedom air bearing table and a two-degree-of-freedom servo rate table. Various AOCS components such as reaction wheels, cold gas jet propulsion system, telemetry/telecommand system and celestial simulators were also developed at INPE. The designs of the test beds as integrated equipments are presented. The main performance parameters and associated experimental results are presented and discussed as well. Author

N88-18743# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio.
EXPERIMENTAL SET-UP AND MATHEMATICAL MODELING OF H-SHAPED BEAM TYPE STRUCTURE M.S. Thesis
ALLEN K. JARRELL 1986 48 p
(AD-A187196; AFIT/CI/NR-87-82T) Avail: NTIS HC A03/MF A01 CSCL 13M

An experimental set up for a flexible H-beam type structure is designed to demonstrate flexible body maneuvers. The equations of motion for the structure are developed using the finite element method. The H-beam is sized by looking at the structural flexibility in the system's response. Specifications necessary for the hardware used in the experiment are given. GRA

N88-18805*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
COMPENSATION OF RELECTOR ANTENNA SURFACE DISTORTION USING AN ARRAY FEED
A. R. CHERRETTE, R. J. ACOSTA, P. T. LAM, and S. W. LEE (Illinois Univ., Urbana.) Jan. 1988 49 p
(Contract NAG3-419)
(NASA-TM-100286; E-3929; NAS 1.15:100286) Avail: NTIS HC A03/MF A01 CSCL 20N

The dimensional stability of the surface of a large reflector antenna is important when high gain or low sidelobe performance is desired. If the surface is distorted due to thermal or structural reasons, antenna performance can be improved through the use of an array feed. The design of the array feed and its relation to the surface distortion are examined. The sensitivity of antenna performance to changing surface parameters for fixed feed array geometries is also studied. This allows determination of the limits of usefulness for feed array compensation. Author

N88-18951*# National Space Development Agency, Tokyo (Japan). Structural Test Dept.
NASDA'S NEW TEST FACILITIES FOR SATELLITES AND ROCKETS
MITSUHIRO TSUCHIYA *In* NASA. Marshall Space Flight Center, The 58th Shock and Vibration Symposium, Volume 2 p 79-90 Feb. 1988
Avail: NTIS HC A10/MF A01 CSCL 09B

The National Space Development Agency of Japan (NASDA) has decided to construct integrated environmental and structural test facilities for large space satellites. These facilities are under construction. The new test facilities are described and some technical considerations, especially for the unique vibration test facility are discussed. Author

N88-19514# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
MOTION SIMULATION FOR IN-ORBIT OPERATIONS
W. FEHSE and R. H. BENTALL *In its* Proceedings of the 1st European In-Orbit Operations Technology Symposium p 263-271 Nov. 1987
Avail: NTIS HC A21/MF A01

Simulation of spaceborne proximity operations such as rendezvous and docking, robotics, telemanipulation, and other servicing operations is discussed. Simulation techniques suitable for dynamic systems analysis, including physical simulations, computer simulations and computer-driven and dynamic simulations are reviewed. The role of the various types of simulation in the definition, development, and verification of an in-orbit operations system are described using the example of a development program for rendezvous and docking. ESA

N88-19533# Technische Hochschule, Darmstadt (West Germany). Fachgebiet Regelsysteemtheorie.
A COMPARATIVE SURVEY OF MATHEMATICAL MODELS FOR DYNAMIC SIMULATION OF IN-ORBIT MANIPULATION OPERATIONS
H. BRUHM, E. ERSUE, and ST. WIENAND *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 431-438 Nov. 1987
(Contract ESA-6482/85-NL-AN)
Avail: NTIS HC A21/MF A01

Requirements for the software simulation of manipulator space-operations, and three methods of dynamic simulation are reviewed. The Lagrangian method is best suited for a simulation which is mainly for analyzing the dynamic behavior of the manipulator arm and for controller-design because of its clear formulation. The dynamic influences are computed explicitly, so thay can be isolated or their contribution to the total dynamic forces seen. However, the Lagrangian formulation requires more computational effort than the others. Kane's method is the most effective as to computational effort. However, automatic generation of the simulation equations in an effective way is not possible. Kane's formulation is well suited for real-time simulations where the manipulator-design is already fixed and no additional results (like forces in the bearings) only simulation of motion, is required. For all other applications the Newton-Euler method is best. Its main advantage is that the forces and torques can be computed explicitly at every point on the manipulator. So the interaction with the environment can be simulated very easily. ESA

N88-19572# Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).
SIMULATION AND TESTS OF A SATELLITE ATTITUDE AND ORBIT CONTROL SYSTEM. GENERAL CONSIDERATIONS CONCERNING AN EXAMPLE CASE (INPE) AND DESIGN OF A SERVO RATE TABLE [SIMULACAO E TESTES DE SISTEMAS DE CONTROLE DE ATITUDE E ORBITA DE SATELITE CONSIDERACOES GERAIS SOBRE UM CASE EXEMPLO (INPE)E PROJETOS DE UMA MESA DE ROTACAO CONTROLADA]
AGENOR DET. FLEURY, PETRONIO N. DESOUZA, GILBERTO

DAC. TRIVELATO, VALTAIR A. FERRARESI, and JOSE F. RIBEIRO Aug. 1987 11 p In PORTUGUESE; ENGLISH summary Submitted for publication
(INPE-4282-PRE/1154) Avail: NTIS HC A03/MF A01

The Attitude and Orbital Control System (AOCS) is a basic component of a satellite. In order to guarantee the correct performance of the AOCS, exhaustive testing has to be done in a laboratory, both at component and at system level. This work intends to present first the implementation of an AOCS Simulation Laboratory by INPE's Space Mechanics and Control Department, as an example case, briefly showing the technological results already accomplished. It presents as well the basic aspects related to design, manufacture, and tests of a one degree-of-freedom servo rate table. It also describes, at an introductory level, the design of a second controlled axis for the table. Author

N88-19797# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
ACTIVE VIBRATION CONTROL OF A CANTILEVERED BEAM WITH THREE ELASTIC COORDINATES M.S. Thesis
THOMAS A. CRISTLER Dec. 1987 194 p
(AD-A188824; AFIT/GA/AA/87D-1) Avail: NTIS HC A09/MF A01 CSCL 20D

Many control methods have been proposed for dealing with the large space structure vibration control problem. To experimentally evaluate these various approaches in a way which will allow consistent comparison of results requires a baseline experiment in which all variables are understood and controlled. From this baseline, the various aspects of each control scheme can be implemented and their relative merits compared on a consistent basis. This experiment was implemented using a vertically suspended cantilever beam with rectangular cross section. Proof mass actuators were developed to provide control force inputs to the structure. Closed loop control was formulated using linear quadratic regulator theory and results are compared with simulation and eigenvalue predictions to establish baseline performance. Modal suppression techniques were implemented to demonstrate control of selected modes while maintaining overall system stability. Results applicable to future testing and development in the large space structure control area are identified. GRA

06

ELECTRONICS

Includes techniques for power and data distribution, antenna RF performance analysis, communications systems, and spacecraft charging effects.

A88-11795#
BINARY MERCURY/ORGANIC RANKINE CYCLE POWER SYSTEMS
ALLEN FOX, J. F. LOUIS (MIT, Cambridge, MA), W. J. GREENLEE, and G. H. PARKER (Sundstrand Corp., Rockford, IL) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 127-132. refs

Binary mercury/organic Rankine systems have been assessed for application to compact space power systems, and have been shown to have the potential to attain cycle efficiencies greater than 40 percent. The efficiency is found to be more sensitive to maximum and minimum cycle temperatures than to the temperature at which heat is transferred from the mercury cycle to the toluene cycle. The specific mass is shown to depend primarily on the solar receiver and heat rejection radiator masses, and to have a minimum of between 62 and 40 kg/kWe. It is noted that the cycle can also be used in a cogeneration mode to provide thermal heat at constant temperature levels between 375 and 1000 K. R.R.

A88-11799*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
SOLAR CONCENTRATOR ADVANCED DEVELOPMENT PROJECT
ROBERT D. CORRIGAN (NASA, Lewis Research Center, Cleveland, OH) and DERIK T. EHRESMAN (Harris Corp., Melbourne, FL) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 156-161.

A solar dynamic concentrator design developed for use with a solar-thermodynamic power generation module intended for the Space Station is considered. The truss hexagonal panel reflector uses a modular design approach and is flexible in attainable flux profiles and assembly techniques. Preliminary structural, thermal, and optical analysis results are discussed. Accuracy of the surface reflectors should be within 5 mrad rms slope error, resulting in the need for close fabrication tolerances. Significant fabrication issues to be addressed include the facet reflective and protective coating processes and the surface specularity requirements. R.R.

A88-11800*# Sanders Associates, Inc., Nashua, N. H.
ADVANCED SOLAR RECEIVER CONCEPTUAL DESIGN STUDY
J. B. KESSELI (Sanders Associates, Inc., Nashua, NH) and D. E. LACY (NASA, Lewis Research Center, Cleveland, OH) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 162-168. refs

High temperature solar dynamic Brayton and Stirling receivers are investigated as candidate electrical power generating systems for future LEO missions. These receivers are smaller and more efficient than conventional receivers, and they offer less structural complexity and fewer thermal stress problems. Use of the advanced Direct Absorption Storage Receiver allows many of the problems associated with working with high-volumetric-change phase-change materials to be avoided. A specific mass reduction of about 1/3 with respect to the baseline receiver has been realized. R.R.

A88-11807*# Grumman Aerospace Corp., Bethpage, N.Y.
HEAT PIPE RADIATORS FOR SOLAR DYNAMIC SPACE POWER SYSTEM HEAT REJECTION
ERIC GUSTAFSON and ALBERT CARLSON (Grumman Aerospace Corp., Space Systems Div., Bethpage, NY) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 214-221. refs
(Contract NAS3-24665)

The paper presents the results of a concept development study of heat rejection systems for Space Station solar dynamic power systems. The thermal performance and weights of each of the heat rejection subsystems have been addressed in detail, and critical technologies which require development tests and evaluation for successful demonstration were assessed and identified. Baseline and several alternate heat rejection system configurations and optimum designs were developed for both Brayton and Rankine cycles. The thermal performance, mass properties, assembly requirements, reliability, maintenance requirements, and life cycle costs were determined for each of the system configurations. Trade studies were performed on each configuration with respect to the heat pipe wall thickness and the amount of redundancy to determine the effects on system reliability, maintenance requirements, and life cycle costs. An optimum design was then selected for each configuration. Author

A88-11811*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
A NOVEL PHOTOVOLTAIC POWER SYSTEM WHICH USES A LARGE AREA CONCENTRATOR MIRROR
ANNE ARRISON (NASA, Lewis Research Center, Cleveland, OH) and NAVID FATEMI (Cleveland State University, OH) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 241-247. refs

A preliminary analysis has been made of a novel photovoltaic power system concept. The system is composed of a small area, dense photovoltaic array, a large area solar concentrator, and a battery system for energy storage. The feasibility of such a system is assessed for space power applications. The orbital efficiency, specific power, mass, and area of the system are calculated under various conditions and compared with those for the organic Rankine cycle solar dynamic system proposed for Space Station. Near term and advanced large area concentrator photovoltaic systems not only compare favorably to solar dynamic systems in terms of performance but offer other benefits as well. Author

A88-11817#
ELECTRICAL POWER SYSTEM FOR LOW EARTH ORBIT SPACECRAFT APPLICATIONS
P. R. K. CHETTY (Fairchild Space Co., Germantown, MD) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 281-287.
(Contract N00014-86-C-2004)

The results of a tradeoff study to select an electrical power system configuration that is best suited for low-earth-orbit (LEO) spacecraft with various output power capabilities are presented. Two EPS configurations used for LEO spacecraft, i.e., (1) one using a direct energy transfer (DET) approach and (2) one using a peak power transfer (PPT) approach are described in detail and compared. At spacecraft power requirement of 800 watts or less, it is highly advantageous to choose the PPT approach to design an electrical power system for low earth orbit spacecraft. However, for a spacecraft in higher orbit and/or with higher power requirements, the DET-based power system is the optimum choice. Author

A88-11857#
A CONCEPT FOR STANDARD LOAD CENTER AUTOMATION
KENNETH A. FREEMAN and CARL O. PISTOLE (Martin Marietta Corp., Denver, CO) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 1. New York, American Institute of Aeronautics and Astronautics, 1987, p. 528-532.

In this paper, the requirements for hardware needed to support automation are examined. The generic functions performed in a spacecraft power system are defined, and they are examined in the context of the Space Station control architecture. Functions performed in local power distribution are developed in this context, and requirements for automation hardware needed to implement the control architecture are then examined. The primary focus of this paper is the local power distribution and control unit known as a load center. Author

A88-11881#
COOPERATING EXPERT SYSTEMS FOR POWER SYSTEMS
DONNIE R. FORD (Alabama, University, Huntsville) IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 2. New York, American Institute of Aeronautics and Astronautics, 1987, p. 665-667. refs

A prototype system containing two expert systems and concerned with subsystem and payload scheduling for the Space Station is described. The first expert system is a fault diagnostic and isolation system and the second is an experiment, payload, and subsystem scheduler. The techniques employed by the Fault Isolation Expert System and the Space Station Experiment Scheduler in order to attain their scheduling objectives are discussed. The interface between the two expert systems is examined. It is determined that the prototype system is effective for scheduling Space Station subsystems and payloads. I.F.

A88-11882#
EXPERT SYSTEM FOR FAULT DETECTION AND RECOVERY FOR A SPACE BASED POWER MANAGEMENT AND DISTRIBUTION SYSTEM
BRYAN WALLS IN: IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 2. New York, American Institute of Aeronautics and Astronautics, 1987, p. 668-671.

This paper describes Starr, an expert system for fault detection and recovery in a representative power management and distribution system such as might appear on the Space Station or other large space based applications. It is modeled on NASA Marshall Space Flight Center's autonomously managed power system (AMPS) breadboard, a system containing a 75 kW solar array simulator, a 16 kw load center, and a large nickel cadmium battery, all controlled by three embedded controllers. Original prototyping is being done on an AI workstation using the Knowledge Engineering Environment. Though based on AMPS, the design has been modular to allow easy change of the expert system for various monitored systems. Author

A88-13187
SPACECRAFT SOLAR ARRAY SUBSTRATE DEVELOPMENT
THU P. STANKUNAS, W. I. GREENWAY, and G. R. HOLMQUIST (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: Advanced materials technology '87; Proceedings of the Thirty-second International SAMPE Symposium and Exhibition, Anaheim, CA, Apr. 6-9, 1987. Covina, CA, Society for the Advancement of Material and Process Engineering, 1987, p. 749-759.

A materials and processes development effort was performed to support the design, fabrication, and evaluation of solar array substrate composite structures for a spacecraft application. For stiffness, weight, and other design requirements, the basic sandwich structure incorporated a high-modulus graphite fiber/epoxy laminate. A film adhesive was utilized for facesheet/core bonding and as a dielectric protective layer on the surface of the substrate structure. Process studies determined cure cycles, fabrication techniques, bonding/assembly procedures, and related processing. Test coupons were fabricated and evaluated. Author

A88-15277
LARGE FLEXIBLE SOLAR ARRAYS
I. V. FRANKLIN (British Aerospace, PLC, Space and Communications Div., Bristol, England) IN: Space Congress, 24th, Cocoa Beach, FL, Apr. 21-24, 1987, Proceedings. Cape Canaveral, FL, Canaveral Council of Technical Societies, 1987, 18 p.

A description is given of a recent European achievement, the solar array for the Hubble Space Telescope which embodies several unique features which have relevance to the needs of Columbus. This is followed by a description of the objective of the present study which was to identify the preliminary design solutions for a 30 kW solar array working in LEO, considering both silicon and GaAs solar cells. The potential needs of the Columbus Resource Module were taken as a reference. The advantages of the double-H configuration flexible roll-out solar array are summarized. B.J.

A88-15851*# National Aeronautics and Space Administration, Washington, D.C.
SPACE STATION INFORMATION SYSTEM - CONCEPTS AND INTERNATIONAL ISSUES
R. B. WILLIAMS, DAVID PRUETT, and DANA L. HALL (NASA, Space Station Program Office, Washington, DC) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 10 p. refs
(IAF PAPER 87-76)

The Space Station Information System (SSIS) is outlined in terms of its functions and probable physical facilities. The SSIS includes flight element systems as well as existing and planned institutional systems such as the NASA Communications System, the Tracking and Data Relay Satellite System, and the data and communications networks of the international partners. The SSIS strives to provide both a 'user friendly' environment and a software environment which will allow for software transportability and interoperability across the SSIS. International considerations are discussed as well as project management, software commonality, data communications standards, data security, documentation commonality, transaction management, data flow cross support, and key technologies. K.K.

A88-15954*# Rockwell International Corp., Canoga Park, Calif.
OPTICAL MEASUREMENTS PERTAINING TO SPACE STATION SOLAR DYNAMIC POWER SYSTEMS
S. HOLLY, T. SPRINGER (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), and K. S. JEFFERIES (NASA, Lewis Research Center, Cleveland, OH) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 16 p.
(IAF PAPER 87-229)

The Space Station solar dynamic power system is a hybrid of solar photovoltaic and solar dynamic systems, the latter of which uses a parabolic reflector to collect solar energy. This paper describes analytical results of an off-axis solar illumination on the intensity distribution in arbitrary target planes perpendicular to the axis of a parabolic reflector. Such computational capability would make it possible to predict optical intensity distributions resulting from off-axis angles of incident radiation on such target planes. To validate the computer code, experimental optical measurements were performed on the multifaceted paraboloidal collecor at the Solar Dynamic Test Facility at Rockedyne's Santa Susana Field Laboratory. The experimental data compared reasonably well with the calculated values. I.S.

A88-15964#
PAST, PRESENT AND FUTURE ACTIVITIES IN SPACE POWER TECHNOLOGY IN THE UK
A. A. DOLLERY (Royal Aircraft Establishment, Farnborough, England) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 2 p.
(IAF PAPER 87-243)

Developments in space power technology in the UK during the last 25 years are discussed. Particular emphasis is given to the Ni-Cd battery, fold-up deployable arrays, CMS cover glass, CMX ceria doped cover glass, and the solar cell evaluation and qualification facility. The development of these technologies and their uses are described. Research is currently being conducted for the development of: (1) a new solar cell cover glass CMZ; (2) a range of nickel-hydrogen battery cells for GEO and LEO; and (3) a range of GaAs solar cells for use on both planar and concentrated types of arrays. I.F.

A88-15989#
POWER REQUIREMENTS FOR AN ORBITING SPACE FARM
S. M. BULL (Medaris Industries, New York) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 7 p. refs
(IAF PAPER 87-242)

The concept of an orbiting space farm for growing and harvesting edible foodstuffs in a single-launch, gravity-induced space station placed in low earth orbit adjacent to the forthcoming NASA Space Station is reviewed with emphasis on power requirements. Alternative power sources are examined, and photovoltaic and solar dynamic power sources are proposed as the principal power supplies. Savings in the electrical storage capacities needed to operate the space farm during the periods when the farm is in the approximately 30-minute eclipse of its LEO orbit are demonstrated. V.L.

A88-16136#
DEVELOPMENT OF ON-BOARD SATELLITE COMMUNICATIONS EQUIPMENT IN THE GEOSTATIONARY PLATFORM ERA
HIROSHI UDA, YUICHI OTSU, NOBUO ISHIZU, KIMIO MIYASAKA (Satellite Communications Research Corp., Japan), and FUSAKI MATSUI (Ministry of Posts and Telecommunications, Tokyo, Japan) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 8 p.
(IAF PAPER 87-495)

The objectives and relevant key technologies of communications payload studies directed toward the Geostationary Communications Platform that are being carried out in Japan are reviewed. In particular, attention is given to land mobile satellite communications, development of a large antenna, development of a solid-state power amplifier, millimeter-wave personal satellite communications, and the development of TWT and low-noise amplifiers. The discussion also covers the development of a high-stability oscillator, enhanced/regional direct broadcasting, and other technical development programs. V.L.

A88-16308* Draper (Charles Stark) Lab., Inc., Cambridge, Mass.
A FREE-FLYING POWER PLANT FOR A MANNED SPACE STATION
M. PALUSZEK and P. MADDEN (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 263-268. refs
(Contract NAS9-16023)

The 0.1 Hz fundamental structural frequency anticipated for the large solar array panels required to power manned space stations is close to the attitude control system bandwidth, and within the bandwidth of crew motion disturbances. Attention is presently given to a detachment of the solar panel system to create a free-flying powerplant for the space station, and to the control system that will maintain its attitude and position relative to the space station by means of thrusters that are supplied with space station state data by a laser/optical sensor system. Power transmission alternatives for this free-flying power system are discussed. O.C.

A88-17023
SOLAR POWER SATELLITES
RICHARD R. VONDRAK (Lockheed Space Sciences Laboratory, Palo Alto, CA) IN: The solar wind and the earth. Tokyo/Dordrecht, Terra Scientific Publishing Co./D. Reidel Publishing Co., 1987, p. 286-307. refs

The construction of a solar power system in space rather than on the surface of the earth has the advantages of higher energy yield, constant power return, and the simplicity of construction; a system in space will in the course of one year generate approximately 10 times the energy of an equivalent system on earth. This paper discusses the major design features and the basic elements of a 5000 MW solar power satellite system, together with the efficiency and the output power for each element of the system. Because of its extraordinary size (a mass of about 5 x 10 to the 7th kg), a new type of rocket launch vehicle would be required, which would be completely reusable and would operate at a high frequency (the construction of a single 5000 MW satellite will require about 200 flights of the heavy-lift launch vehicle to low-earth orbit). The estimated expenditures needed for the deployment of the first solar power satellite are outlined, and the environmental effects are identified. I.S.

A88-17599
A NEAR FIELD TEST SYSTEM FOR VERY LARGE ANTENNAS
P. J. WOOD (Canadian Astronautics, Ltd., Ottawa, Canada) IN: International Conference on Antennas and Propagation, 5th, York, England, Mar. 30-Apr. 2, 1987, Proceedings. Part 1. London, Institution of Electrical Engineers, 1987, p. 489-492.

Some problems associated with the selection of a near field test system for the Canadian Radarsat satellite, a C-band planar array of 1.5x15 m, are examined. On the basis of considerations such as ease of implementation, measurement time, and accuracy,

the cylindrical method is found to be more suitable than the planar one. A special version of the cylindrical method is described wherein the cylinder axis is horizontal, linear probing is carried out in overlapping subdomains, and the linear motion is the fast motion of the two-dimensional raster scan. V.L.

A88-18523* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
OXIDATION-RESISTANT REFLECTIVE SURFACES FOR SOLAR DYNAMIC POWER GENERATION IN NEAR EARTH ORBIT
DANIEL A. GULINO (NASA, Lewis Research Center, Cleveland, OH), ROBERT A. EGGER (Cleveland State University, OH), and WILLIAM F. BANHOLZER (General Electric Co., Schenectady, NY) Journal of Vacuum Science and Technology A (ISSN 0734-2101), vol. 5, July-Aug. 1987, p. 2737-2741. Previously announced in STAR as N87-10960. refs

Reflective surfaces for Space Station power generation systems are required to withstand the atomic oxygen-dominated environment of near earth orbit. Thin films of platinum and rhodium, which are corrosion resistant reflective metals, have been deposited by ion beam sputter deposition onto various substrate materials. Solar reflectances were then measured as a function of time of exposure to a RF-generated air plasma. Author

A88-19002
SOLAR POWER SATELLITES - STILL IN THE DARK
MILES WEISS Space World (ISSN 0038-6332), vol. X-11-287, Nov. 1987, p. 21-25.

The technological potential and problems of solar power satellites (SPS) are reviewed. The benefits of solar power brought to one African village by NASA and AID are described. The history of the SPS project in the United States is recounted, giving the reasons for the eventual renunciation of the project. The possiblity of using lunar materials for the SPS is addressed. The prospects for a Soviet SPS are considered. C.D.

A88-19869
DAMMING THE DATA STREAM FROM SPACE
DAVID SLOGGET Space (ISSN 0267-954X), vol. 3, Nov.-Dec. 1987, p. 30-34.

The Polar Platform of the NASA Space Station will be a highly complex data collection system with transmission rates placing large burdens on the ground segment in terms of data processing, dissemination, and archiving. The candidate areas for onboard instrument processing are data compression, bulk correction, image interpretation, and supporting instrumentation. The major task of onboard processing should be transmission bandwidth reduction which can be achieved most efficiently via data compression. K.K.

A88-20350* Air Force Geophysics Lab., Hanscom AFB, Mass.
THE EFFECT OF PHOTOELECTRONS ON BOOM-SATELLITE POTENTIAL DIFFERENCES DURING ELECTRON BEAM EJECTION
SHU T. LAI, HERBERT A. COHEN (USAF, Geophysics Laboratory, Hanscom AFB, OH), THOMAS L. AGGSON (NASA, Goddard Space Flight Center, Greenbelt, MD), and WILLIAM J. MCNEIL (Radex, Inc., Lexington, MA) Journal of Geophysical Research (ISSN 0148-0227), vol. 92, Nov. 1, 1987, p. 12319-12325. refs
(Contract F19628-83-C-0105)
(AD-A190390; AFGL-TR-87-0336)

Data taken on the SCATHA satellite at geosynchronous altitudes during periods of electron beam ejection in sunlight showed that the potential difference between an electrically isolated boom and the satellite main body was a function of beam current, energy, and boom-sun angle. The potential difference decreased as the boom area illuminated by the sun increased; the maximum and minimum potential differences were measured when minimum and maximum boom areas, respectively, were exposed to the sun. It is shown that photoelectrons, created on the boom, could be engulfed in the electrostatic field of the highly charged satellite main body. Theoretical calculations made using a simple current balance model showed that these electrons could provide a substantial discharging current to the main body and cause the observed variations in the potential difference between the main body and the booms. Author

A88-21601
PHOTOVOLTAICS FOR COMMERCIAL SOLAR POWER APPLICATIONS; PROCEEDINGS OF THE MEETING, CAMBRIDGE, MA, SEPT. 18, 19, 1986
DAVID ADLER, ED. (MIT, Cambridge, MA) Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 706), 1986, 115 p. For individual items see A88-21602 to A88-21608.
(SPIE-706)

Papers are presented on efficient multijunction monolithic cascade solar cells, high efficiency silicon solar cells, point contact silicon cells, and space solar cell research. Also considered are photovoltaic power plants, the reliability of photovoltaic modules, the continuous fabrication of amorphous silicon solar cells on polymer substrates, and the density of states of amorphous silicon. Other topics include breaking the efficiency-stability-production barrier in amorphous photovoltaics, the development of flexible a-SiC/a-Si heterojunction solar cells and stable a-SiC/a-Si tandem cells with blocking barriers, and performance aspects for thin-film-silicon-hydrogen solar cells. R.R.

A88-21618
OPTICAL FIBER WAVEGUIDES FOR SPACECRAFT APPLICATIONS
E. J. FRIEBELE, K. L. DORSEY, and M. E. GINGERICH (U.S. Navy, Naval Research Laboratory, Washington, DC) IN: Fiber optics in adverse environments III; Proceedings of the Meeting, Cambridge, MA, Sept. 25, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 98-103. refs

Optical fiber waveguides may be subjected to unique adverse environments onboard spacecraft, including wide temperature ranges and low dose rate radiation exposures. Since fiber reliability is essential, an accelerated life test has been designed to simulate deployment on the Space Station. The initial induced losses following exposure at -150 C are much lower in the fibers with pure silica cores than in those with doped silica cores. Good long-term recovery is evident at this low temperature in fibers which do not contain P, provided light is being transmitted in the waveguide, since photobleaching is the dominant recovery mechanism in both types of fiber at -150 C. Except for the P-doped waveguides, the worst-case incremental losses are extrapolated to be less than 10 dB/km for a 10-year, 1 rad/day exposure at -150 C with a -20 dBm signal in the fiber. Author

A88-22082#
NETWORK MANAGEMENT FOR THE SPACE STATION INFORMATION SYSTEM
JOHN V. PIETRAS and MICHAEL A. ALLEN (Mitre Corp., Greenbelt, MD) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 8 p. refs
(AIAA PAPER 88-0118)

NASA's Space Station Information System (SSIS) communications networks will furnish computer-to-computer data, audio, and video traffic services, as well as traditional spacecraft command and telemetry data flows. The SSIS will accomplish this by means of a combination of NASA institutional, public, and international networks, using several protocol suites. The 'network management' task of integrating, controlling, and monitoring this concentration of networks is presently discussed with a view to the formulation of a candidate network management architecture. O.C.

A88-22320#
A SIMPLE MODEL FOR THE INITIAL PHASE OF A WATER PLASMA CLOUD ABOUT A LARGE STRUCTURE IN SPACE
D. E. HASTINGS, N. A. GATSONIS, and T. MOGSTAD (MIT, Cambridge, MA) AIAA, Aerospace Sciences Meeting, 26th, Reno,

NV, Jan. 11-14, 1988. 12 p. refs
(Contract F19628-86-K-0018)
(AIAA PAPER 88-0430)

Large structures in the ionosphere will outgas or eject neutral water and perturb the ambient neutral environment. This water can undergo charge exchange with the ambient oxygen ions and form a water plasma cloud. Additionally, water dumps or thruster firings can create a water plasma cloud. A simple model for the evolution of a water plasma cloud about a large space structure is obtained. It is shown that if the electron density around a large space structure is substantially enhanced above the ambient density then the plasma cloud will move away from the structure. As the cloud moves away it will become unstable and will eventually break up into filaments. A true steady state will exist only if the total electron density is unperturbed from the ambient density. When the water density is taken to be consistent with Shuttle based observations the cloud is found to slowly drift away on a timescale of many tens of milliseconds. This time is consistent with the Shuttle observations. Author

A88-22323#
OBSERVATIONS OF IONS GENERATED ON OR NEAR SATELLITE SURFACES
C. W. NORWOOD, R. C. OLSEN (U.S. Naval Postgraduate School, Monterey, CA), and W. W. LI (California, University, La Jolla) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 8 p. refs
(AIAA PAPER 88-0434)

Ion measurements with charged particle detectors on negatively charged spacecraft have revealed anomalous fluxes of low energy ions, at energies below the charging peak. These 'spacecraft generated ions' have been noted on ATS-5, ATS-6, ISEE-1, and P78-2 (SCATHA). On SCATHA, the measurements generally take the form of a shadow peak, at an energy below the main peak in flux associated with the satellite potential. Such peaks follow the satellite potential, for constant detector look angle. When the detector look direction is varied, the energy of the peak varies; minimum energies are observed tangential to the satellite body. Occasionally, a broad spectrum of ion fluxes is observed below the charging peak, as on ATS-5. The principle source appears presently to be sputtering from the satellite surface, although outgassing molecules ionized by photons or ambient particles may play a significant role. Author

A88-25854
PROPOSAL OF ADAPTIVELY CONTROLLED TRANSMITTING ARRAY FOR MICROWAVE POWER TRANSMISSION IN SPACE
K. KOMOYAMA and I. YOKOSHIMA (Ministry of International Trade and Industry, Electrotechnical Laboratory, Tsukuba, Japan) Electronics Letters (ISSN 0013-5194), vol. 24, Jan. 21, 1988, p. 87-89. refs

An adaptively controlled transmitting antenna array system is proposed for use in microwave energy transmission between spacecraft. Monitoring detectors are used for feedback control of both main beam and sidelobe. Computer simulation shows the possibility of accurate control for the main beam and a sidelobe. Author

A88-26150
SOLAR-THERMODYNAMIC POWER SYSTEMS IN SPACE [SOLARNO-TERMODYNAMICZNE UKLADY ZASILANIA W KOSMOSIE]
MARIAN KLEIN (Polskie Towarzystwo Astronautyczne, Katowice, Poland) Postepy Astronautyki (ISSN 0373-5982), vol. 20, no. 1-2, 1987, p. 145-158. In Polish. refs

The physical characteristics of a dynamic solar system with the organic Rankine cycle are presented. It is shown that dynamic power generation can satisfy the high energy requirements of future space applications. A theoretical diagram and physical equations for efficiency are presented as well as a functional scheme of the device. Toluene is shown to be the optimal working fluid. K.K.

A88-28250
OPTIMIZATION OF THE PARAMETERS OF A SOLAR PHOTOELECTRIC SYSTEM EXPOSED TO COSMIC RAYS [OPTIMIZATSIIA PARAMETROV SOLNECHNOI FOTOELEKTRICHESKOI USTANOVKI, PODVERZHENNOI VOZDEISTVIIU KOSMICHESKOI RADIATSII]
O. F. ZAITSEV Geliotekhnika (ISSN 0130-0997), no. 6, 1987, p. 23-28. In Russian. refs

A model and an algorithm are developed for the optimization of the performance characteristics of concentration-type solar photoelectric systems consisting of planar solar arrays, concentrator reflecting films, and supporting structures. The model and the algorithm make it possible to accurately predict the parameters of concentration-type photoelectric systems at the design stage. It is shown that, under conditions of considerable radiation-induced damage, the performance of such systems can be improved by using low-potential concentration systems and discrete reservation of output power. V.L.

N88-11719 Centre d'Etude Spatiale des Rayonnements, Toulouse (France). Dept. d'Etudes et de Recherches en Technologie Spatiale.
EXTERNAL SURFACE CHARGING MECHANISMS
LEON LEVY *In* CNES, Space Environment Technology p 441-457 Apr. 1987 In FRENCH; ENGLISH summary
Avail: CEPADUES-Editions, Toulouse, France

Absolute and differential charging on geosynchronous satellites is introduced. It is the consequence of particle injection associated with substorm development. The importance of conductivity and secondary emission for the behavior of electron bombarded dielectrics is emphasized. An environment worst-case depending on material properties is discussed. ESA

N88-11721 TRW Defense and Space Systems Group, Redondo Beach, Calif.
MODELING OF ENVIRONMENTALLY-INDUCED EFFECTS WITHIN SATELLITES. PART 1: NASCAP MODELING OF SATELLITES
N. JOHN STEVENS *In* CNES, Space Environment Technology p 497-510 Apr. 1987
Avail: CEPADUES-Editions, Toulouse, France

The use of the NASCAP computer code to predict the charging of spacecraft surfaces in response to geomagnetic substorm environments is treated. Spacecraft models corresponding to a spin and three-axis stabilized satellite are discussed. The models are run primarily to determine the charge storage in the dielectrics and to locate the possible sites for discharges. The possibility of utilizing expanded NASCAP models to view potential profiles in more detail is illustrated. ESA

N88-11723 Centre d'Etude Spatiale des Rayonnements, Toulouse (France). Dept. d'Etudes et de Recherches en Technologie Spatiale.
DISCHARGE PHENOMENA
LEON LEVY *In* CNES, Space Environment Technology p 523-543 Apr. 1987 In FRENCH; ENGLISH summary
Avail: CEPADUES-Editions, Toulouse, France

The different ways of discharging likely to occur on satellite external surfaces are divided into two large categories: dielectric and metallic discharges. For each category, breakdown criteria are indicated. ESA

N88-11730 European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
ENVIRONMENTAL INTERACTIONS OF SOLAR GENERATORS IN SPACE
K. BOGUS *In* CNES, Space Environment Technology p 663-679 Apr. 1987
Avail: CEPADUES-Editions, Toulouse, France

The effects on deployable solar generators of Sun/eclipse thermal cycles, low Earth orbit plasma, atomic oxygen, ultraviolet radiation and particles, the residual atmosphere, micrometeorites,

and magnetic substrorms are reviewed. Space environment simulation test results are discussed. ESA

N88-11732 European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
DISCHARGE PREVENTION OF GEOSYNCHRONOUS ORBIT CONDUCTIVE THERMAL CONTROL MATERIALS AND GROUNDING SYSTEMS
F. LEVADOU *In* CNES, Space Environment Technology p 695-715 Apr. 1987 In FRENCH; ENGLISH summary
Avail: CEPADUES-Editions, Toulouse, France

Research on the prevention of discharges in geosynchronous orbit for telecommunications and scientific satellites is summarized. Materials properties characterization, electrostatic discharge tests, grounding system development, and evaluation of materials and processes are discussed. ESA

N88-11948*# General Dynamics Corp., San Diego, Calif. Space Systems Div.
THE AC POWER SYSTEM TESTBED Final Report
J. MILDICE and R. SUNDBERG Nov. 1987 138 p
(Contract NAS3-24399)
(NASA-CR-175068; NAS 1.26:175068) Avail: NTIS HC A07/MF A01 CSCL 09C

The object of this program was to design, build, test, and deliver a high frequency (20 kHz) Power System Testbed which would electrically approximate a single, separable power channel of an IOC Space Station. That program is described, including the technical background, and the results are discussed showing that the major assumptions about the characteristics of this class of hardware (size, mass, efficiency, control, etc.) were substantially correct. This testbed equipment was completed and delivered and is being operated as part of the Space Station Power System Test Facility. Author

N88-13814# Centre National d'Etudes Spatiales, Toulouse (France).
THE HIGH PERFORMANCE SOLAR ARRAY GSR3
A. MAMODE, J. BARTEVIAN, J. L. BASTARD, P. AUFFRAY, and A. PLAGNE (Societe Nationale Industrielle Aerospatiale, Les Mureaux, France) Paris, France SNIAS 1987 10 p Previously announced as N87-28972
(SNIAS-872-422-108; ETN-88-91209) Avail: NTIS HC A02/MF A01

A foldout solar array for communication satellites was developed. A wing composed of 4 panels of 1.6 x 1.5 m and a Y-shaped yoke, and a wing with 3 panels of 2.4 x 2.4 m were made. End of life performance goal is greater than 35 W/kg with BSR 180 micron solar cells, and 50 W/kg using 50 micron BSFR cells. Analysis shows that all identified requirements can be covered with current skin made of open weave very high modulus carbon fiber; reinforcements of unidirectional carbon fiber; honeycomb in current section; hold-down inserts made of wound carbon fibers; titanium hinge fitting; and Kapton foil (25 or 50 micron thickness). Tests confirm performance predictions. ESA

N88-15838*# *National Aeronautics and Space Administration.* Lewis Research Center, Cleveland, Ohio.
STATUS OF 20 KHZ SPACE STATION POWER DISTRIBUTION TECHNOLOGY
IRVING G. HANSEN Jan. 1988 12 p Presented at the Applied Power Electronics Conference and Exposition (APEC 88), New Orleans, La., 1-5 Feb. 1988; sponsored by IEEE
(NASA-TM-100781; E-3951; NAS 1.15:100781) Avail: NTIS HC A03/MF A01 CSCL 10B

Power Distribution on the NASA Space Station will be accomplished by a 20 kHz sinusoidal, 440 VRMS, single phase system. In order to minimize both system complexity and the total power coversion steps required, high frequency power will be distributed end-to-end in the system. To support the final design of flight power system hardware, advanced development and demonstrations have been made on key system technologies and components. The current status of this program is discussed. Author

N88-16189# Technische Univ., Berlin (West Germany). Inst. of Aerospace.
DEFINITION AND ECONOMIC EVALUATION OF SPACE SOLAR POWER SYSTEMS (SSPS), PART 1
H. H. KOELLE, K. SPUTEK, and M. SCHULZE 15 Aug. 1987 37 p
(ILR-MITT-184-1(1987); ETN-88-91444) Avail: NTIS HC A03/MF A01

A life cycle model of a typical space power system (SPS) in the first half of the next century is described. Inputs for this logistics model are: life cycle duration (100 yr); power level of the SPS at the end of life cycle assumed (500 GW); power level for single SPS unit (5 GW); availability of space power units (90 %); and specific mass (Mg/MW) of SPS as a function of time. A system of 100 operating space power units in geostationary orbit with an output of 500 GW in its 50th year requires in this year a total mass flow of 200,000 T. To operate the system, a crew size in GEO is 600 people. The total mass installed in the SPS is 6 million metric tons. To transport this material to the GEO from Earth and from the Moon, average annual launch rates of 300 for the lunar bus and 340 for the heavy lift launch vehicle during the 50 yr time period are required. The average annual output of the SPS is economically attractive: 2188 TWh at 7.4 mills/kWh. ESA

N88-16190# Technische Univ., Berlin (West Germany). Inst. of Aerospace.
DEFINITION AND ECONOMIC EVALUATION OF SPACE SOLAR POWER SYSTEMS (SSPS), PART 2
H. H. KOELLE, K. SPUTEK, and M. SCHULZE 15 Aug. 1987 79 p
(ILR-MITT-184-2(1987); ETN-88-91445) Avail: NTIS HC A05/MF A01

A life cycle model of a typical space power system (SPS) in the first half of the next century is described. Inputs for this logistics model are: life cycle duration (100 yr); power level of the SPS at the end of life cycle assumed (500 GW); power level for single SPS unit (5 GW); availability of space power units (90 %); and specific mass (Mg/MW) of SPS as a function of time. The simulation model comprises 171 equations describing the interrelationships between the system variables and parameters. The computer code developed for this simulation model is available upon request. The printouts of all system variables calculated as functions of time are presented. ESA

N88-16423*# Boeing Aerospace Co., Huntsville, Ala.
FOUNDATION: TRANSFORMING DATA BASES INTO KNOWLEDGE BASES
R. B. PURVES, JAMES R. CARNES, and DANNIE E. CUTTS (Boeing Co., Huntsville, Ala.) *In* NASA. Marshall Space Flight Center, Third Conference on Artificial Intelligence for Space Applications, Part 1 p 353-357 Nov. 1987
Avail: NTIS HC A18/MF A01 CSCL 05B

One approach to transforming information stored in relational data bases into knowledge based representations and back again is described. This system, called Foundation, allows knowledge bases to take advantage of vast amounts of pre-existing data. A benefit of this approach is inspection, and even population, of data bases through an intelligent knowledge-based front-end. Author

N88-16577*# National Academy of Sciences - National Research Council, Washington, D. C.
CRITICAL ISSUES IN NASA INFORMATION SYSTEMS Final Report
Jun. 1987 68 p
(Contract NASW-4124)
(NASA-CR-182380; NAS 1.26:182380; PB88-101027) Avail: NTIS HC A04/MF A01 CSCL 05B

The National Aeronautics and Space Administration has

developed a globally-distributed complex of earth resources data bases since LANDSAT 1 was launched in 1972. NASA envisages considerable growth in the number, extent, and complexity of such data bases, due to the improvements expected in its remote sensing data rates, and the increasingly multidisciplinary nature of its scientific investigations. Work already has begun on information systems to support multidisciplinary research activities based on data acquired by the space station complex and other space-based and terrestrial sources. In response to a request from NASA's former Associate Administrator for Space Science and Applications, the National Research Council convened a committee in June 1985 to identify the critical issues involving information systems support to space science and applications. The committee has suggested that OSSA address four major information systems issues; centralization of management functions, interoperability of user involvement in the planning and implementation of its programs, and technology. GRA

N88-16773# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
SATELLITE POWER SYSTEMS UNDER CONSIDERATION BY THE UNITED NATIONS
D. KASSING *In its* ESA Bulletin No. 25 p 53-59 Feb. 1981
Avail: NTIS HC A05/MF A01

It is argued that satellite power systems (SPS) could generate electrical energy on a large scale. There are, however, a number of technical, environmental, and socioeconomic uncertainties that require further study before any decision regarding SPS implementation can be envisaged in the late 1980s or early 1990s. *Issues associated with SPS that require international cooperation* are addressed. Author (ESA)

N88-16809# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
MODEL OF SPACE PLATFORM ELECTROMAGNETIC (EMC) CONFIGURATION Final Report
Paris, France ESA 30 Jun. 1987 114 p
(Contract ESA-6536/85-NL-MA(SC))
(ESA-CR(P)-2500; ETN-88-91705) Avail: NTIS HC A06/MF A01

The ESAESA tool containing an electromagnetic compatibility (EMC) data base, EMC prediction programs, EMC management data, and descriptive data (e.g., test set-ups) was developed, based on the Test Data Analysis System (TDAS), for EMC analysis of Columbus. The goals of ESAESA include improved project economics, harmonization, complete coverage of EMC work, improvement of tests and prediction data quality, and the ability to handle problems related to in-orbit assembly. ESA

07

ADVANCED MATERIALS

Includes matrix composites, polyimide films, thermal control coatings, bonding agents, antenna components, manufacturing techniques, and space environmental effects on materials.

A88-13188
NOVEL COMPOSITE MATERIALS FOR SPACE STRUCTURES AND SYSTEMS
EDWARD J. A. POPE and JOHN D. MACKENZIE (California, University, Los Angeles) IN: Advanced materials technology '87; Proceedings of the Thirty-second International SAMPE Symposium and Exhibition, Anaheim, CA, Apr. 6-9, 1987. Covina, CA, Society for the Advancement of Material and Process Engineering, 1987, p. 760-771. *USAF-supported research.* refs

Some novel composite materials that could be useful for space structure applications are reviewed. Criteria utilized in the selection of such materials are considered. Novel materials, such as hollow fiber/resin composites, transparent sol-gel-derived glass/polymer, and new 'triphasic' composites made of ceramic, glass, and polymer phases are presented. Specific strength, specific modulus, vibrational damping, and other properties are examined. Author

A88-13189
FABRICATION AND ASSEMBLY OF AN ADVANCED COMPOSITE SPACE STATION TETRATRUSS CELL
MICHAEL J. ROBINSON (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: Advanced materials technology '87; Proceedings of the Thirty-second International SAMPE Symposium and Exhibition, Anaheim, CA, Apr. 6-9, 1987. Covina, CA, Society for the Advancement of Material and Process Engineering, 1987, p. 772-781.

In a Space Station Phase B development effort, McDonnell Douglas Astronautics Company has fabricated a deployable tetratruss cell made almost entirely of graphite/epoxy composite materials. The cell consists of 24 struts, each 10 ft long, 15 of which bend in the middle to allow the cell to collapse. The strut tubes were fabricated with unidirectional preimpregnated graphite tape. Hinge fittings, tube end fittings, and truss nodes were compression molded using tape and chopped fiber molding compounds. The fully deployed cell measures approximately 20 ft by 17.5 ft by 8.5 ft and collapses into a bundle 10 ft long and about 20 in in diameter. The manufacturing processes discussed include composite material layup and molding, assembly tooling design and fabrication, subassembly drilling and adhesive bonding operations, and final assembly. Author

A88-13202
CARBOFLEX - A NEW GENERAL PURPOSE PITCH-BASED CARBON FIBER
JOHN W. NEWMAN (Ashland Petroleum Co., KY) IN: Advanced materials technology '87; Proceedings of the Thirty-second International SAMPE Symposium and Exhibition, Anaheim, CA, Apr. 6-9, 1987. Covina, CA, Society for the Advancement of Material and Process Engineering, 1987, p. 938-944. refs

A unique petroleum pitch feedstock has been used in a proprietary process to manufacture pitch-based Carboflex carbon fibers suitable for asbestos substitution. The fiber possesses thermal conductivity, chemical inertness, and the strength of steel at 1/5 the weight. Carboflex fibers have asbestos-substitution applications in brakes, gaskets, flooring, and furnace insulation; high technology applications encompass X-ray tables, space platform structures, medical prostheses, storage batteries, chemical warfare filters, and surface-activated filter chemical systems. O.C.

A88-13239* Boeing Aerospace Co., Seattle, Wash.
PROTECTIVE COATINGS FOR COMPOSITE TUBES IN SPACE APPLICATIONS
HARRY W. DURSCH and CARL L. HENDRICKS (Boeing Aerospace Co., Seattle, WA) IN: Advanced materials technology '87; Proceedings of the Thirty-second International SAMPE Symposium and Exhibition, Anaheim, CA, Apr. 6-9, 1987. Covina, CA, Society for the Advancement of Material and Process Engineering, 1987, p. 1569-1580. Previously announced in STAR as N87-18669.
(Contract NAS1-16854)

Protective coatings for graphite/epoxy (Gr/Ep) tubular structures for a manned Space Station truss structure were evaluated. The success of the composite tube truss structure depends on its stability to long-term exposure to the low earth orbit (LEO) environment, with particular emphasis placed on atomic oxygen. Concepts for protectively coating Gr/Ep tubes include use of inorganic coated metal foils and electroplating. These coatings were applied to Gr/Ep tubes and then subjected to simulated LEO environment to evaluate survivability of coatings and coated tubes. Evaluation included: atomic oxygen resistance, changes in optical properties and adhesion, abrasion resistance, surface preparation required, coating uniformity, and formation of microcracks in the Gr/Ep tubes caused by thermal cycling. Program results demonstrated that both phosphoric and chromic acid anodized Al foil provided excellent adhesion to Gr/Ep tubes and exhibited stable optical properties when subjected to simulated

LEO environment. The SiO2/Al coatings sputtered onto Al foils also resulted in an excellent protective coating. Electroplated Ni exhibited unacceptable adhesion loss to Gr/Ep tubes during atomic oxygen exposure. Author

A88-16006#
THE USE OF ADVANCED MATERIALS IN SPACE STRUCTURE APPLICATIONS
D. C. G. EATON and E. J. SLACHMUYLDERS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 15 p. refs
(IAF PAPER 87-305)

The increasing use of composite materials is discussed as well as the integrity control of primary structures fabricated from composite materials (manned flight). New composite materials required to retain their properties up to at least 200 C are expected to be used extensively in the Hermes spaceplane. To ensure a safe structure, consideration should be given to mixed metal-composite load carrying structures, aeroelastic behavior, acoustic fatigue, crashworthiness, and hypersonic velocity meteoroid/debris impact (among many other factors). K.K.

A88-16011#
STRESS AND DEFORMATION ANALYSIS AND TESTS OF COMPOSITE STRUCTURES FOR SPACE APPLICATION
O. HAIDER and K. PFEIFER (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 15 p.
(IAF PAPER 87-312)

Stress tests and finite element analyses of composite structures for various space applications (including solar panels, antenna structures, and link connections in cryostats) are discussed. Tests were performed to determine the influence of the Young's modulus and the thicknesses of the face sheets and the core on the wrinkling stress of composite solar panels. FEM studies are used to design composite antenna structures with low thermal expansion coefficients. Glass and carbon composites with low thermal conductivity are used to design cryogenic links with small cross sections due to high tensile stress. R.R.

A88-16183#
DYNAMICS OF ORBITING DEBRIS CLOUDS AND THE RESULTING COLLISION HAZARD TO SPACECRAFT
V. A. CHOBOTOV (Aerospace Corp., Los Angeles, CA) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 9 p. refs
(IAF PAPER 87-571)

The dynamics of a cloud of particles resulting from a breakup of an object in orbit is presented. 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 effects of earth's oblateness on the temporal evolution of the cloud are included. Author

A88-16866* Alabama Univ., Huntsville.
A MEASUREMENT OF THE ANGULAR DISTRIBUTION OF 5 EV ATOMIC OXYGEN SCATTERED OFF A SOLID SURFACE IN EARTH ORBIT
JOHN C. GREGORY (Alabama, University, Huntsville) and PALMER N. PETERS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: International Symposium on Rarefied Gas Dynamics, 15th, Grado, Italy, June 16-20, 1986, Proceedings. Volume 1. Stuttgart, B. G. Teubner, 1986, p. 644-654. refs
(Contract NAGW-812; NAS8-36189)

The angular distribution of 5 eV atomic oxygen scattered off a polished vitreous carbon surface was measured on a recent Space Shuttle flight. The experimental apparatus was of novel design, completely passive, and used thin silver films as the recording device for oxygen atoms. Most of the incident oxygen was contained in the reflected beam and remained in an active form and probably still atoms. Allowance was made for 12 percent loss of incident atoms which are converted to CO at the carbon surface. The scattered distribution which is wide lobular, peaking 15 deg in the forward direction, shows almost but not quite full accommodation. Author

A88-17944
ARTIFICIAL SPACE DEBRIS
NICHOLAS L. JOHNSON and DARREN S. MCKNIGHT Malabar, FL, Orbit Book Co., 1987, 120 p. refs

An account is given of the nature of anthropogenic debris in orbital space, and an evaluation is made of the hazards posed by its existence to future spacecraft. Attention is given to the deterioration and fragmentation of spacecraft in orbit, methods for the determination of debris size and dispersion, and the impact theory and debris models developed to date for the study of this phenomenon. Projections are made of debris hazards to geosynchronous satellites, and the degree of institutional awareness of the space debris problem. The possibility of this environment's cleaning-up in the future is discussed. O.C.

A88-18173#
MONITORING ELASTIC STIFFNESS DEGRADATION IN GRAPHITE/EPOXY COMPOSITES
R. D. KRIZ (NBS, Fracture and Deformation Div., Boulder, CO) IN: Solid mechanics research for quantitative non-destructive evaluation. Dordrecht, Martinus Nijhoff Publishers, 1987, p. 389-395. refs

Many stiffness-critical aerospace structures exploit the high specific stiffness of graphite/epoxy composites. Elastic-stiffness degradation of these materials is therefore important. Here, a nondestructive technique is described that measures stiffness degradation of the graphite-fibers and epoxy-matrix. This technique monitors variations in the direction of stress-wave propagation (energy-flux) corresponding to a change in composite stiffness. Author

A88-18230* Harris Corp., Melbourne, Fla.
DEVELOPMENT OF COMPOSITE FACETS FOR THE SURFACE OF A SPACE-BASED SOLAR DYNAMIC CONCENTRATOR
SCHUYLER R. AYERS, DONALD E. MOREL, and JAMES A. SANBORN (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: Advanced composites: The latest developments; Proceedings of the Second Conference, Dearborn, MI, Nov. 18-20, 1986. Metals Park, OH, ASM International, 1986, p. 55-60.
(Contract NAS3-24670)

An account is given of the composite fabrication techniques envisioned for the production of mirror-quality substrates furnishing the specular reflectance required for the NASA Space Station's solar dynamic concentrator energy system. The candidate materials were graphite fiber-reinforced glass, aluminum, and polymer matrices whose surfaces would be coated with thin metal layers and with atomic oxygen degradation-inhibiting protective coatings to obtain the desired mirror surface. Graphite-epoxy mirror substrate samples have been found to perform satisfactorily for the required concentrator lifetime. O.C.

A88-18398
THE DANGERS OF SPACE DEBRIS - NEW DEVELOPMENTS AND DISCOVERIES [DIE GEFAHREN DER WELTRAUM-TRUEMMER - NEUE ENTWICKLUNGEN UND ERKENNTNISSE]
ELMAR VITT Zeitschrift fuer Luft- und Weltraumrecht (ISSN 0340-8329), vol. 36, Sept. 1987, p. 249-260. In German. refs

The current status of debris in earth orbit, the measures which could be undertaken to prevent further debris, and the legal implications of the debris problem are reviewed. Topics addressed include the rapid increase in the number of spacecraft being tracked, the fact that much larger numbers of untracked objects of cm and sub-mm size are also in orbit, and the relative contributions of accidental explosions and ASAT tests to the debris.

Particular attention is given to the debris hazard for large structures such as the Space Station and for astronauts performing EVAs, the reentry of large satellite fragments (including radioactive materials from reactors), and the difficulties satellites and debris pose for astronomers. It is argued that present international agreements and regulations are inadequate to control debris or hold the producers of nonaccidental debris liable for subsequent damages. T.K.

A88-20701
LOOKING AHEAD FOR MATERIALS AND PROCESSES; PROCEEDINGS OF THE EIGHTH SAMPE (EUROPEAN CHAPTER) INTERNATIONAL CONFERENCE, LA BAULE, FRANCE, MAY 18-21, 1987
JACQUES DE BOSSU, ED. (Brochier, S.A., Neuilly-sur-Seine, France), GUY BRIENS, ED. (Aerospatiale, Suresnes, France), and PIERRE LISSAC, ED. (Hexcel-Genin, S.A., Lyons, France) Conference sponsored by SAMPE, Aerospatiale, Brochier, S.A., et al. Amsterdam, Elsevier (Materials Science Monographs. Volume 41), 1987, 508 p. For individual items see A88-20702 to A88-20729.

The present conference on emerging advanced materials and processes encompasses topics in low temperature cure polymers, aeronautical applications, adhesives, naval and maritime applications, spaceborne materials, composite behavior, ceramics, and thermoplastic polymers. Attention is given to glass-matrix composites' manufacture and performance, aluminum- and steel-matrix composites, novel materials used in the Rafale fighter, UV processing of prepregs, cost-effective thermoplastic composite processing, lightning protection for aircraft and space vehicles, the aging effects of sea water on materials, GFRP for OTEC plant cold water intakes, atomic oxygen effects in low orbit, and the properties of the Nextel 440 ceramic fiber. O.C.

A88-21605* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
SPACE SOLAR CELL RESEARCH - PROBLEMS AND POTENTIAL
DENNIS J. FLOOD (NASA, Lewis Research Center, Cleveland, OH) IN: Photovoltaics for commercial solar power applications; Proceedings of the Meeting, Cambridge, MA, Sept. 18, 19, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 34-39. Previously announced in STAR as N86-31793. refs

The value of a passive, maintenance-free, renewable energy source was immediately recognized in the early days of the space program, and the silicon solar cell, despite its infancy, was quickly pressed into service. Efficiencies of those early space solar arrays were low, and lifetimes shorter than hoped for, but within a decade significant advances had been made in both areas. Better performance was achieved because of a variety of factors, ranging from improvements in silicon single crystal material, to better device designs, to a better understanding of the factors that affect the performance of a solar cell in space. Chief among the latter, particularly for the mid-to-high altitude (HEO) and geosynchronous (GEO) orbits, are the effects of the naturally occurring particulate radiation environment. Although not as broadly important to the photovoltaic community at large as increased efficiency, the topic of radiation damage is critically important to use of solar cells in space, and is a major component of the NASA research program in space photovoltaics. This paper will give a brief overview of some of the opportunities and challenges for space photovoltaic applications, and will discuss some of the current reseach directed at achieving high efficiency and controlling the effects of radiation damage in space solar cells. Author

A88-22286#
LARGE SPACE SYSTEMS ENVIRONMENTAL ENTANGLEMENTS
CARL J. FRUSHON and JOHN A. GAUDET (USAF, Geophysics Laboratory, Bedford, MA) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 27 p. refs
(AIAA PAPER 88-0388)

The most important adverse environmental impacts on future space systems are identified and discussed. Charging, radiation, contamination, atomic oxygen erosion, particle impacts, high-voltage interactions, and thermal forces are considered. Research on ways to mitigate these forces and counteract their adverse impacts is addressed. C.D.

A88-22919
RADIATION HAZARDS ON SPACE MISSIONS
JOHN R. LETAW (Severn Communications Corp., Severna Park, MD), REIN SILBERBERG, and C. H. TSAO (U.S. Navy, E. O. Hulburt Center for Space Research, Washington, DC) Nature (ISSN 0028-0836), vol. 330, Dec. 24, 1987, p. 709, 710. Navy-DOE-supported research. refs

Calculations of the radiation dose equivalents to astronauts from Galactic cosmic radiation (GCR) and from energetic solar particle events are presented. Previous results identifying GCR as a significant factor in the space radiation dose are extended. In particular, the components of the radiation dose are determined, and the relationship between dose and shielding thickness is determined. Shielding requirements are proposed for future spaceflights. A storm shelter protected by at least 9 cm of aluminum or its equivalent is recommended for all spaceflights outside the magnetosphere. On long-duration flights, such as a Mars mission, all habitable spaces should be shielded with 7.5 cm aluminum or its equivalent. C.D.

A88-24846
DEBRIS HAZARD POSES FUTURE THREAT
RALPH D. LORENZ Spaceflight (ISSN 0038-6340), vol. 30, Jan. 1988, p. 4-7.

Space debris comprises three classes: particles, fragments, and artifacts; here the broad characteristics of these classes (such as mass, size, and composition) are listed in a table. The causes of spacecraft destruction are discussed, including antisatellite weapons system testing, self-destruction in order to prevent their impact on populated areas of the earth's surface, and the break-up of the nuclear power supplies of some satellites. Radar observations and computer models indicate that the worst position for the satellite is in an 800-km orbit with an inclination of about 120 degrees, and orbits from about 500 km to 1100 km are hazardous. Some of the more well-documented cases of spacecraft colliding with artificial space debris are analyzed. It is concluded that within 20 years or so it will be necessary to clear up at least some of the existing debris. The NASA Orbital Maneuvering Vehicle (OMV), which is able to reach some 2700 km above a Space Shuttle orbit, is discussed. A.S.

A88-26965
MATERIALS SELECTION AS RELATED TO CONTAMINATION OF SPACECRAFT CRITICAL SURFACES
CHARLES E. VEST, ROBERT M. BUCHA, and MICHAEL J. LENKEVICH (Johns Hopkins University, Laurel, MD) SAMPE Quarterly (ISSN 0036-0821), vol. 19, Jan. 1988, p. 29-35. refs

The contamination of spacecraft scientific instrumentation, thermal control surfaces, and other critical components, may be substantially due to improper selection of construction materials as well as inadequate attention to cleanliness during fabrication, assembly, testing, etc. An account is presently given of materials selection and contamination control plan-related procedures. Attention is given to the sources of contaminating films on sensors, the classification of spacecraft conditions, the management of a simulated VUV instrument's decontamination, and the removal of contaminating films while in orbit. O.C.

A88-29585
HIGH TEMPERATURE RESISTANT COMPLIANT MODIFIED EPOXIES
S. L. OLDHAM and W. E. ELIAS (Hughes Aircraft Co., El Segundo, CA) SAMPE Journal (ISSN 0091-1062), vol. 24, Mar.-Apr. 1988, p. 9-11, 165.

A family of compliant modified epoxies has been synthesized for use as adhesives, coatings, and encapsulants; the base resins

exhibited low viscosities, glass transition temperatures, and outgassing characteristics with high peel temperatures and decomposition temperatures. Attention is presently given to baseline material data obtained for one of these modified resins, HRG-3, which is a viable, solvent-free, toughened epoxy system for applications in which thermal stability, repairability, abrasion and moisture resistance, and low outgassing, are all important, as in spacecraft structures subjected to LEO particulate bombardment. O.C.

A88-30317#
FLUID LOSS FROM A PUNCTURE OF A SPACE RADIATOR
D. E. TILTON and L. C. CHOW (Kentucky, University, Lexington) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 2, Jan. 1988, p. 84-86. Previously cited in issue 18, p. 2615, Accession no. A86-39925. refs
(Contract F49620-82-C-0035)

A88-31388*# Boeing Aerospace Co., Seattle, Wash.
HYPERVELOCITY IMPACT DAMAGE ASSESSMENT FOR SPACE STATION
ALEX R. CORONADO, MARTIN N. GIBBINS, and PAUL H. STERN (Boeing Aerospace Co., Seattle, WA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 90-98. refs
(Contract NAS8-36426)
(AIAA PAPER 88-2465)

To inhibit damage and limit the probability of penetration of the Space Station pressure wall by micrometeoroids and orbital debris, a shield placed away from the wall is used to form a double wall. To determine shield effectiveness and assess impact damage, existing test data were reviewed and additional testing was performed for Space Station double wall designs. Empirical spallation and penetration functions derived from the data show that shield thickness and impact angle affect the damage to the wall. Thick shields reduce wall damage for low angle impacts but increase damage for oblique impacts. Multilayer insulation between the shield and wall reduces impact damage to the wall. A relationship between impact velocity and spall damage to the wall is demonstrated. Preliminary test results on Li-Al shield material indicate possible improved effectiveness over Al shields. C.D.

A88-31389*# Lockheed Missiles and Space Co., Sunnyvale, Calif.
DEVELOPMENT AND PROPERTIES OF ALUMINUM-CLAD GRAPHITE/EPOXY TUBES FOR SPACE STRUCTURES
R. R. JOHNSON and M. H. KURAL (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 99-107. refs
(Contract NAS1-17660)
(AIAA PAPER 88-2472)

This paper presents the development and properties of seamless aluminum-clad P75/Epoxy tubes and the unique manufacturing method used in their production. Thermo-mechanical properties of the tubes were determined analytically and verified by tests. These properties were shown to be suitable for space structures that require high stiffness, low weight and thermal expansion, and dimensional stability during operational life. A special feature of the tubes is the ability to tune the tube for thermal expansion after fabrication by a chemical milling process. The tubes are also resistant to atomic oxygen and handling damage. The toughness of the tubes was demonstrated by impact testing. Cyclic thermal testing showed no adverse effects on the expansion and stiffness behavior of the tubes. The paper also includes a discussion of a joining method that uses aluminum end fittings and an efficient scarf joint configuration. Additional studies considered various adhesives and fitting materials. Joint allowables were higher for titanium and B4C particulate magnesium fittings. The effect of different adhesives under static loading conditions favored the high-strength adhesives. Author

A88-31390*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
RESPONSE OF COMPOSITE MATERIALS TO THE SPACE STATION ORBIT ENVIRONMENT
S. S. TOMPKINS, D. E. BOWLES, W. S. SLEMP, and L. A. TEICHMAN (NASA, Langley Research Center, Hampton, VA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 108-116. refs
(AIAA PAPER 88-2476)

The rationale for selecting composite materials with an anodized aluminum foil coating for the Space Station is presented. Data on the effects of the space service environment on these materials are given. Results are also presented on the effect of optical properties of an aluminum/aluminum oxide coating on the thermal balance of the cylindrical structural members. The resistance of this coating to solar ultraviolet degradation is discussed. C.D.

A88-31391#
STRESS RUPTURE BEHAVIOR OF CARBON-FIBER METAL-LINED PRESSURE VESSELS FOR 30-YEAR OPERATION IN SPACE
HANK BABEL, DAVID HEMMERLING (McDonnell Douglas Astronautics Co., Saint Louis, MO), TONY PEARCE, and REX HADDOCK (Structural Composites Industries, Inc., Pomona, CA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 117-120. refs
(AIAA PAPER 88-2479)

Initial results obtained in a 30-year program undertaken to evaluate high-strength carbon fibers for pressure vessels subjected to long-term sustained pressures with superimposed temperature and pressure cycles are reported. The stress-rupture behavior of several high-strength carbon fibers suitable for filament-winding pressure vessels was studied, using hydraulically loaded, approximately 4-in. diameter pressure vessels as test specimens. Future work planned in the program is described. C.D.

A88-31404
OUTGASSING OF SPACECRAFT COMPOSITES
ROBERT D. KARAM (Fairchild Space Co., Germantown, MD) IN: Composite structures 4; Proceedings of the Fourth International Conference, Paisley, Scotland, July 27-29, 1987. Volume 1. London and New York, Elsevier Applied Science, 1987, p. 1.45-1.58. refs

Diffusion and outgassing of contaminants in spacecraft composite structures are evaluated. The generalized mass and heat transfer equations are simplified for application to thin platforms, and a mathematical model is constructed for predicting outgassing rates as a function of orbital temperatures. It is found that small changes in temperature can have a major influence on the time needed for a structure to reach a specified level of residual contamination. Numerical examples are presented to illustrate application of the theory, and recommendations are given for testing and for monitoring orbital temperatures. Author

A88-31600#
COMPARISON OF EXPERIMENTAL TECHNIQUES IN THE MEASUREMENT OF DAMPING CAPACITY OF METAL-MATRIX COMPOSITES
A. K. RAY, G. G. WREN, and V. K. KINRA (Texas A & M University, College Station) IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 221-227. Research supported by the Martin Marietta Corp. refs

Structural damping incorporates both material damping and energy dissipation due to macroscopic mechanisms such as joint friction. Numerous experimental techniques have been developed to obtain a measure of damping. However, there has been little distinction in the literature between material and structural damping.

This paper discusses two experimental techniques for determining a measure of damping, namely, uniaxial tension-tension fatigue and free-free flexural resonance, and demonstrates that each of these methods measures a different type of damping, namely, material and structural damping, respectively. Author

A88-31605*# Auburn Univ., Ala.
EXPERIMENTAL STUDY OF DAMPING OF GRAPHITE EPOXY COMPOSITE MATERIAL OF THE SPACE TELESCOPE TRUSS SYSTEM
M. D. RAO, M. J. CROCKER (Auburn University, AL), and S. H. GUEST (NASA, Marshall Space Flight Center, Huntsville, AL) IN: The role of damping in vibration and noise control; Proceedings of the Eleventh Biennial Conference on Mechanical Vibration and Noise, Boston, MA, Sept. 27-30, 1987. New York, American Society of Mechanical Engineers, 1987, p. 271-277. refs
(Contract NAS8-36146)

The truss system of the Hubble Space Telescope is made of graphite epoxy tubes and beams that have very low material damping. This paper describes a systematic experimental evaluation of the damping capacity of the graphite epoxy material used in the telescope truss system. The damping capacity of the composite material was measured both under normal and elevated temperatures in atmospheric conditions and in vacuum. Both free decay and steady state methods were used to measure the damping ratio of different specimens under different boundary conditions. A method that involves an iterative least-squares curve-fitting technique for the measured frequency response data has been developed to improve the accuracy of the damping ratio estimation. A unique experimental setup was developed to measure the damping of the material in a vacuum chamber. It was found that outgassing (moisture desorption) has little effect on the damping of the specimen. On the other hand, it was observed that temperature has a significant effect on both the damping and resonance frequencies of the specimen. Author

A88-32307# Alabama Univ., Huntsville.
ANALYSIS OF OBLIQUE HYPERVELOCITY IMPACT PHENOMENA
WILLIAM P. SCHONBERG (Alabama, University, Huntsville) and ROY A. TAYLOR (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 1252-1261. refs
(AIAA PAPER 88-2370)

This paper describes the results of an experimental investigation of phenomena associated with the oblique hypervelocity impact of spherical projectiles on multisheet aluminum structures. A model that can be employed in the design of meteoroid and space debris protection systems for space structures is developed. The model consists of equations that relate crater and perforation damage of a multisheet structure to parameters such as projectile size, impact velocity, and trajectory obliquity. The equations are obtained through a regression analysis of oblique hypervelocity impact test data. This data shows that the response of a multisheet structure to oblique impact is significantly different from its response to normal hypervelocity impact. It was found that obliquely incident projectiles produce ricochet debris that can severely damage panels or instrumentation located on the exterior of a space structure. Obliquity effects of high-speed impact must, therefore, be considered in the design of any structure exposed to a meteoroid or space debris environement. Author

N88-10070*# Boeing Aerospace Co., Seattle, Wash.
SPACE STATION INTEGRATED WALL DESIGN AND PENETRATION DAMAGE CONTROL
A. R. CORONADO, M. N. GIBBINS, M. A. WRIGHT, and P. H. STERN Jul. 1987 312 p
(Contract NAS8-36426)
(NASA-CR-179169; NAS 1.26:179169; D180-30550-4) Avail: NTIS HC A14/MF A01 CSCL 22B

The analysis code BUMPER executes a numerical solution to the problem of calculating the probability of no penetration (PNP) of a spacecraft subject to man-made orbital debris or meteoroid impact. The codes were developed on a DEC VAX 11/780 computer that uses the Virtual Memory System (VMS) operating system, which is written in FORTRAN 77 with no VAX extensions. To help illustrate the steps involved, a single sample analysis is performed. The example used is the space station reference configuration. The finite element model (FEM) of this configuration is relatively complex but demonstrates many BUMPER features. The computer tools and guidelines are described for constructing a FEM for the space station under consideration. The methods used to analyze the sensitivity of PNP to variations in design, are described. Ways are suggested for developing contour plots of the sensitivity study data. Additional BUMPER analysis examples are provided, including FEMs, command inputs, and data outputs. The mathematical theory used as the basis for the code is described, and illustrates the data flow within the analysis. B.G.

N88-10117*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
OUTGASSING DATA FOR SELECTING SPACECRAFT MATERIALS
WILLIAM A. CAMPBELL, JR. and RICHARD S. MARRIOTT Aug. 1987 323 p Revised
(NASA-RP-1124; REPT-87B0347; NAS 1.61:1124) Avail: NTIS HC A14/MF A01 CSCL 11D

Outgassing data, derived from tests at 398 K (125 C) for 24 hours in vacuum as per ASTM E 595-77, have been compiled for numerous materials for spacecraft use. The data presented are the total mass loss (TML) and the collected volatile condensable materials (CVCM). The various materials are listed by likely usage and alphabetically. Author

N88-10121*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
MECHANICAL PROPERTIES CHARACTERIZATION OF COMPOSITE SANDWICH MATERIALS INTENDED FOR SPACE ANTENNA APPLICATIONS
KENNETH J. BOWLES and RAYMOND D. VANNUCCI 1986 17 p Presented at Test Methods and Design Allowables for Fiber Composites: 2nd Symposium, Phoenix, Ariz., 3-4 Nov. 1986; sponsored by the American Society for Testing and Materials
(NASA-TM-88893; E-3310; NAS 1.15:88893) Avail: NTIS HC A03/MF A01 CSCL 11D

The composite materials proposed for use in the Advanced Communications Technology Satellite (ACTS) Program contains a new, high modulus graphite fiber as the reinforcement. A study was conducted to measure certain mechanical properties of the new fiber-reinforced material as well as of a composite-faced aluminum honeycomb sandwich structure. Properties were measured at -157, 22, and 121 C. Complete characterization of this material was not intended. Longitudinal tensile, picture-frame shear, short-beam shear, and flexural tests were performed on specimens of the composite face-sheet materials. Unidirectional, cross-plied, and quasi-isotropic fiber composite ply layup designs were fabricated and tested. These designs had been studied by using NASA's Integrated Composite Analyzer (ICAN) computer program. Flexural tests were conducted on (+/- 60/0 deg) sub s composite-faced sandwich structure material. Resistance strain gages were used to measure strains in the tensile, picture-frame, and sandwich flexural tests. The sandwich flexural strength was limited by the core strength at -157 and 22 C. The adhesive bond strength was the limiting factor at 121 C. Adhesive mechanical properties are reflected in sandwich structure flexural properties when the span-to-depth ratio is great enough to allow a significant shear effect on the load-deflection behavior of the sandwich beam. Most measured properties agreed satisfactorily with the properties predicted by ICAN. Author

N88-10847*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
HIGH INTENSITY 5 EV O-ATOM EXPOSURE FACILITY FOR MATERIAL DEGRADATION STUDIES

J. B. CROSS, L. H. SPANGLER, M. A. HOFFBAUER, F. A. ARCHULETA, LUBERT LEGER, JAMES VISENTINE, and DON E. HUNTON (Air Force Geophysics Lab., Hanscom AFB, Mass.) *In* NASA- Goddard Space Flight Center, Greenbelt, Md. Fourteenth Space Simulation Conference: Testing for a Permanent Presence in Space p 209-226 1986
Avail: NTIS HC A19/MF A01 CSCL 07D

An atomic oxygen exposure facility was developed for studies of material degradation. The goal of these studies is to provide design criteria and information for the manufacture of long life (20 to 30 years) construction materials for use in low Earth orbit. The studies that are being undertaken will provide: (1) absolute reaction cross sections for the engineering design problems, (2) formulations of reaction mechanisms for use in the selection of suitable existing materials and the design of new more resistant ones, and (3) the calibration of flight hardware (mass spectrometers, etc.) in order to directly relate experiments performed in low Earth orbit to ground based investigations. The facility consists of a CW laser sustained discharge source of O-atoms, an atomic beam formation and diagnostics system, a spinning rotor viscometer, and provision for using the system for calibration of actual flight instruments.
Author

N88-10896*# Case Western Reserve Univ., Cleveland, Ohio. Dept. of Physics.
DEGRADATION MECHANISMS OF MATERIALS FOR LARGE SPACE SYSTEMS IN LOW EARTH ORBIT Final Report, 6 Oct. 1982 - 5 Jan. 1985
WILLIAM L. GORDON and R. W. HOFFMAN Nov. 1987 32 p
(Contract NAG3-352)
(NASA-CR-181472; NAS 1.26:181472) Avail: NTIS HC A03/MF A01 CSCL 11D

Degradation was explored of various materials used in aerospace vehicles after severe loss of polymeric material coatings (Kapton) was observed on an early shuttle flight in low Earth orbit. Since atomic oxygen is the major component of the atmosphere at 300 km, and the shuttle's orbital velocity produced relative motion corresponding to approx. 5 eV of oxygen energy, it was natural to attribute much of this degradation to oxygen interaction. This assumption was tested using large volume vacuum systems and ion beam sources, in an exploratory effort to produce atomic oxygen of the appropriate energy, and to observe mass loss from various samples as well as optical radiation. Several investigations were initiated and the results of these investigations are presented in four papers. These papers are summarized. They are entitled: (1) The Space Shuttle Glow; (2) Laboratory Degradation of Kapton in a Low Energy Oxygen Ion Beam; (3) The Energy Dependence and Surface Morphology of Kapton Degradation Under Atomic Oxygen Bombardment; and (4) Surface Analysis of STS 8 Samples. Author

N88-11715 Centre d'Etude Spatiale des Rayonnements, Toulouse (France). Dept. d'Etudes et de Recherches en Technologie Spatiale.
SPACECRAFT SURFACE EXPOSURE TO ATOMIC OXYGEN IN LOW EARTH ORBIT
ALAIN PAILLOUS *In* CNES, Space Environment Technology p 353-375 Apr. 1987 In FRENCH; ENGLISH summary
Avail: CEPADUES-Editions, Toulouse, France

Flight experiments in the shuttle payload bay showing that interaction of oxygen atoms with surfaces can cause significant erosion of materials and components in low Earth orbits are discussed. Neutral atmospheric composition and its variations are described. Reaction efficiencies of various spacecraft surface materials are given. The fluences to which surfaces in typical orbits are exposed are estimated. The problems of the simulation techniques to be used in laboratory are considered. ESA

N88-12429*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
LOW EARTH ORBIT ENVIRONMENTAL EFFECTS ON THE SPACE STATION PHOTOVOLTAIC POWER GENERATION SYSTEMS
HENRY K. NAHRA 1987 20 p Proposed for presentation at the 1988 Solar Energy Conference, Golden, Colo., 10-14 Apr. 1988; sponsored by ASME
(NASA-TM-100230; E-3852; NAS 1.15:100230) Avail: NTIS HC A03/MF A01 CSCL 10A

A summary of the Low Earth Orbital Environment, its impact on the Photovoltaic Power systems of the space station and the solutions implemented to resolve the environmental concerns or issues are described. Low Earth Orbital Environment (LEO) presents several concerns to the Photovoltaic power systems of the space station. These concerns include atomic oxygen interaction with the polymeric substrate of the solar arrays, ionized environment effects on the array operating voltage, the effects of the meteoroids and debris impacts and penetration through the different layers of the solar cells and their circuits, and the high energy particle and radiation effects on the overall solar array performance. Potential solutions to some of the degrading environmental interactions that will provide the photovoltaic power system of the space station with the desired life are also summarized. Author

N88-12529*# McDonnell-Douglas Astronautics Co., Houston, Tex.
SPACECRAFT MATERIAL FLAMMABILITY TESTING AND CONFIGURATIONS
PAUL W. LEDOUX *In* NASA, Lewis Research Center, Spacecraft Fire Safety p 95-98 1987
Avail: NTIS HC A07/MF A01 CSCL 11D

Material and configuration testing for the Space Shuttle is mainly at 30 percent oxygen concentration at 70 kPa (10.2 psia). This is the worst case atmosphere during a mission and occurs 10 hours prior to extravehicular activity. The pressure is reduced from the nominal 101 kPa (14.7 paia) and the oxygen concentration is increased to 30 percent for medical reasons to prevent the bends during the extravehicular activity. NASA has tested many materials at 23.8, 25.9 and 30 percent oxygen levels for the Shuttle program. Data is given to show how flammability of material is affected by percentage of oxygen for those materials that would be considered for spacecraft applications. Author

N88-12546# United Technologies Research Center, East Hartford, Conn.
CARBON FIBER REINFORCED GLASS MATRIX COMPOSITES FOR SPACE BASED APPLICATIONS Annual Report, 1 Jul. 1986 - 30 Jun. 1987
WILLIAM K. TREDWAY and KARL M. PREWO 31 Aug. 1987 89 p
(Contract N00014-85-C-0332)
(AD-A184355; UTRC/R87-917470-1) Avail: NTIS HC A05/MF A01 CSCL 11D

High elastic modulus (HMU) carbon fibers were combined with several different glass and glass ceramic matrix compositions. The importance of the fiber matrix interface in the control of composite performance was central to the investigation and was evaluated by correlating mechanical properties with microstructural and microchemical analysis of the interfacial region. Lithium aluminosilicate (LAS) glass-ceramic matrix composites were developed with tensile stress-strain behavior comparable to borosilicate glass matrix composites. Carbon fiber reinforced glass matrix composites of 0/90 deg orientation were found to be relatively notch insensitive. Lowering of the processing temperature of 7740/HMU composites was found to affect composite mechanical performance through matrix consolidation effects. Interfacial reactions between the carbon fiber and various matrix additives (nb205, mo03) were found to have a profound effect on composite mechanical behavior via formation of an interfacial carbide layer which increased fiber-matrix interfacial bond strength. GRA

N88-15077*# Boeing Aerospace Co., Seattle, Wash.
CHROMIC ACID ANODIZING OF ALUMINUM FOIL Final Report
H. DURSCH Jan. 1988 40 p

(Contract NAS1-18224)
(NASA-CR-178417; NAS 1.26:178417) Avail: NTIS HC A03/MF A01 CSCL 11C

The success of the Space Station graphite/epoxy truss structure depends on its ability to endure long-term exposure to the LEO environment, primarily the effects of atomic oxygen and the temperture cycling resulting from the 94 minute orbit. This report describes the development and evaluation of chromic acid anodized (CAA) aluminum foil as protective coatings for these composite tubes. Included are: development of solar absorptance and thermal emittance properties required of Al foil and development of CAA parameters to achieve these optical properties; developing techniques to CAA 25 ft lengths of Al foil; developing bonding processes for wrapping the Al foil to graphite/epoxy tubes; and atomic oxygen testing of the CAA Al foil. Two specifications were developed and are included in the report: Chromic Acid Anodizing of Aluminum Foil Process Specification and Bonding of Anodized Aluminum Foil to Graphite/Epoxy Tubes. Results show that CAA Al foil provides and excellent protective and thermal control coating for the Space Station truss structure. Author

N88-15082*# College of William and Mary, Williamsburg, Va. Dept. of Chemistry.
SPACE ENVIRONMENTAL EFFECTS ON POLYMERIC MATERIALS Semiannual Progress Report, 1 Jun. - 30 Nov. 1987
RICHARD L. KIEFER and ROBERT A. ORWOLL 15 Feb. 1988 6 p
(Contract NAG1-678)
(NASA-CR-182418; NAS 1.26:182418) Avail: NTIS HC A02/MF A01 CSCL 11B

Polymer-matrix composites have considerable potential for use in the construction of orbiting structures such as the space station and space antennas because of their light weight, high strength, and low thermal expansion. However, they can suffer surface erosion by interaction with atomic oxygen in low-Earth orbit and degradation and/or embrittlement by electrons and ultraviolet radiation especially in geosynchronous orbit. Thus, a study of the effect of these environmental hazards on polymeric materials is an important step in the assessment of such materials for future use in space. Author

N88-15933*# Analex Corp., Fairview Park, Ohio.
SPACE ENVIRONMENTAL CONSIDERATIONS FOR A LONG-TERM CRYOGENIC STORAGE VESSEL
SHIGEO NAKANISHI *In* NASA. Lewis Research Center, Cleveland, Ohio. Cryogenic Fluid Management Technology Workshop. Volume 1: Presentation Material and Discussion p 175-191 Sep. 1987 Avail: NTIS HC A17/MF A01 CSCL 20D

Information is given on the kind of protection that is needed against impact and perforation of a long-term cryogenic storage vessel in space by meteoroids and space debris. The long-term effects of the space environment on thermal control surfaces and coatings, and the question of whether the insulation and thermal control surfaces should be encased in a vacuum jacket shell are discussed. R.J.F.

N88-16824# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany).
INTEGRITY CONTROL OF CARBON FIBER REINFORCED PLASTICS (CFRP) STRUCTURAL ELEMENTS. CONCLUSION WITH RESPECT TO THE CONTROL METHODOLOGY OF CFRP PRIMARY STRUCTURES IN MANNED SPACE FLIGHT AND THE IMPLICATIONS TO THE DESIGN, ANALYSIS AND TESTING OF CFRP STRUCTURAL ELEMENTS, EXECUTIVE SUMMARY Supplement to Final Report
WERNER H. PAUL Paris, France ESA 1985 87 p
(Contract ESA-4442/80-NL-AK(SC))
(MBB-TR-RB517-014/85; ESA-CR(P)-2517; ETN-88-91709)
Avail: NTIS HC A05/MF A01

A three fold control logic related to development, manufacturing, and operation of safety relevant structures is established in order to exclude catastrophic failures of CFRP-elements due to the existence of global degradation or local defects. Verification of integrity control requirements during development; design concepts for critical structural items; global deviations and local defects; stress evaluation; material properties; the impact of macroscopic defects on the static capability; the degradation of capabilities with increasing operational life; nondestructive inspection of CFRP elements; and a simplified design procedure are discussed. ESA

N88-16879*# College of William and Mary, Williamsburg, Va. Dept. of Chemistry.
SPACE ENVIRONMENTAL EFFECTS ON POLYMERIC MATERIALS Final Technical Report, 1 May 1986 - 31 May 1987
RICHARD L. KIEFER and ROBERT A. ORWOLL 1987 31 p
(Contract NAG1-678)
(NASA-CR-182454; NAS 1.26:182454) Avail: NTIS HC A03/MF A01 CSCL 11B

Polymeric materials that may be exposed on spacecraft to the hostile environment beyond Earth's atmosphere were subjected to atomic oxygen, electron bombardment, and ultraviolet radiation in terrestrial experiments. Evidence is presented for the utility of an inexpensive asher for determining the relative susceptibility of organic polymers to atomic oxygen. Kapton, Ultem, P1700 polysulfone, and m-CBB/BIS-A (a specially formulated polymer prepared at NASA Langley) all eroded at high rates, just as was observed in shuttle experiments. Films of Ultem, P1700 polysulfone, and m-CBB/BIS-A were irradiated with 85 keV electrons. The UV/VIS absorbance of Ultem was found to decay with time after irradiation, indicating free radical decay. The tensile properties of Ultem began to change only after it had been exposed to 100 Mrads. The effects of dose rate, temperature, and simultaneous vs. sequential electron and UV irradiation were also studied. Author

N88-17688*# Boeing Aerospace Co., Seattle, Wash.
SPACE STATION INTEGRATED WALL DAMAGE AND PENETRATION DAMAGE CONTROL. TASK 5: SPACE DEBRIS MEASUREMENT, MAPPING AND CHARACTERIZATION SYSTEM Final Report, 1 Aug. - 16 Dec. 1987
B. M. LEMPRIERE 16 Dec. 1987 107 p
(Contract NAS8-36426)
(NASA-CR-179281; NAS 1.26:179281; D180-30708-1) Avail: NTIS HC A06/MF A01 CSCL 22A

The procedures and results of a study of a conceptual system for measuring the debris environment on the space station is discussed. The study was conducted in two phases: the first consisted of experiments aimed at evaluating location of impact through panel response data collected from acoustic emission sensors; the second analyzed the available statistical description of the environment to determine the probability of the measurement system producing useful data, and analyzed the results of the previous tests to evaluate the accuracy of location and the feasibility of extracting impactor characteristics from the panel response. The conclusions were that for one panel the system would not be exposed to any event, but that the entire Logistics Module would provide a modest amount of data. The use of sensors with higher sensitivity than those used in the tests could be advantageous. The impact location could be found with sufficient accuracy from panel response data. The waveforms of the response were shown to contain information on the impact characteristics, but the data set did not span a sufficient range of the variables necessary to evaluate the feasibility of extracting the information. Author

N88-18734*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
OXIDATION AND PROTECTION OF FIBERGLASS-EPOXY COMPOSITE MASTS FOR PHOTOVOLTAIC ARRAYS IN THE LOW EARTH ORBITAL ENVIRONMENT
SHARON K. RUTLEDGE, PHILLIP E. PAULSEN, JOYCE A. BRADY (Cleveland State Univ., Ohio.), and MICHAEL L. CIANCONE 1988 12 p Presented at the Spring Meeting of the Materials Research Society, Reno, Nev., 5-9 Apr. 1988

(NASA-TM-100839; E-4027; NAS 1.15:100839) Avail: NTIS HC A03/MF A01 CSCL 11B

Fiberglass-epoxy composites are considered for use as structural members for the mast of the space station solar array panel. The low Earth orbital environment in which space station is to operate is composed mainly of atomic oxygen, which has been shown to cause erosion of many organic materials and some metals. Ground based testing in a plasma asher was performed to determine the extent of degradation of fiberglass-epoxy composites when exposed to a simulated atomic oxygen environment. During exposure, the epoxy at the surface of the composite was oxidized, exposing individual glass fibers which could easily be removed. Several methods of protecting the composite were evaluated in an atomic oxygen environment and with thermal cycling and flexing. The protection techniques evaluated to date include an aluminum braid covering, an indium-tin eutectic and a silicone based paint. The open aluminum braid offered little protection while the CV-1144 coating offered some initial protection against atomic oxygen, but appears to develop cracks which accelerate degradation when flexed. Coatings such as the In-Sn eutectic may provide adequate protection by containing the glass fibers even though mass loss still occurs. Author

N88-19592*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

MAST MATERIAL TEST PROGRAM (MAMATEP)

MICHAEL L. CIANCONE and SHARON K. RUTLEDGE 1988 13 p Presented at Issues of the International Space Station, Williamsburg, Va., 21-22 Apr. 1988; sponsored by AIAA (NASA-TM-100821; E-4005; NAS 1.15;100821; AIAA-88-2475) Avail: NTIS HC A03/MF A01 CSCL 11D

The Mast Material Test Program (MAMATEP) at NASA Lewis is discussed. Objectives include verifying the need for, and evaluating the performance of, various protection techniques for the Solar Array Assembly mast of the Space Station Photovoltaic Power Module. Mast material samples were evaluated in terms of mass and bending modulus, measured before and after environmental exposure. Test environments included atomic oxygen exposure (RF plasma asher), thermal cycling, and mechanical flexing. Protective coatings included CV-1144 silicon, a Ni/Au/InSn eutectic, and an open weave, Al braid. Results indicate that unprotected samples degrade in an atomic oxygen environment at a steady rate. Open weave, Al braid offers little protection for the fiberglass-epoxy sample in an asher environment. Ni/Au/InSn eutectic offers excellent protection in an asher environment prior to thermal cycling and mechanical flexing. Long duration asher results from unprotected samples indicate that, even though the fiberglass-epoxy degrades, a protection technique may not be necessary to ensure structural integrity. However, a protection technique may be desirable to limit or contain the amount of debris generated by the degradation of the fiberglass-epoxy. Author

08

ASSEMBLY CONCEPTS

Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.

A88-13572#

SIMULATION TOOLS FOR THE DEVELOPMENT OF AN AUTONOMOUS RENDEZVOUS AND DOCKING SYSTEM

A. ELFVING and W. FEHSE (ESA, Control, Robotics and RVD Div., Noordwijk, Netherlands) ESA Journal (ISSN 0379-2285), vol. 11, no. 2, 1987, p. 197-214. refs

The use of computer simulations and test beds for the ground-based development support, performance evaluation, and verification process for the rendezvous and docking system (RVD) is examined. The role of man in the RVD operation, the features of LEO which affect the RVD system, and RVD phases and basic strategies are discussed. A model mission for the RVD system is described. Consideration is given to the objectives, design, capabilities, and applications of the RVD guidance simulation program, the docking simulation program, performance verification software, and a European operations simulator. I.F.

A88-14995

CONTROL OF GRIPPER POSITION OF A COMPLIANT LINK USING STRAIN GAUGE MEASUREMENTS

D. NEMIR, A. J. KOIVO, and R. L. KASHYAP (Purdue University, Lafayette, IN) IN: IEEE Conference on Decision and Control, 25th, Athens, Greece, Dec. 10-12, 1986, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 1140-1144. NSF-supported research. refs

A self-tuning type algorithm is proposed for the control of a single rotating compliant link. At each sampling time, strain measurements along the link are used to assess modal content. Knowledge of the first mode together with the hub position may be used to determine the angular position of a hub to tip projection. A self-tuning control is devised by treating this angle as belonging to an equivalent rigid link. Laboratory experiments show this control to lead to an improved performance over a control which ignores compliance. Author

A88-14996

ON THE MODELLING AND CONTROL OF A FLEXIBLE MANIPULATOR ARM BY POINT ACTUATORS

A. G. CHASSIAKOS and G. A. BEKEY (Southern California, University, Los Angeles, CA) IN: IEEE Conference on Decision and Control, 25th, Athens, Greece, Dec. 10-12, 1986, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 1145-1150. refs

In this paper the modeling and control of a single-link manipulator with link flexibility is discussed. A linear state-space model is obtained and a controller is proposed with the actuators and measurements located at points along the length of the arm. Also a method for the optimal selection of the controllers' locations is presented, so that bending is minimized during the arm motion. The results are validated by simulations. Author

A88-15280

RENDEZVOUS AND DOCKING TECHNOLOGY FOR FUTURE EUROPEAN MISSIONS

I. WIDJAJA and J. SOMMER (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: Space Congress, 24th, Cocoa Beach, FL, Apr. 21-24, 1987, Proceedings. Cape Canaveral, FL, Canaveral Council of Technical Societies, 1987, 25 p. ESA-supported research.

Future European missions will require space vehicles with RVD capabilities to provide the ability of in-orbit servicing and maintenance. ESA sponsored development activities on RVD technology comprises a variety of tasks assigned to different companies and research organizations. This paper discusses one of the key elements of RVD technology, i.e., the development of a prototype on-board software for autonomous rendezvous and proximity operations. It is expected that Columbus missions will benefit from this technology program. Current MTFF (Man Tended Free Flyer) mission concepts foresee servicing at the U.S. Space Station for which adequate rendezvous and berthing capabilities are to be provided. The conceptual design of a maneuver plan in which typical flight modes of the above mentioned prototype on-board software have been implemented, will be discussed. The verification plan involving ground simulation facilities will be addressed. Author

A88-15816*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

NASA'S TELEROBOTICS R & D PROGRAM - STATUS AND FUTURE DIRECTIONS

DONNA SHIRLEY PIVIROTTO (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and GIULIO VARSI (NASA, Washington, DC) IAF, International Astronautical Congress, 38th,

Brighton, England, Oct. 10-17, 1987. 8 p. refs
(Contract NAS7-918)
(IAF PAPER 87-24)

NASA's telerobotics technology program is described as well as the process for the transfer of this technology to the Space Station, and some of the implications of the technology for station design and operations, including those for international cooperation. A diagram is presented of the NASREM control heirarchy with the Office of Aeronautics and Space Technology telerobot testbed architecture superimposed. In telerobotics, the following areas were identified as possible subjects for developing data to support international standards: (1) task boards, (2) system performance measures on task boards, (3) human performance measures on task boards with teleoperation, and (4) autonomous-telerobotic-teleoperated performance comparisons. K.K.

A88-15817*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
THE FLIGHT TELEROBOTIC SERVICER (FTS) - A FOCUS FOR AUTOMATION AND ROBOTICS ON THE SPACE STATION
SANFORD W. HINKAL, JAMES F. ANDARY, JAMES G. WATZIN, and DAVID E. PROVOST (NASA, Goddard Space Flight Center, Greenbelt, MD) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 9 p. refs
(IAF PAPER 87-25)

The concept, fundamental design principles, and capabilities of the FTS, a multipurpose telerobotic system for use on the Space Station and Space Shuttle, are discussed. The FTS is intended to assist the crew in the performance of extravehicular tasks; the telerobot will also be used on the Orbital Maneuvering Vehicle to service free-flyer spacecraft. The FTS will be capable of both teleoperation and autonomous operation; eventually it may also utilize ground control. By careful selection of the functional architecture and a modular approach to the hardware and software design, the FTS can accept developments in artificial intelligence and newer, more advanced sensors, such as machine vision and collision avoidance. V.L.

A88-15838#
SCANNING LASER RADAR SYSTEM FOR RENDEZVOUS AND DOCKING IN SPACE
HIROBUMI SAITO, ICHIRO NAKATANI, KEIKEN NINOMIYA (Tokyo, University, Japan), and AKIRA FURUYA (Mitsubishi Electric Corp., Kamakura, Japan) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 7 p. refs
(IAF PAPER 87-53)

A scanning laser radar system for rendezvous and docking in space is being developed. This laser radar system will be utilized in an autonomous satellite retrieval experiment which is planned as one of the future missions to be conducted on Japanese Space Flyer Unit (SFU) in 1990s. Rendezvous and retrieval operation will be automatically performed by on-board instruments. The laser radar system performs ranging, tracking, as well as attitude determination in short range. Author

A88-15852#
MAN IN SPACE
V. A. SOLOV'EV (Mission Control Centre, Moscow, USSR) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 4 p.
(IAF PAPER 87-77)

Some of the EVA operations performed by the cosmonauts on Salyut 7 are described. The EVAs involved: (1) repairing the propulsion system; (2) installing additional solar cells; and (3) installing and testing a truss structure deployed on the station surface. The need for specific tools for these operations and the difficulty of the activities performed are discussed. I.F.

A88-15859*# National Research Council of Canada, Ottawa (Ontario).
ASSEMBLING, MAINTAINING AND SERVICING SPACE STATION
K. H. DOETSCH, H. WERSTIUK (National Research Council of Canada, Space Div., Ottawa), W. CREASY (NASA, Johnson Space Center, Houston, TX), and R. BROWNING (NASA, Goddard Space Flight Center, Greenbelt, MD) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 10 p.
(IAF PAPER 87-85)

The assembly, maintenance, and servicing of the Space Station and its facilities are discussed. The tools and facilities required for the assembly, maintenance, and servicing of the Station are described; the ground and transportation infrastructures needed for the Space Station are examined. The roles of automation and robotics in reducing the EVAs of the crew, minimizing disturbances to the Space Station environment, and enhancing user friendliness are investigated. Servicing/maintenance tasks are categorized based on: (1) urgency, (2) location of servicing/maintenance, (3) environmental control, (4) dexterity, (5) transportation, (6) crew interactions, (7) equipment interactions, and (8) Space Station servicing architecture. An example of a servicing mission by the Space Station for the Hubble Space Telescope is presented. I.F.

A88-16309
MODELLING AND SIMULATION OF DISTRIBUTED FLEXIBILITY IN A SPACEBORNE MANIPULATOR
J. P. CHRETIEN, M. DELPECH, and A. LOUHMADI (Toulouse, Centre d'Etudes et de Recherches, France) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 269-277. refs
(Contract CNES-82-0766; CNES-83-721)

The modal impedance, assumed-mode, and fictitious joint-introduction approaches to the characterization of distributed flexibility are evaluated for the case of an in-plane, two-degrees-of-freedom manipulator. General, multipurpose software for the geometric, kinematic, and dynamic analysis of rigid multibody mechanical systems is used. The introduction of fictitious joints is used to solve problems associated with simulation, kinematic inversion, and closed-loop analysis. O.C.

A88-16311
CONTROL TECHNIQUES FOR RENDEZ-VOUS AND DOCKING
B. CLAUDINON (Matra, S.A., Velizy-Villacoublay, France), PH. MARCHAL (CNES, Toulouse, France), and W. FEHSE (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 287-294. refs

An evaluation is made of novel control system alternatives for the on-board estimation of the homing, approach, and docking phases of spacecraft. The algorithms discussed represent control theory applications involving state observers and state controllers. The number of mission phases and reference frames that have to be considered makes on-board algorithm implementation extremely complex. The performance levels achievable are illustrated with simulations; a low-impact docking concept is envisioned on the basis of the present techniques for future in-orbit operations. O.C.

A88-16313
CONTROL ASPECTS OF A EUROPEAN SPACE MANIPULATOR SYSTEM
W. VAN LEEUWEN (Fokker, Schiphol, Netherlands) IN: Automatic control in space 1985. Oxford and New York, Pergamon Press, 1986, p. 303-309.

The aim of this study was to review existing design techniques for robots on the matter of their applicability for the design and development of a space manipulator system. Attention is paid to the definition and the design approach of the overall control system. Special emphasis is given to the control elements dealing with task-definition, path construction, and on-board control. Also, a number of on-board implementation aspects are considered. Furthermore, a comparison is made with the Remote Manipulator Control, as used on the Space Shuttle. Author

A88-17000* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE TELEROBOTICS TECHNOLOGY DEMONSTRATION PROGRAM
S. Z. SZIRMAY, P. S. SCHENKER, G. RODRIGUEZ, and R. L. FRENCH (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Guidance and control 1987; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 31-Feb. 4, 1987. San Diego, CA, Univelt, Inc., 1987, p. 435-444. refs
(AAS PAPER 87-045)

The paper reports the ongoing development of a telerobot demonstrator. The demonstrator is implemented as a laboratory-based research testbed, and will show proof-of-concept for supervised automation of space assembly, servicing, and repair operations. The demonstrator system features a hierarchically layered intelligent control architecture which enables automated planning and run-time sequencing of complex tasks by a supervisory human operator. The demonstrator also provides a full bilateral force-reflecting hand control teleroperations capability. The operator may switch smoothly between the automated and teleroperated tasking modes in run-time, either on a preplanned or operator-designated basis. Author

A88-19866
ROBOTS - AUTONOMOUS SPACE WORKERS
D. R. SLOGGETT Space (ISSN 0267-954X), vol. 3, Nov.-Dec. 1987, p. 6-10.

Crew safety, increased capability, and productivity drive the potential applications for robots in space. Enhanced astronaut safety, due to the reduced need for EVA, coupled with the ability to deal safely with malfunctions that cause hazardous conditions in the vicinity of the failed equipment are the main goals of using robots in space. In order to operate in space, the robots must be hardened against high energy particles, small meteorites, and radiation. NASA-sponsored work has shown the need to support features such as gross and dexterous manipulation, handling flexible objects, execution of 'learned' sequences, and multiarm operations. The use of intelligent robots on the Space Station is discussed. K.K.

A88-20475
ASSEMBLING THE SPACE STATION
PHILIP CHIEN Space World (ISSN 0038-6332), vol. X-12-288, Dec. 1987, p. 16-20.

The sequence of events by which the NASA Space Station will be assembled is reviewed. The purposes of the various planned Manned Base flights and Logistics flights are summarized. The structural, functional, and operational differences between the Space Station and Skylab are described. C.D.

A88-21095
EVA FOR A EUROPEAN SCENARIO
NIKOLAUS HERBER (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 9 p.
(SAE PAPER 871432)

A new project has been established in the European Space Scenario namely the build up of a European EVA capability, based on both the request for European autonomy and the realization that EVA is a part of manned spaceflight. As a major element of EVA Systems, a medium pressure hybrid suit is proposed allowing a prebreathing-free transition from the Hermes cabin (700 hPa) into the suit. Development risk factors seems to be medium - with the exception of some criitical items - so that a basic European EVA capability might be available for the first Hermes flight on 1996. Author

A88-21148
ON-ORBIT SERVICING ENHANCEMENTS WITH CREWLOCK EVA OPERATIONS FROM THE SPACEHAB MODULE
WILLIAM E. HAYNES (Science Applications International Corp., La Jolla, CA), THOMAS C. TAYLOR, and ROBERT CITRON (SPACEHAB, Inc., Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 12 p.
(SAE PAPER 871496)

The design and the operation principles of the Crewlock device (to be used in conjunction with the Spacehab module) for EVA operations are discussed. In Crewlock, the task of transiting from a volume at one pressure to another volume at a different pressure is approached in a manner different from that of airlocks. A Crewlock transit chamber is close form-fit to the transiting body; thus, the loss of and possible contaminants from pressurant gases become negligible; the need for pumps is eliminated; the mass, volume, and complexity of the lock is reduced; and the time required for transit is shorter. The Spacehab module will accomodate the Crewlock and provide storage space for the added suit components and expendables. By using Crewlock in a Spacehab module, the permissible working EVA's on a single Shuttle flight will be limited only by the Shuttle stay time and the crew endurance; if alternate crewmembers are available, the Space Station assembly manhours can be increased to over 100 hrs for a ten day orbit stay. I.S.

A88-21150* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
NEW TOOLS FOR EVA OPERATIONS
C. E. WHITSETT (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 12 p.
(SAE PAPER 871499)

Effective extravehicular-activity (EVA) operations depend upon having the proper tools from simple wrenches to smart powered socket drives to powered adjustable foot restraints. The Space Shuttle carries a standard toolkit in the cargo bay for emergencies. Many special tools have been developed for the recent satellite repair missions; i.e., Solar Max, Westar/Palapa, and Leasat. Many more are being developed to maintain the Hubble Space Telescope on orbit for 15 years. The EVA tools developed and used in space to date are summarized and some of the new tools now in development are described herein. Finally, the requirements are given for several additional tools which may be needed in the future. Author

A88-21163
EVOLUTIVE CONCEPT OF AN EVA SPACE SUIT
LOUIS LEMAIGNEN and MARC WEIBEL (Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France) SAE, Intersociety Conference on Environmental Systems, 17th, Seattle, WA, July 13-15, 1987. 12 p.
(SAE PAPER 871518)

After a short review of the European needs for EVAs (space Extra Vehicular Activities), the paper analyzes the different requirements and constraints of a space station and of a space plane for the EVA aspects. The leading factors which affect the space suit design are presented and analyzed at the light of the evolution of American and Soviet space suits. Among these factors, are: conflict of vehicle and suit pressure choices, protection against radiation, cost of EVA in terms of weight, volume and energy, interfaces with the carrier vehicle, maintainability and vulnerability. From this analysis, two types of suits seem to emerge as optimal solutions. An evolutive approach is proposed in which a common hard upper torso fulfils the requirements of both the space station and the space plane. Modular items are used in accordance with the vehicle to service. The geometrical concept is presented with CAE analysis of the donning procedure. The technology of the major suit components is shortly discussed. Author

A88-21637
AUTOMATIC PLANNING RESEARCH APPLIED TO ORBITAL CONSTRUCTION
WILLIAM T. PARK (SRI International Applied Artificial Intelligence Laboratory, Menlo Park, CA) IN: Space Station automation II; Proceedings of the Meeting, Cambridge, MA, Oct. 28-30, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation

Engineers, 1987, p. 59-66. refs
(Contract N00014-83-C-0649; N00014-85-C-0294; NSF ECS-82-00615)

Parplan, a recently developed experimental automatic planning program for the Space Station, is described. The implementation, internal representations and operation, goals and actions, plan refinement, constraints on the order of events, action descriptions, subgoals, planning process, and design objectives pertaining to Parplan are addressed. A review is also given of issues in automatic planning for Space Station construction. C.D.

A88-21648* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A TECHNIQUE TO AID IN THE DESIGN OF OPTIMAL ROBOTS FOR USE IN SPACE APPLICATIONS
GERALD ROSTON (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation II; Proceedings of the Meeting, Cambridge, MA, Oct. 28-30, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 161-164. refs

A method is presented which gives robot designers a starting point for designing 'optimal' robots for space applications. Test results on a robot kinematically similar to a Puma 560 are summarized, indicating the inadequacies of current kinematic design. The work that still needs to be done to achieve a full, working system is described. C.D.

A88-21649* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SYSTEM ARCHITECTURE FOR TELEROBOTIC SERVICING AND ASSEMBLY TASKS
F. WALLACE HARRISON, JR. and JACK E. PENNINGTON (NASA, Langley Research Center, Hampton, VA) IN: Space Station automation II; Proceedings of the Meeting, Cambridge, MA, Oct. 28-30, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 165-171. refs

The architecture of an integrated telerobotics laboratory which is being used for research on the mechanisms, controls, sensing, and operator interface required to accomplish space telerobotic tasks is described. The laboratory hardware is considered, including manipulator and controller, end effector, and vision. The virtual architecture, a common reference model for most of the laboratory applications, is discussed. Teleoperator and robotics system simulations which have been performed using the system are discussed. C.D.

A88-21650* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
COMPUTING ARCHITECTURE FOR TELEROBOTS IN EARTH ORBIT
A. K. BEJCZY, R. S. DOTSON, and Z. SZAKALY (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation II; Proceedings of the Meeting, Cambridge, MA, Oct. 28-30, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 172-177.

Based on generic operational and computational requirements associated with the control of telerobots in earth orbit, a multibus-based distributed but integrated computing architecture is proposed. An experimental system of that kind under development at the Jet Propulsion Laboratory (JPL) is briefly described. It uses Intel Multibus I at both control station and remote robot (telerobot) computing nodes. An essential element within each multibus is a Unified (or Universal) Computer Control Subsystem (UCCS) for telerobot and control station motor components. The two multibus-based computing nodes can be linked by parallel or high speed serial links for real-time data transmission and for closing the real-time bilateral (force-reflecting) control loop between telerobot and control station. The experimental system is briefly commented, followed by a brief discussion of future development plans and possibilities. Author

A88-21651* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE NASA TELEROBOT TECHNOLOGY DEMONSTRATOR
P. S. SCHENKER, R. L. FRENCH, A. R. SIROTA, and J. R. MATIJEVIC (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation II; Proceedings of the Meeting, Cambridge, MA, Oct. 28-30, 1986. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 178-188. refs

The ongoing development of a telerobot technology demonstrator is reported. The demonstrator is implemented as a laboratory-based research testbed, and will show proof-of-concept for supervised automation of space assembly, servicing, and repair operations. The demonstrator system features a hierarchically layered intelligent control architecture which enables automated planning and run-time sequencing of complex tasks by a supervisory human operator. The demonstrator also provides a full bilateral force-reflecting hand control teleoperations capability. The operator may switch smoothly between the automated and teleoperated tasking modes in run-time, either on a preplanned or operator-designated basis. Author

A88-22332*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
TELESCIENCE TESTBEDDING FOR LIFE SCIENCE MISSIONS ON THE SPACE STATION
D. RASMUSSEN (NASA, Ames Research Center, Moffett Field, CA), A. MIAN (RCA, New York), and J. BOSLEY (NASA, Ames Research Center; Bionetics Corp., Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 26th, Reno, NV, Jan. 11-14, 1988. 6 p. refs
(AIAA PAPER 88-0446)

'Telescience', defined as the ability of distributed system users to perform remote operations associated with NASA Space Station life science operations, has been explored by a developmental testbed project allowing rapid prototyping to evaluate the functional requirements of telescience implementation in three areas: (1) research planning and design, (2) remote operation of facilities, and (3) remote access to data bases for analysis. Attention is given to the role of expert systems in telescience, its use in realistic simulation of Space Shuttle payload remote monitoring, and remote interaction with life science data bases. O.C.

A88-22957
OFF TO SEE THE WIZARD
GARY GRAF Space World (ISSN 0038-6332), vol. X-4-280, April 1987, p. 26-29.

A redesigned spacesuit is considered to be a necessary complement to the Space Station. The new suit is to operate at the Station's constant pressure of one earth atmosphere, and should be maintainable in orbit. Experiments conducted at NASA-Ames have led to the belief that the suit should be made entirely out of metal or other rigid material with joints of reinforced fabric or metal to give the astronaut the mobility needed for space work. K.K.

A88-24101
NASA TO EVALUATE TWO SUIT DESIGNS FOR SPACE STATION
CAROLE A. SHIFRIN Aviation Week and Space Technology (ISSN 0005-2175), vol. 129, Jan. 11, 1988, p. 36-39.

Two different space suit configurations are undergoing testing to evaluate usefulness in EVAs associated with the NASA Space Station, which will be of longer duration than heretofore. NASA's Johnson Space Center developed the Zero Prebreathe Suit (ZPS) Mk.3, while NASA Ames developed the AX-5. Both designs use a rear torso hatch for ingress and egress; while the ZPS uses a combination of hard and soft elements, however, the AX-5 is composed entirely of solid, articulated segments. During testing, crew members will engage in assembly and construction tasks simulating the building of the Space Station structures. O.C.

A88-24239* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
INTELLIGENT SYSTEMS AND ROBOTICS FOR AN EVOLUTIONARY SPACE STATION
JON D. ERICKSON (NASA, Johnson Space Center, Houston, TX) British Interplanetary Society, Journal (Mission Automation Systems) (ISSN 0007-084X), vol. 40, Oct. 1987, p. 471-481. refs

The Space Station will be a multipurpose space facility to acquire and exploit unique knowledge with a planned lifetime of greater than 20 years. It will include laboratories for science and manufacturing, provide a platform for earth and interplanetary observations, conduct satellite servicing, and serve as a transportation node for potential manned geosynchronous, lunar, and Mars missions. Environmental safety considerations and limited manpower resources require the extensive use of intelligent systems and flexible robotics on the Space Station. Design accommodations must be planned in advance to allow incorporation of these advancing technologies on the evolutionary Space Station. Author

A88-26420
SPACE STATION ASSEMBLY - TECHNIQUES AND STRUCTURES
E. J. PELKA (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Lockheed Horizons (ISSN 0459-6773), Dec. 1987, p. 32-49.

Two Lockheed independent research and development projects are discussed. The first, Space Station Assembly Technology, addresses on-orbit structural assembly from the viewpoint of the EVA astronaut and emphasizes human factors engineering, operations, and EVA optimization. The second, Aluminum-Clad Graphite/Epoxy Struts, stresses areas of materials, structures, and manufacturing in the production of full-scale prototype truss elements that can be fine-tuned to a zero coefficient of thermal expansion after the metal/composite strut has been produced. It is shown that as the Space Station physical characteristics will continue to change, the Station's subsystems, ground support systems, and operations methods must similarly evolve to accommodate technological advances. A.S.

A88-26975#
DEVELOPMENT OF A MASTER SLAVE MANIPULATOR SYSTEM FOR SPACE USE
YOSHITSUGU TODA, KAZUO MACHIDA, TOSHIAKI IWATA, and MASAKUNI KAWADA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 406, 1987, p. 546-553. In Japanese, with abstract in English. refs

A generalized master slave manipulator system which was assumed to operate near/or around the Space Station was developed. A standardized serial communication line was used between the master and the slave manipulator. The master manipulator was designed to be self-balanced to simulate operation under the zero-gravity condition. A force/torque reflecting bilateral control using the force-torque sensor settled at the wrist of the slave manipulator was adopted. An experiment in which the slave manipulator was in a vacuum chamber was performed, within restricted sight of cameras set up in the chamber. The problems which would result from adopting a generalized master slave manipulator system were almost solved, except for the delay caused by the calculation time. Author

A88-27542#
PROSPECTS ON FUTURE EVA COMMUNICATIONS
GERARD MARAL (Ecole Nationale Superieure des Telecommunications, Toulouse, France) IN: AIAA International Communication Satellite Systems Conference, 12th, Arlington, VA, Mar. 13-17, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 148-156.
(AIAA PAPER 88-0767)

This paper discusses a number of design approaches for an EVA communications system. The links to be established for an EVA communications subsystem facility and the conditions for EVA communications are identified. Issues for EVA communications are discussed, including compliance with radio regulations, considerations related to spherical coverage, and EVA communication network architecture. C.D.

A88-31274
AN INITIAL STUDY OF REMOTELY MANIPULATED STUD WELDING FOR SPACE APPLICATIONS
K. MASUBUCHI, A. IMAKITA, and M. MIYAKE (MIT, Cambridge, MA) Welding Journal (ISSN 0043-2296), vol. 67, April 1988, p. 25-34. refs

Technical information generated during a research program for advancing the technology of welding in space is presented. The technical background to this research is reviewed, the stud welding process is outlined, and the experimental apparatus is described. The reported results show that stud welding in vacuum is possible for an AL6061 plate with AL5000 studs, an AL2219 plate with AL2319 studs, and an SUS304 plate with SUS305 studs. The alloy AL2219 shows promising experimental results for space application. C.D.

A88-31379#
SHUTTLE BASED ASSEMBLY OF SPACE STATION
KAREN R. ARCHARD (Rockwell International Corp., Space Transportation Systems Div., Downey, CA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 14-22.
(AIAA PAPER 88-2452)

Relying primarily on underwater neutral buoyancy simulations at Johnson Space Center's Weightless Environment Training Facility, Shuttle-based assembly tasks involving the assembly fixture, truss structure joint design, and utility tray concepts were evaluated. The results indicate that construction of the Integrated Truss Assembly by EVA is practical via any of the methods examined. Truss joint configuration and the installation sequence were found to be critical to assembly. A positive lock-lock feature for joints and a marking scheme to aid in installation was developed. Utility installation findings favored deployable trays with quick attach mechanisms. C.D.

A88-31381#
EVA CONSTRUCTION AND REPAIR OF TUBULAR SYSTEMS ON SPACE STATION
RAY H. ANDERSON and SHIRLEY J. PEARSON (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 32-38. refs
(AIAA PAPER 88-2456)

The components of a study program on the EVA construction and repair of tubular systems on the Space Station are described. The program involves: (1) determining the feasibility of using metallurgical processes for tube joining; (2) determining the feasibility of installing and repairing currently available aerospace tube fittings in environments typical of those for the Space Shuttle; (3) evaluating the ability of EVA-suited subjects to assemble or disassemble candidate quick-disconnect couplings; and (4) leak testing of both installed and repaired tube fittings and assembled quick-disconnect couplings at pressures and thermal cycles expected for the Space Station. C.D.

A88-31382*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ASTRONAUT/EVA CONSTRUCTION OF SPACE STATION
WALTER L. HEARD, JR., HAROLD G. BUSH, JUDITH J. WATSON (NASA, Langley Research Center, Hampton, VA), SHERWOOD C. SPRING, and JERRY L. ROSS (NASA, Johnson Space Center, Houston, TX) IN: AIAA SDM Issues of the International Space Station, Conference, Williamsburg, VA, Apr. 21, 22, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 39-46. refs
(AIAA PAPER 88-2459)

Four early space construction tests performed in neutral

buoyancy and/or on-orbit to evaluate EVA for assembly of truss structures are reviewed and astronaut observations are presented. In addition, two ongoing ground test programs that address EVA assembly of full scale Space Station truss structure using a mobile transporter equipped with astronaut positioning arms are described. A truss joint design that enables EVA assembly while meeting structural design goals is also discussed. Author

N88-10089*# Air Force Space Div., Los Angeles, Calif.
SPACE ASSEMBLY, MAINTENANCE, AND SERVICING STUDY (SAMSS)
JOSEPH WONG *In* NASA-Lewis Research Center, Spacecraft 2000 p 59-69 Jul. 1986
Avail: NTIS HC A11/MF A01 CSCL 22B

The goal is to define and establish Space Assembly, Maintenance, and Servicing (SAMS) capabilities to meet requirements for improved space systems. Consolidated requirements, hardware/tool concepts, systems analysis, related studies interaction, and schedule/milestones are outlined. This presentation is represented by charts and figures only. B.G.

N88-10090*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
TELEROBOTICS
DONNA L. PIVIROTTO *In* NASA-Lewis Research Center, Spacecraft 2000 p 71-75 Jul. 1986
Avail: NTIS HC A11/MF A01 CSCL 13I

This presentation summarizes NASA's future plans and current technology programs for telerobotics and is represented by charts. Author

N88-10341# MATRA Espace, Paris-Velizy (France). Space Branch.
ROBOTIC SENSORS AND ACTUATORS FOR A SERVICE MANIPULATOR SYSTEM. VOLUME 1: EXECUTIVE SUMMARY Final Report
TH. BLAIS, J. L. LACOMBE, G. BERGER, G. CLEMENT, U. HILZENBECHER, and J. DELTORO (Sener, S.A., Madrid, Spain) Paris, France ESA Jun. 1986 62 p Original contains color illustrations
(Contract ESA-5739/83-NL-AN(SC))
(MATRA-EPT/DT/VT187/120; ESA-CR(P)-2403-VOL-1; ETN-87-90536) Avail: NTIS HC A04/MF A01

The state of the art of robotics, telemanipulation, and servicing was reviewed in order to develop a service manipulator system (SMS) for in-orbit servicing. An SMS concept is described. Development activities and test requirements in vision systems, control techniques, end effector grapple mechanisms, force/torque sensors, and hinge joints are outlined. A development plan is presented. ESA

N88-10342# MATRA Espace, Paris-Velizy (France). Space Branch.
ROBOTIC SENSORS AND ACTUATORS FOR A SERVICE MANIPULATOR SYSTEM. VOLUME 2: SERVICE MANIPULATOR SYSTEM (SMS) HANDBOOK Final Report
TH. BLAIS, J. L. LACOMBE, G. BERGER, G. CLEMENT, U. HILZENBECHER, and J. DELTORO (Sener, S.A., Madrid, Spain) Paris, France ESA Jun. 1986 113 p
(Contract ESA-5739/83-NL-AN(SC))
(MATRA-EPT/DT/VT187/227; ESA-CR(P)-2403-VOL-2; ETN-87-90537) Avail: NTIS HC A06/MF A01

A service manipulator system (SMS) for in-orbit servicing is described. The mechanical characteristics, electrical architecture, sensors, control system, software, thermal control, mass/power/communication budgets, and SMS mass distribution, reference frames, and flight segment are presented. The SMS specifications, quality assurance provisions, and preparation for delivery are outlined. ESA

N88-10343# MATRA Espace, Paris-Velizy (France). Space Branch.
ROBOTIC SENSORS AND ACTUATORS FOR A SERVICE MANIPULATOR SYSTEM. VOLUME 3, PHASE A REPORT AND PROGRAM PLAN Final Report
TH. BLAIS, J. L. LACOMBE, G. BERGER, G. CLEMENT, U. HILZENBECHER, and J. DELTORO (Sener, S.A., Madrid, Spain) Paris, France ESA Jun. 1986 233 p
(Contract ESA-5739/83-NL-AN(SC))
(MATRA-EPT/DT/VT187/228; ESA-CR(P)-2403-VOL-3; ETN-87-90538) Avail: NTIS HC A11/MF A01

The state of the art of robotics, telemanipulation, and servicing was reviewed in order to develop a service manipulator system (SMS) for in-orbit servicing. An SMS concept is described. Development activities and test requirements in vision systems, control techniques, end effector grapple mechanisms, force/torque sensors, and hinge joints are outlined. A development plan is presented. ESA

N88-10346# Oak Ridge National Lab., Tenn.
TRACTION-DRIVE SEVEN DEGREES-OF-FREEDOM TELEROBOT ARM: A CONCEPT FOR MANIPULATION IN SPACE
D. P. KUBAN and D. M. WILLIAMS 1987 21 p Presented at the 21st Aerospace Mechanisms Symposium, Houston, Tex., 29 Apr. 1987
(Contract DE-AC05-84OR-21400)
(DE87-010895; CONF-8704161-1) Avail: NTIS HC A03/MF A01

As man seeks to expand his dominion into new environments, the demand increases for machines that perform useful functions in remote locations. This new concept for manipulation in space is based on knowledge and experience gained from manipulator systems developed to meet the needs of remote nuclear applications. It merges the best characteristics of teleoperation and robotic technologies. This paper summarizes the report of a study performed for NASA Langley Research Center. The design goals for the telerobot, a mechanical description, and technology areas that must be addressed for successful implementation will be presented and discussed. The concept incorporates mechanical traction drives, redundant kinematics, and modular arm subelements to provide a backlash-free manipulator capable of obstacle avoidance. Further development of this arm is in progress at the Oak Ridge National Laboratory. DOE

N88-10870*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SPACE CONSTRUCTION
JANE A. HAGAMAN, ed. Oct. 1987 308 p Conference held in Hampton, Va., 6-7 Aug. 1986
(NASA-CP-2490; L-16378; NAS 1.55:2490) Avail: NTIS HC A14/MF A01 CSCL 22B

The purpose was to present to the aerospace community an in-depth review of Experimental Assembly of Structures on EVA (EASE)/Assembly Concept for Construction of Erectable Space Structures (ACCESS) space flight experiments and to present the status of activities regarding future space flight experiments and accompanying technology developments that will demonstrate the capability of on-orbit construction required for the Space Station.

N88-10872*# Massachusetts Inst. of Tech., Cambridge. Space Systems Lab.
EXPERIMENTAL ASSEMBLY OF STRUCTURES IN EVA: HARDWARE MORPHOLOGY AND DEVELOPMENT ISSUES
ROBERT S. WOLF and MARY L. BOWDEN *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 13-30 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

A large body of data was obtained by MIT during neutral boyancy testing at Marshall Space Flight Center from 1980 to the present. These efforts, and the most significant results are summarized. The Experimental Assembly of Structure in EVA (EASE) flight experiment was undertaken to validate these results and flown on

the STS 61-B in November 1985. The EASE experiment hardware is discussed and how the experiment goals dictate its size, shape, and operational characteristics, are illustrated. B.G.

N88-10879*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
A SYNOPSIS OF THE EVA TRAINING CONDUCTED ON EASE/ACCESS FOR STS-61-B
KATHRYN A. HAVENS *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 153-182 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 05I

Experimental Assembly of Structure in EVA (EASE)/Assembly Concept for Construction of Erectable Space Structures (ACCESS) training problems; photography/television coverage; training schedules; flight data file (FDF), and flight rules production are summarized. B.G.

N88-10881*# Massachusetts Inst. of Tech., Cambridge. Space Systems Lab.
EASE (EXPERIMENTAL ASSEMBLY OF STRUCTURES IN EVA) OVERVIEW OF SELECTED RESULTS
DAVID L. AKIN *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 199-227 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

Experimental Assembly of Structures in EVA (EASE) objectives, experimental protocol, neutral buoyancy simulation, task time distribution, assembly task performance, metabolic rate/biomedical readouts are summarized. This presentation is shown in charts, figures, and graphs. B.G.

N88-10882*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
OVERVIEW OF CREW MEMBER ENERGY EXPENDITURE DURING SHUTTLE FLIGHT 61-B EASE/ACCESS TASK PERFORMANCE
D. J. HORRIGAN, J. W. WALIGORA, J. STANFORD, and B. F. EDWARDS (Technology, Inc., Houston, Tex.) *In* NASA. Langley Research Center, Hampton, Va. Space Construction p 228-235 Oct. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The energy expenditure of the Shuttle Flight 61-B crewmembers during the extravehicular performance of Experimental Assembly of Structures in EVA (EASE) and Assembly Concept of Construction of Space Structures (ACCESS) construction system tasks are reported. These data consist of metabolic rate time profiles correlated with specific EASE and ACCESS tasks and crew comments. Average extravehicular activity metabolic rates are computed and compared with those reported from previous Apollo, Shylab, and Shuttle flights. These data reflect total energy expenditure and not that of individual muscle groups such as hand and forearm. When correlated with specific EVA tasks and subtasks, the metabolic profile data is expected to be useful in planning future EVA protocols. For example, after experiencing high work rates and apparent overheating during some Gemini EVAs, it was found useful to carefully monitor work rates in subsequent flights to assess the adequacy of cooling garments and as an aid to preplanning EVA procedures. This presentation is represented by graphs and charts. Author

N88-12105*# Alabama Univ., Huntsville.
TELEOPERATOR AND ROBOTICS SYSTEM ANALYSIS Final Report
WILLIAM TEOH 30 Sep. 1987 243 p
(Contract NAS8-35670)
(NASA-CR-179220; NAS 1.26:179220) Avail: NTIS HC A11/MF A01 CSCL 13I

The Orbital Maneuvering Vehicle (OMV) was designed to operate as a remotely controlled space teleoperator. The design and implementation of OMM (a mathematical model of the OMV) are discussed. The State Vector Transformation Module (SVX), an interface between the OMV simulation model and the mobile base (TOM-B) of the flat floor simulation system is described. A summary of testing procedures and conclusions are presented together with the test data obtained. B.G.

N88-12927*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
SPACE SUIT EXTRAVEHICULAR HAZARDS PROTECTION DEVELOPMENT
JOSEPH J. KOSMO Aug. 1987 29 p
(NASA-TM-100458; S-565; NAS 1.15:100458) Avail: NTIS HC A03/MF A01 CSCL 06K

Presented is an overview of the development of the integral thermal/micrometeoroid garment (ITMG) used for protection of a space-suited crewmember from hazards of various extravehicular environments. These hazard conditions can range from thermal extremes, meteoroid and debris particles, and radiation conditions in near-earth orbits and free space to sand and dust environments encountered on lunar and planetary surfaces. Representative ITMG materials cross-section layups are identified and described for various space suit configurations ranging from the Gemini program to planned protective requirements and considerations for anticipated Space Station EV operations. Author

N88-13908*# Catholic Univ. of America, Washington, D.C. Dept. of Electrical Engineering.
CARTESIAN PATH CONTROL OF A TWO-DEGREE-OF-FREEDOM ROBOT MANIPULATOR Semiannual Report
CHARLES C. NGUYEN and FARHAD J. POORAN Jan. 1988 24 p
(Contract NAG5-780)
(NASA-CR-182331; NAS 1.26:182331) Avail: NTIS HC A03/MF A01 CSCL 09B

The problem of cartesian trajectory control of a closed-kinematic chain mechanism robot manipulator with possible space station applications is considered. The study was performed by both computer simulation and experimentation for tracking of three different paths: a straight line, a sinusoid and a circle. Linearization and pole placement methods are employed to design controller gains. Results show that the controllers are robust and there are good agreements between simulation and experimentation. Excellent tracking quality and small overshoots are also evident. Author

N88-14876*# Texas A&I Univ., Kingsville. Dept. of Civil and Mechanical Engineering.
DYNAMICS, CONTROL AND SENSOR ISSUES PERTINENT TO ROBOTIC HANDS FOR THE EVA RETRIEVER SYSTEM Final Report
ROBERT A. MCLAUCHLAN *In* NASA. Lyndon B. Johnson Space Center, Houston, Tex. NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program, 1987. Volume 2 20 p Nov. 1987
Avail: NTIS HC A15/MF A01 CSCL 13I

Basic dynamics, sensor, control, and related artificial intelligence issues pertinent to smart robotic hands for the Extra Vehicular Activity (EVA) Retriever system are summarized and discussed. These smart hands are to be used as end effectors on arms attached to manned maneuvering units (MMU). The Retriever robotic systems comprised of MMU, arm and smart hands, are being developed to aid crewmen in the performance of routine EVA tasks including tool and object retrieval. The ultimate goal is to enhance the effectiveness of EVA crewmen. Author

N88-14883*# Southern Univ., Baton Rouge, La. Coll. of Engineering.
AUTOMATIC ANTENNA SWITCHING DESIGN FOR EXTRA VEHICULAR ACTIVITY (EVA) COMMUNICATION SYSTEM Final Report
MANJIT S. RANDHAWA *In* NASA. Lyndon B. Johnson Space Center, Houston, Tex. NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program, 1987. Volume 2 20 p Nov. 1987
Avail: NTIS HC A15/MF A01 CSCL 17B

An Extra Vehicular Activity (EVA) crewmember had two-way communications with the space station in the Ku-band frequency (12 to 18 GHz). The maximum range of the EVA communications link with the space station is approximately one kilometer for nominal values for transmitter power, antenna gains, and receiver noise figure. The EVA Communications System, that will continue to function regardless of the astronaut's position and orientation, requires an antenna system that has full spherical coverage. Three or more antennas that can be flush mounted on the astronaut's space suit (EMU) and/or his propulsive backpack (MMU), will be needed to provide the desired coverage. As the astronaut moves in the space station, the signal received by a given EVA antenna changes. An automatic antenna switching system is needed that will switch the communication system to the antenna with the largest signal strength. A design for automatic antenna switching is presented and discussed. Author

N88-15196*# Alabama Univ., Huntsville.
PERSONNEL OCCUPIED WOVEN ENVELOPE ROBOT POWER Semiannual Report
30 Nov. 1987 115 p Prepared in cooperation with Pace and Waite, Inc., Huntsville, Ala. and Wyle Labs., Inc., Huntsville, Ala. (Contract NAGW-847)
(NASA-CR-182367; NAS 1.26:182367) Avail: NTIS HC A06/MF A01 CSCL 14B

The Human Occupied Space Teleoperator (HOST) system currently under development utilizes a flexible tunnel/Stewart table structure to provide crew access to a pressurized manned work station or POD on the space station without extravehicular activity (EVA). The HOST structure facilitates moving a work station to multiple space station locations. The system has applications to orbiter docking, space station assembly, satellite servicing, space station maintenance, and logistics support. The conceptual systems design behind HOST is described in detail. J.P.B.

N88-15825# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
DOCKING/BERTHING SUBSYSTEM (DBS). DEVELOPMENT PART 1: LATCHING ANALYSIS Final Report
Paris, France ESA 27 Jul. 1987 127 p Revised Prepared in cooperation with Societe Anonyme Belge de Constructions Aeronautiques, Brussels, Belgium, and Sener S.A., Madrid, Spain (Contract ESTEC-6409/85-NL-AN(SC))
(ESA-CR(P)-2479; ETN-88-91425) Avail: NTIS HC A07/MF A01

Based on a low impact docking concept and a latching mechanism concept, a docking/berthing subsystem and its operations were defined. A set of four breadboard models of the latch were manufactured and docking tests were performed on a four degree of freedom air bearing table. The tests demonstrate feasibility of the low impact docking concept under the test facility conditions. ESA

N88-16370*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
TELEROBOTIC CONTROLLER DEVELOPMENT
W. S. OTAGURO, L. O. KESLER (McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.), KEN LAND, and DON RHOADES *In* NASA. Marshall Space Flight Center, Third Conference on Artificial Intelligence for Space Applications, Part 1 p 65-71 Nov. 1987
Avail: NTIS HC A18/MF A01 CSCL 09B

To meet NASA's space station's needs and growth, a modular and generic approach to robotic control which provides near-term implementation with low development cost and capability for growth into more autonomous systems was developed. The method uses a vision based robotic controller and compliant hand integrated with the Remote Manipulator System arm on the Orbiter. A description of the hardware and its system integration is presented. Author

N88-16388*# Alabama Univ., Huntsville. Center for Applied Optics.
GOAL DRIVEN KINEMATIC SIMULATION OF FLEXIBLE ARM ROBOT FOR SPACE STATION MISSIONS Abstract Only
P. JANSSEN and A. CHOUDRY *In* NASA. Marshall Space Flight Center, Third Conference on Artificial Intelligence for Space Applications, Part 1 p 151 Nov. 1987
Avail: NTIS HC A18/MF A01 CSCL 09B

Flexible arms offer a great degree of flexibility in maneuvering in the space environment. The problem of transporting an astronaut for extra-vehicular activity using a space station based flexible arm robot was studied. Inverse kinematic solutions of the multilink structure were developed. The technique is goal driven and can support decision making for configuration selection as required for stability and obstacle avoidance. Details of this technique and results are given. Author

N88-16409*# Alabama Univ., Huntsville. Center for Applied Optics.
SOLID MODELLING FOR THE MANIPULATIVE ROBOT ARM (POWER) AND ADAPTIVE VISION CONTROL FOR SPACE STATION MISSIONS Abstract Only
V. HARRAND and A. CHOUDRY *In* NASA. Marshall Space Flight Center, Third Conference on Artificial Intelligence for Space Applications, Part 1 p 271 Nov. 1987
(Contract NAGW-847)
Avail: NTIS HC A18/MF A01 CSCL 09B

The structure of a flexible arm derived from concatenation of the Stewart-Table-based links were studied. Solid modeling provides not only a realistic simulation, but is also essential for studying vision algorithms. These algorithms could be used for the adaptive control of the arm, using the well-known algorithms such as shape from shading, edge detection, orientation, etc. Details of solid modeling and its relation to vision based adaptive control are discussed. Author

N88-16416*# McDonnell-Douglas Corp., St. Louis, Mo. Artificial Intelligence Group.
PLANNING AND SCHEDULING FOR ROBOTIC ASSEMBLY
BARRY R. FOX *In* NASA. Marshall Space Flight Center, Third Conference on Artificial Intelligence for Space Applications, Part 1 p 309-313 Nov. 1987
Avail: NTIS HC A18/MF A01 CSCL 09B

A system for reasoning about robotic assembly tasks is described. The first element of this system is a facility for itemizing the constraints which determine the admissible orderings over the activities to be sequenced. The second element is a facility which partitions the activities into independent subtasks and produces a set of admissible strategies for each. Finally, the system has facilities for constructing an admissible sequence of activities which is consistent with the given constraints. This can be done off-line, in advance of task execution, or it can be done incrementally, at execution time, according to conditions in the execution environment. The language of temporal constraints and the methods of inference presented in related papers are presented. It is shown how functional and spatial relationships between components impose temporal constraints on the order of assembly and how temporal constraints then imply admissible strategies and feasible sequences. Author

N88-16769# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Communications Satellite Dept.
SATELLITE ASSEMBLY IN GEOSTATIONARY ORBIT: A PLUG-AND-SOCKET CONCEPT
A. W. PREUKSCHAT *In its* ESA Bulletin No. 25 p 10-15 Feb. 1981
Avail: NTIS HC A05/MF A01

A space-segment construction concept, satellite assembly in geostationary orbit, is described. It can remove mass constraints and appears to have the potential to reduce procurement costs for future communications space segments. A possible configuration has a power-augmented service module (EM) satellite

system (the socket) and four payload module (PM) satellites attached (the plugs). The assembly sequence could be launch of the basic SM satellite; launch and docking of three (small) PM satellites, launch and docking of the PFM satellite to augment the system's power capabilities prior to launch and docking of a large, high-power Payload-Module satellite; subsequent launch and attachment of a fourth (small) PM satellite. Author (ESA)

N88-17269*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TELEROBOTIC RESEARCH AT NASA LANGLEY RESEARCH CENTER
NANCY E. SLIWA *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 465-469 Oct. 1987
Avail: NTIS HC A23/MF A01 CSCL 13I

An overview of Automation Technology Branch facilities and research is presented. Manipulator research includes dual-arm coordination studies, space manipulator dynamics, end-effector controller development, automatic space structure assembly, and the development of a dual-arm master-slave telerobotic manipulator system. Sensor research includes gravity-compensated force control, real-time monovision techniques, and laser ranging. Artificial intelligence techniques are being explored for supervisory task control, collision avoidance, and connectionist system architectures. A high-fidelity dynamic simulation of robotic systems, ROBSIM, is being supported and extended. Cooperative efforts with Oak Ridge National Laboratory have verified the ability of teleoperators to perform complex structural assembly tasks, and have resulted in the definition of a new dual-arm master-slave telerobotic manipulator. A bibliography of research results and a list of technical contacts are included. Author

N88-17270*# Rockwell International Corp., Downey, Calif. Space Station Systems Div.
MANIPULATOR ARM DESIGN FOR THE EXTRAVEHICULAR TELEOPERATOR ASSIST ROBOT (ETAR): APPLICATIONS ON THE SPACE STATION
MARGARET M. CLARKE, CHARLES J. DIVONA, and WILLIAM M. THOMPSON (NSA Electro-Mechanidcal Systems Div., Breta, Calif.) *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 471-475 Oct. 1987
(Contract NAS8-36629)
Avail: NTIS HC A23/MF A01 CSCL 13I

The preliminary conceptual design of a new teleoperator robot manipulator system for space station maintenance missions has been completed. The system consists of a unique pair of arms that is part of a master-slave, force-reflecting servomanipulator. This design allows greater dexterity and greater volume coverage than that available in current designs and concepts. The teleoperator manipulator is specifically designed for space applications and is a valuable extension of the current state-of-the-art earthbound manipulators marketed today. The manipulator and its potential application on the space station are described. Author

N88-17272*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
TELEROBOTIC TRUSS ASSEMBLY
PHILIP L. SHERIDAN *In its* First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 487-491 Oct. 1987
Avail: NTIS HC A23/MF A01 CSCL 13I

The ACCESS truss was telerobotically assembled in order to gain experience with robotic assembly of hardware designed for astronaut extravehicular (EVA) assembly. Tight alignment constraints of the ACCESS hardware made telerobotic assembly difficult. A wider alignment envelope and a compliant end effector would have reduced the problem. The manipulator had no linear motion capability, but many of the assembly operations required straight line motion. The manipulator was attached to a motion table in order to provide the X, Y, and Z translations needed. A programmable robot with linear translation capability would have eliminated the need for the motion table and streamlined the assembly. Poor depth perception was a major problem. Shaded paint schemes and alignment lines were helpful in reducing this problem. The four cameras used worked well for only some operations. It was not possible to identify camera locations that worked well for all assembly steps. More cameras or movable cameras would have simplified some operations. The audio feedback system was useful. Author

N88-17274*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
TELEROBOT FOR SPACE STATION
LYLE M. JENKINS *In its* First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 497-499 Oct. 1987
Avail: NTIS HC A23/MF A01 CSCL 13I

The Flight Telerobotic Servicer (FTS), a multiple arm dexterous manipulation system, will aid in the assembly, maintenance, and servicing of the space station. Fundamental ideas and basic conceptual designs for a shuttle-based telerobot system have been produced. Recent space station studies provide additional concepts that should aid in the accomplishment of mission requirements. Currently, the FTS is in contractual source selection for a Phase B preliminary design. At the same time, design requirements are being developed through a series of robotic assessment tasks being performed at NASA and commercial installations. A number of the requirements for remote operation on the space station, necessary to supplement extravehicular activity (EVA), will be met by the FTS. Finally, technology developed for telerobotics will advance the state of the art of remote operating systems, enhance operator productivity, and prove instrumental in the evolution of an adaptive, intelligent autonomous robot. Author

N88-17279*# Mitre Corp., Houston, Tex.
TASK-LEVEL ROBOT PROGRAMMING: INTEGRAL PART OF EVOLUTION FROM TELEOPERATION TO AUTONOMY
JAMES C. REYNOLDS *In* NASA. Lyndon B. Johnson Space Center, Houston, Texas, First Annual Workshop on Space Operations Automation and Robotics (SOAR 87) p 533-540 Oct. 1987
Avail: NTIS HC A23/MF A01 CSCL 09B

An explanation is presented of task-level robot programming and of how it differs from the usual interpretation of task planning for robotics. Most importantly, it is argued that the physical and mathematical basis of task-level robot programming provides inherently greater reliability than efforts to apply better known concepts from artificial intelligence (AI) to autonomous robotics. Finally, an architecture is presented that allows the integration of task-level robot programming within an evolutionary, redundant, and multi-modal framework that spans teleoperation to autonomy. Author

N88-17999*# National Bureau of Standards, Gaithersburg, Md. Robot Systems Div.
NASA/NBS (NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/NATIONAL BUREAU OF STANDARDS) STANDARD REFERENCE MODEL FOR TELEROBOT CONTROL SYSTEM ARCHITECTURE (NASREM) Final Report
J. S. ALBUS, H. G. MCCAIN, and R. LUMIA Jul. 1987 94 p Sponsored by NASA
(PB88-124773; NBS/TN-1235; NAS 1.15:89726; NASA-TM-89726) Avail: NTIS HC A05/MF A01; also Avail: SOD $4.50 as SN003-003-02819-3 CSCL 13I

The NASA Standard Reference Model (NASREM) Architecture for the Space Station Telerobot Control System is described. It defines the functional requirements and high level specifications of the control system for the NASA Space Station document for the functional specification, and a guideline for the development of the control system architecture, of the IOC Flight Telerobot Servicer. The NASREM telerobot control system architecture defines a set of standard modules and interfaces which facilitates software design, development, validation, and test, and makes

possible the integration of telerobotics software from a wide variety of sources. Standard interfaces also provide the software hooks necessary to incrementally upgrade future Flight Telerobot Systems as new capabilities develop in computer science, robotics, and autonomous system control. GRA

N88-19483# Army Construction Engineering Research Lab., Champaign, Ill.
STATE-OF-THE-ART TECHNOLOGIES FOR CONSTRUCTION IN SPACE: A REVIEW Final Report
CHARLES C. LOZAR and L. D. STEPHENSON Sep. 1987
88 p
(Contract MIPR-W31RPD-7-D4099; DA PROJ. 4A1-62731-AT-41) (AD-A188412; CERL-TR-M-87/17) Avail: NTIS HC A05/MF A01 CSCL 22B

Future exploration and enterprise in low-Earth orbit will most likely require space stations for support. In addition, promotion of the Strategic Defense Initiative (SDI) is mandating research and development (R and D) into technologies for building structures to serve military objectives in space. However, an assessment of the state of the art for space construction technology has revealed that the field is immature, with little conceptual and experimental research completed. The U.S. Army Construction Engineering Research Laboratory (USA-CERL) has collected information on existing technologies for possible application in designing large space structures (LSS) for military support. This work is part of an effort by the U.S. Army Corps of Engineers (USACE) to ensure mission-responsiveness in anticipation of a role in space construction. USA-CERL is USACE's designated lead laboratory for this program. Military structures will require design criteria much different from those of experimental space stations. Proposed conceptual criteria for both types structures are compared and differences are noted. Much R and D is needed before any of these structures can be deployed in space. GRA

N88-19490# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
ASSEMBLY OF USER SYSTEMS AT SPACE STATION
HELMUT P. CLINE and THOMAS A. LAVIGNA *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 39-45 Nov. 1987
Avail: NTIS HC A21/MF A01

The technical and programmatic benefits of on-orbit assembly are outlined. Operational and automation considerations relating to on-orbit assembly are reviewed. Space Station capabilities for orbital assembly are discussed. ESA

N88-19491# Tecnospazio S.p.A., Milan (Italy).
IN-ORBIT AUTOMATIC ASSEMBLY OF RETICULAR STRUCTURES
P. G. MAGNANI and G. COLOMBINA *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 47-52 Nov. 1987
Avail: NTIS HC A21/MF A01

Automatic in-orbit assembly of reticular structures by a general-purpose robot assembler is proposed. The robot can crawl on the structure and act on its main elements (rods, corner blocks) by means of a suitable manipulative system. Evaluations show that a two arm system (nine degrees of freedom each arm) is adequate. The robot can operate under sequencer control or under human teleoperation. The level of sensoriality is high, including vision capability, laser range system, proximity sensor, and force/torque and strain/stress sensors. The considerations presented are for assembling a repetitive automatizable process as for an industrial application. Further analyses are necessary to take into account all the aspects related to space environment as well the future trend for large space structures. ESA

N88-19504# LABEN Space Instrumentation and Systems, Milan (Italy).
ROBOTIC INTELLIGENCE ISSUES FOR SPACE MANIPULATOR MONITORING, CONTROL PROGRAMMING
P. DONZELLI, R. CORTINOVIS, and S. MASSARI (Centro Studi ed Applicazioni in Tecnologie Avanzate, Bari, Italy) *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 165-173 Nov. 1987
Avail: NTIS HC A21/MF A01

Software requirements and artificial intelligence techniques for robotics for the Space Station Service Manipulator System (SMS) were studied. Intelligence requirements to be applied on the SMS, a framework of distributed knowledge based systems for SMS monitoring, programming, and control, and a plan of research for the practical experimentation of such architecture are presented. ESA

N88-19505# Technische Hochschule, Darmstadt (West Germany).
ON A KNOWLEDGE BASED ASSISTED SYSTEM FOR HIGHLY AUTONOMOUS CONTROL OF EXPERIMENT-MANIPULATORS IN THE MAN-TENDED FREE FLYER
G. KEGEL, A. ABDULWAHAB, and R. BRUDER *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 175-183 Nov. 1987 Sponsored by BMFT
Avail: NTIS HC A21/MF A01

A knowledge based control and sensor-feedback hierarchy concept which performs global task-oriented manipulation sequences filled with specific knowledge and initialized by the general ground station command is presented. It is intended for the control systems for in-orbit experiment and maintenance manipulators, where highly autonomous performance of multisensor controlled task sequences is used as an alternative to direct teleoperation. The theoretical knowledge base concept, similar to the Winston-Horn frame structure, is elaborated into implementable data structures. The knowledge represented in rules and physical data used by algorithms for planning a subcommand sequence consisting of single steps of various sensor feedback configurations is discussed. An implemented robot-control interface library and the sensor-equipped end effector for verification of expected performances is described. ESA

N88-19506# Technische Hochschule, Darmstadt (West Germany). Dept. of Control Engineering.
A KNOWLEDGE-BASED APPROACH FOR SENSORY-CONTROLLED ASSEMBLY OPERATIONS
W. SIMON, E. ERSUE, and ST. WIENAND *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 185-190 Nov. 1987 Sponsored by Deutsche Forschungsgeimschaft
Avail: NTIS HC A21/MF A01

The approach for a knowledge-based robot operation system using different types of sensory information is presented. The system is intended for orbital assembly, maintenance, and repair tasks in a semiautomatic or automatic manner, using a general knowledge base. The components of this knowledge base are examined and a knowledge representation scheme based on a combination of rules and frames is proposed. A prototype of the approach implemented on a robotic hardware test bed is discussed for the part-mating problem. ESA

N88-19509# Technische Hochschule, Darmstadt (West Germany).
REMOTE MANIPULATION IN ORBITAL CONSTRUCTION, SERVICING AND REPAIR MISSIONS: IS ONE ARM ENOUGH? A COMPARATIVE EVALUATION OF THE PERFORMANCE FEATURES OF ROBOTS WITH ONE OR MORE ARMS
H. BRUHM *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 217-225 Nov. 1987
Avail: NTIS HC A21/MF A01

Qualitative and quantitative performance features which are expected to make the difference between single and multiarm systems for orbital robots are reviewed. Methods for comparative evaluation of single and multiarm systems with respect to their maximum force/torque capability, payload positioning accuracy, repeatability, and stiffness are presented. The capabilities of multiarm systems are highlighted by the analysis of two tasks. The use of single-arm systems is not recommended. ESA

N88-19520# University Coll., London (England).
COVARIANT CONTROL OF BILATERAL SERVOS FOR IN-ORBIT MANIPULATION
J. E. E. SHARPE and K. V. SIVA (United Kingdom Atomic Energy Authority, Harwell, England) *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 317-323 Nov. 1987 Sponsored by Fairey Engineering Ltd.
Avail: NTIS HC A21/MF A01

A class of covariant bilateral force reflecting systems for teleoperation that enables the operator to use sensory feel to control the slave with a total transmission delay of 200 msec is introduced. The prototype 3 kWe electrohydraulic master-slave system has a forward positional bandwidth of 20 Hz and is capable of positioning a mass of 4 kg flexibly supported at 0.75 m radius at a slew rate of 200 deg/sec. The reflected sensory force has a bandwidth greater than 250 Hz. Experimental evidence shows the master-slave system to appear transparent to the operator within the normal positional bandwidth. The operators therefore feel that they are directly swinging the load mass at the end of a flexible rod and are able to control the vibrations of the rod. This is not possible with simple positional control as the resonant system is outside the control loop. The operator uses the high frequency sensory information in an adaptive manner. However, with the transmission delay it is necessary to reduce the sensory force gain to obtain stability. ESA

N88-19527# MATRA Espace, Paris-Velizy (France).
UTILIZATION OF ROBOTICS AND TELEOPERATION FOR FUTURE IN-ORBIT OPERATIONS
TH. BLAIS, J. L. LACOMBE, and P. WETZEL *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 377-383 Nov. 1987
Avail: NTIS HC A21/MF A01

The main in-orbit elements and operations required by the future in-orbit infrastructure are reviewed. Man's role and location with respect to the operations areas is a major design element for space teleoperation and robotics systems. It is shown that robotics/teleoperation and man have to be considered as complementary, enabling large operational automony of the robotics system when man performs on-ground or remote supervision (e.g., from a space station). This is applicable for assembly (external robotics) and payload operations (internal robotics). Efficient and safe work share between the external manipulator arm and the man in pressurized area (on the same space system) may be an alternative to extravehicular activity (EVA) or preferably the nominal way to perform operations which cannot be fully completed by EVA only (large load transfer). The telemanipulator arm provides both the astronaut transfer capability (with loads and tools) and a firm support at work site (open cherry picker), increasing the effectiveness of EVA (less astronaut fatigue, shorter transfer time). A man in the pressurized area ensures supervision. ESA

N88-19529# Sener S.A., Madrid (Spain).
ROBOTICS SERVICING EXPERIMENT
C. COMPOSTIZO, M. FUENTES, D. KASSING, and M. VANWINNENDAEL (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 391-398 Nov. 1987
Avail: NTIS HC A21/MF A01

The Robotics Servicing Experiment (ROSE) which is part of a complete robotic servicing demonstration program to provide the future European in orbit infrastructure with a well qualified robotic servicing system is introduced. The objectives of ROSE include: (1) verification of subsystems and performances of the Robotic System which cannot be completed on ground; (2) Validation of robotic servicing operations and techniques (task planning, teleoperation procedures, and associated techniques such as capture and berthing); (3) Validation by comparison of ground and in orbit test results of tools, facilities, and methods used within the on ground verification program of the robotic system. (Simulation models, test facilities, overall verification program philosophy); and (4) Validation of the complete robotic system including associated equipment and interfaces by its operation under realistic in orbit environmental conditions. The system is considered validated after the updating and validation of the ground verification program which covers a higher number of operational cases and conditions. ESA

N88-19535# British Aerospace Public Ltd. Co., Bristol (England). Space and Communications Div.
EVA, THE TECHNOLOGICAL CHALLENGE
T. J. CARTWRIGHT and P. A. BLYTHE *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 451-457 Nov. 1987
Avail: NTIS HC A21/MF A01

The technological challenge which must be overcome if man is to work outside the mother spacecraft is considered. Within the context of a space suit system hardware architecture the key requirements are discussed and a baseline subsystem design proposed for operations from the Hermes spaceplane. The technological issues and in particular the levels of technological maturity associated with this baseline are assessed in order to appraise the readiness of European industry to respond to extravehicular activity needs. With due consideration to the magnitude of the development required a plan is proposed for a European space suit system. Close consultation with U.S. and/or Soviet specialists is a possibility and technology transfer is addressed. ESA

N88-19537# British Aerospace Public Ltd. Co., Stevenage (England). Space and Communications Div.
A TELEOPERATED MANIPULATOR SYSTEM CONCEPT FOR UNMANNED PLATFORMS
J. MURDOCH and J. S. SHEPPARD *In* ESA. Proceedings of the 1st European In-Orbit Operations Technology Symposium p 469-474 Nov. 1987
Avail: NTIS HC A21/MF A01

A Platform Manipulator System (PMS) concept is proposed to provide, as a primary function, a means of exchanging payload and utility orbit replacement units (ORU) between an unmanned platform and a docked logistics vehicle without the need for man in orbit. The concept is principally directed towards Columbus Polar Platform in order to avoid the requirement to de-orbit for a servicing operation, but is also applicable to the external servicing of the resource module of the Man-Tended Free Flyer. Features of the proposed system include teleoperation from ground, a dual berthing/ORU exchange function, a limited rotational transportation capability of the manipulator base, and a bi-arm end effector concept. ESA

N88-19538# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
MAN-TENDED OPTIONS FOR EUROPEAN SPACE ROBOTICS
R. H. BENTALL and D. KASSING *In its* Proceedings of the 1st European In-Orbit Operations Technology Symposium p 475-483 Nov. 1987
Avail: NTIS HC A21/MF A01

Options and applications for robotics in European man-tended and autonomous operations in space are discussed, and future options for European robotics are identified. Man-tended robotics operations for internal and external servicing (including the Hermes robot arm) are reviewed. A technology demonstration program is proposed. ESA

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PROPULSION

Includes propulsion concepts and designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.

A88-15944*# Washington Univ., Seattle.
RAM ACCELERATOR DIRECT LAUNCH SYSTEM FOR SPACE CARGO
A. P. BRUCKNER and A. HERTZBERG (Washington, University, Seattle) IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987. 12 p. refs
(Contract NAG1-746)
(IAF PAPER 87-211)

The ram accelerator, a chemically-propelled mass driver, is presented as a new approach for directly launching acceleration-insensitive pay-loads into LEO. The cargo vehicle resembles the centerbody of a conventional ramjet and travels through a launch tube filled with a premixed gaseous fuel and oxidizer mixture. The tube acts as the outer cowling of the ramjet and the combustion process travels with the vehicle. Two modes of ram accelerator drive are described, which when used in sequence, are capable of accelerating the cargo vehicle to 10 km/sec. The requirements for placing a 2000 kg vehicle with 50 percent payload fraction into a 400 km orbit, with a minimum of on-board rocket propellant for circularization maneuvers, are examined. It is shown that aerodynamic heating during atmospheric transit results in very little ablation of the nose. Both direct and indirect orbital insertion scenarios are investigated, and a three-step maneuver consisting of two burns and aerobraking is found to minimize the on-board propellant mass. A scenario involving a parking orbit below the desired final orbit is suggested as a means to increase the flexibility of the mass launch concept. Author

N88-11753*# Martin Marietta Aerospace, Denver, Colo.
SPACE STATION INTEGRATED PROPULSION AND FLUID SYSTEM STUDY: FLUID SYSTEMS CONFIGURATION DATABOOK
L. ROSE, B. BICKNELL, D. BERGMAN, and S. WILSON 9 Jul. 1987 99 p
(Contract NAS8-36438)
(NASA-CR-179215; NAS 1.26:179215; MCR-87-578; EP-2.1)
Avail: NTIS HC A05/MF A01 CSCL 21H

This databook contains fluid system requirements and system descriptions for Space Station program elements including the United States and International modules, integrated fluid systems, attached payloads, fluid servicers and vehicle accommodation facilities. Separate sections are devoted to each of the program elements and include a discussion of the overall system requirements, specific fluid systems requirements and systems descriptions. The systems descriptions contain configurations, fluid inventory data and component lists. In addition, a list of information sources is referenced at the end of each section. M.G.

N88-17480# British Aerospace Dynamics Group, Bristol (England). Space and Communications Div.
STUDY OF LARGE SOLAR ARRAYS (SOLA). PHASE 2A: AMPLIFYING INFORMATION TO FINAL REPORT (SS/1109) Final Report
Paris, France Jul. 1983 112 p
(Contract ESA-4903/81-NL-JS(SC))
(BAE-SS/1110; ESA-CR(P)-1819-VOL-2; ETN-87-90512) Avail: NTIS HC A06/MF A01

It is shown that it is feasible to manufacture a basic module from which arrays of various sizes can be constructed within acceptable limits defined by power losses and power-to-weight criteria in the range from 150 to 30 kW, in steps of 2 kW, with a choice of low (52 V) or high (156 V) operating voltage levels. This modular design can be extended to provide array system powers up to 60 kW, although above 30 kW only the high voltage operating level is practical, due to the high resistive power losses associated with the length of array, hence harness, required for such operating power levels. Operating levels are 30 W/kg at 15 kW and 42 W/kg at 30 kW. These levels could be increased by optimizing the design for specific operating power levels, but at the expense of modularity. It is unlikely that the 50 W/kg goal can be reached. Author (ESA)

N88-17728*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
MAGNETIC EMISSIONS TESTING OF THE SPACE STATION ENGINEERING MODEL RESISTOJET
DANIEL BRIEHL Feb. 1988 11 p
(NASA-TM-100788; E-3961; NAS 1.15:100788) Avail: NTIS HC A03/MF A01 CSCL 22B

The engineering model resistojet intended for altitude maintenance onboard the space station was tested for magnetic radiation emissions in the Radio Frequency Interference (RFI) facility at the Goddard Space Flight Center. The resistojet heater was supplied with power at 20 kHz and low voltage through a power controller. The resistojet was isolated from its power supply in the RFI enclosure, and the magnetic emission measured at three locations around the resistojet at various heater currents. At a heater current of 18.5 A the maximum magnetic emission was 61 dBpt at a distance of 1 m from the resistojet and at a location at the rear of the thruster. Calculations indicate that the case and heat shields provided a minimum of 4 dB of attenuation at a current of 18.5 A. Maximum radiation was measured at the rear of the resistojet along its major axis and was thought to be due to the magnetic radiation from the power leads. At a distance of 37 cm from the resistojet the maximum magnetic radiation measured was 73 dBpt at a current of 11.2 A. The power input leads were also a source of magnetic radiation. The engineering model resistojet requires about 20 dB of additional shielding. Author

N88-19575*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
AEROASSISTED ORBIT TRANSFER VEHICLE TRAJECTORY ANALYSIS
ROBERT D. BRAUN and WILLIAM T. SUIT Jan. 1988 21 p
(NASA-TM-89138; NAS 1.15:89138) Avail: NTIS HC A03/MF A01 CSCL 22A

The emphasis in this study was on the use of multiple pass trajectories for aerobraking. However, for comparison, single pass trajectories, trajectories using ballutes, and trajectories corrupted by atmospheric anomolies were run. A two-pass trajectory was chosen to determine the relation between sensitivity to errors and payload to orbit. Trajectories that used only aerodynamic forces for maneuvering could put more weight into the target orbits but were very sensitive to variations from the planned trajectors. Using some thrust control resulted in less payload to orbit, but greatly reduced the sensitivity to variations from nominal trajectories. When compared to the non-thrusting trajectories investigated, the judicious use of thrusting resulted in multiple pass trajectories that gave 97 percent of the payload to orbit with almost none of the sensitivity to variations from the nominal. Author

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GENERAL

Includes either state-of-the-art or advanced technology which may apply to Large Space Systems and does not fit within the previous categories. Publications of conferences, seminars, and workshops are covered in this area.

A88-11776
IECEC '87; PROCEEDINGS OF THE TWENTY-SECOND INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE, PHILADELPHIA, PA, AUG. 10-14, 1987. VOLUMES 1, 2, 3, & 4
Conference sponsored by AIAA, AChS, SAE, et al. New York, American Institute of Aeronautics and Astronautics, 1987, p. Vol. 1, 623 p.; vol. 2, 601 p.; vol. 3, 500 p.; vol. 4, 519 p. For individual items see A88-11777 to A88-12012.

Papers are presented on space power requirements and issues, space photovoltaic systems, space solar dynamic systems, space thermal systems, manned and unmanned space power systems, thermionics, and thermoelectrics. Also considered are high power devices for space power systems, high power conversion for space power systems, 1-10 kWe nuclear space power sources, 100-kW class nuclear power concepts, space reactor safety, and multimegawatt space nuclear power systems. Other topics include space power systems automation, space kilovolt technology, space power electronics, space lithium and nickel-cadmium batteries, lithium sodium storage, and space fuel cells. Papers are also presented on space nickel hydrogen batteries, alternative energy concepts and fuels, fuel cell technology, flow batteries, high-temperature batteries, energy conservation, battery energy storage, thermal energy storage, heat engines, MHD power systems, nuclear fission, and the Stirling cycle. R.R.

A88-12526
AIAA COMPUTERS IN AEROSPACE CONFERENCE, 6TH, WAKEFIELD, MA, OCT. 7-9, 1987, TECHNICAL PAPERS
Conference sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1987, 397 p. For individual items see A88-12527 to A88-12579.

Papers are presented on the analysis of Ada as a prototyping language; the evaluation of a dual processor implementation for a fault inferring nonlinear detection system; fault-tolerant systems; intelligent interfaces to aircraft systems; the implementation of a research prototype on a fault monitoring and diagnosis system; future data acquisition capabilities; and the application of AI technology to the analysis and synthesis of reliable software systems. Topics discussed include the spaceplane's astronaut's associate; model-based health monitoring for reusable launch vehicles; Space Shuttle telemetry analysis by a real-time expert system; avionics, AI, and embedded processing systems; methodology requirements for intelligent systems architecture; and commonsense reasoning and superconductivity for self-replicating telerobots. Consideration is given to autonomous spacecraft operations; semiautonomous control for satellite servicing; and expert system control for airborne radar surveillance. I.F.

A88-13126
ADVANCED MATERIALS TECHNOLOGY '87; PROCEEDINGS OF THE THIRTY-SECOND INTERNATIONAL SAMPE SYMPOSIUM AND EXHIBITION, ANAHEIM, CA, APR. 6-9, 1987
RALPH CARSON, ED., MARTIN BURG, ED., KENDALL J. KJOLLER, ED., and FRANK J. RIEL, ED. Symposium and Exhibition sponsored by SAMPE. Covina, CA, Society for the Advancement of Material and Process Engineering (Science of Advanced Materials and Process Engineering Series. Volume 32), 1987, 1623 p. For individual items see A88-13127 to A88-13239.

The present conference on advanced materials considers topics in the fields of novel bismaleimide resin systems, USAF Materials Laboratory technology-development forecasts, high performance thermoplastics, ceramic-matrix composites, high temperature thermosetting resins, pressure-sensitive adhesives, advanced filament-winding methods, metal-matrix composites, and impact damage tolerance and control in filament-wound structures. Also discussed are spacecraft materials applications, epoxy resin technology, automated materials processing equipment, asbestos-substitute fibers, thermally hardened electronic materials, carbon/carbon composites, and pultrusion technology. O.C.

A88-13448#
THE APPLICABLE LEGAL REGIME FOR INTERNATIONAL COOPERATION
I. H. PH. DIEDERIKS-VERSCHOOR (International Institute of Space Law, Paris, France) IN: The commercial use of space stations: The legal framework of trans-Atlantic cooperation; International Colloquium, Hanover, Federal Republic of Germany, June 12, 13, 1986, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1986, p. 73-85. refs

The applicability of international agreements and United Nations space treaties to space stations operated cooperatively by more than one nation is examined, reviewing several recent proposals and opinions. Topics addressed include the interpretation of Article XII of the Space Treaty of 1967; the composition, duties, and rights of a space station management board; the Liability Convention of 1972; the Convention on Registration of Objects of 1976; and the legal questions posed by multicomponent space stations. T.K.

A88-13449#
LEGAL PROBLEMS IN THE CONSTRUCTION OF SPACE STATIONS [RECHTSPROBLEME BEIM BAU VON WELTRAUMSTATIONEN]
HERMANN ERSFELD (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: The commercial use of space stations: The legal framework of trans-Atlantic cooperation; International Colloquium, Hanover, Federal Republic of Germany, June 12, 13, 1986, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1986, p. 88-117. In German.

Legal questions which could arise during the construction of the International Space Station are discussed from a European perspective. Topics addressed include the differences between treaties and executive (e.g., NASA-ESA) agreements under U.S. law; the registration, jurisdiction, and control of space objects (as defined under United Nations agreements); property rights; and regulation of the obligations undertaken by the Space Station partners. Consideration is given to the responsibilities of the partners for their own components and astronauts, technology transfer and information sharing, access without discrimination to U.S. installations, waiver of import and export limitations and duties, patent questions during transport to space and aboard the Space Station, and liability and insurance questions. T.K.

A88-15276
SPACE CONGRESS, 24TH, COCOA BEACH, FL, APR. 21-24, 1987, PROCEEDINGS
Congress sponsored by the Canaveral Council of Technical Societies. Cape Canaveral, FL, Canaveral Council of Technical Societies, 1987, 656 p. For individual items see A88-15277 to A88-15314.

Topics covered include space colonization, European technology development, expendable launch vehicles in the USA and Europe, Space Station technologies, Space Station servicing, and Columbus and Eureca. Consideration is also given to second generation STS/launch vehicle technology, computers, contracts and management, and technology spinoffs. B.J.

A88-15476
NATIONAL SPACE ENGINEERING SYMPOSIUM, 2ND, SYDNEY, AUSTRALIA, MAR. 25-27, 1986, PREPRINTS. VOLUMES 1 & 2
Symposium sponsored by the Institution of Engineers, Australia and AUSSAT. Barton, Australia/Brookfield, VT, Institution of

Engineers, Australia/Brookfield Publishing Co. (National Conference Publication, No. 86/3), 1986, p. Vol. 1, 325 p.; vol. 2, 327 p. For individual items see A88-15477 to A88-15527.

Papers are presented on such topics as Aussat development and operations; the Australia Telescope Project; Australian ground reception facilities for ERS 1; the Australian Landsat station at X-band; satellite lightwave communications; laser solar power satellites; Australia and the regulation of the geostationary orbit; Project Endeavor; and Quasat. Consideration is also given to technical and economic aspects of small digital earth stations; earth station antennas for multiple satellite access; the Mirrabooka X-ray detector and spacecraft design study; the ITU space conference; an Australian international business satellite communications system; an Australian thin route satellite communication system; and a hydrogen scramjet with sidewall injection. B.J.

A88-16976
GUIDANCE AND CONTROL 1987; PROCEEDINGS OF THE ANNUAL ROCKY MOUNTAIN GUIDANCE AND CONTROL CONFERENCE, KEYSTONE, CO, JAN. 31-FEB. 4, 1987
ROBERT D. CULP, ED. (Colorado, University, Boulder) and TERRY J. KELLY, ED. (Ball Corp., Ball Aerospace Systems Div., Boulder, CO) Conference sponsored by AAS. San Diego, CA, Univelt, Inc., 1987, 638 p. For individual items see A88-16977 to A88-17000, A88-17002 to A88-17008.

The conference presents papers on innovative approaches to guidance, navigation, and control; guidance and control storyboard displays; test versus simulation in development of guidance and control systems; remote operations through robotics; and recent experiences. Particular attention is given to fault protection design for unmanned interplanetary spacecraft, linear quadratic stationkeeping on travelling ellipses, a heirarchic control architecture for intelligent structures, gyro technology, and the development and testing of a breadboard model star sensor for application in spacecraft systems. Other topics include directed energy weapons tracking and pointing space experiments, dynamics and control of a planar manipulator with elastic links, in-flight experiences with the attitude control system of the IRAS, and GPS reaction wheel system anomaly. K.K.

A88-22000
PROCEEDINGS OF THE FOURTH ANNUAL L5 SPACE DEVELOPMENT CONFERENCE
FRANK HECKER, ED. (L-5 Society, Tucson, AZ) San Diego, CA (Science and Technology Series. Volume 68), Univelt, Inc., 1987, 268 p. No individual items are abstracted in this volume.

Scientific, technological, and political aspects of present and planned U.S. space activities are discussed in reviews and reports. Topics addressed include space and U.S. politics, space resources, international space ventures, space-age education, and space biomedicine. Consideration is given to communities in space, space tourism, the 'pure' space sciences, and the cultural drive for space. Diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

A88-23925#
THE CIVIL SPACE PROGRAM: AN INVESTMENT IN AMERICA - REPORT OF AN AIAA WORKSHOP
Washington, DC, American Institute of Aeronautics and Astronautics, 1987, 64 p. refs

In the interest of formulating a strategic view of U.S. civil space systems' development, the AIAA convened a workshop to review current and prospective commitments of NASA and other competent agencies. Such goals as the creation of space-based global information systems and the agressive development of space-processed industrial products require the intensive funding of space infrastructure resources. These resources will encompass space stations and platforms, lunar/planetary bases, and larger space transportation systems employing more advanced technology than the current Space Shuttle. O.C.

A88-26197
COLLOQUIUM ON THE LAW OF OUTER SPACE, 28TH, STOCKHOLM, SWEDEN, OCT. 7-12, 1985, PROCEEDINGS
Colloquium sponsored by IAF. New York, American Institute Aeronautics and Astronautics, 1986, 317 p. No individual iten are abstracted in this volume.

The legal implications of recent advances in space technolog and exploitation are explored in reviews and reports. The emphasi is on efforts to limit military activities in space, but consideratior is also given to comparisons of sea law and space law governing exploration and exploitation, the legal problems of registering space objects, and particular space activities as the subjects of space law. Topics addressed include nuclear winter, ballistic missile defense, and the legal regime for outer space; space law and space offensive weapons; an interdisciplinary approach to the SDI debate; the effect of fiber-optic communication on space radio regulations; the registration treaty and nuclear power sources; protecting the security of space traffic; the problem of orbital debris; plans for the International Space Station; and technicolegal and medicolegal aspects of manned space stations. T.K.

A88-26209
APPLYING TECHNOLOGY TO SYSTEMS; AEROSPACE COMPUTER SECURITY CONFERENCE, 3RD, ORLANDO, FL, DEC. 7-11, 1987, TECHNICAL PAPERS
Conference sponsored by AIAA, American Society for Industrial Security, and IEEE. Washington, DC, American Institute of Aeronautics and Astronautics, 1987, 170 p. For individual items see A88-26210 to A88-26213.

The present conference discusses the Secure Distributed Operating System project for the verification of hookup security, active vs. passive security models, an expert system for the classification and sanitizing of texts, developments in guidance for trusted computer networks, the interconnection of accredited systems, and engineering systems applicable to embedded multilevel secure operations. Also discussed are network covert channel analysis, NASA Space Station program threat and vulnerability analysis, criterion extension for distributed systems, a transport encapsulation security protocol, and the protection of sensitive systems and data in an open governmental agency. O.C.

A88-27301
1987 AMERICAN CONTROL CONFERENCE, 6TH, MINNEAPOLIS, MN, JUNE 10-12, 1987, PROCEEDINGS. VOLUMES 1, 2, & 3
Conference sponsored by the American Automatic Control Council. New York, Institute of Electrical and Electronics Engineers, 1987, p. Vol. 1, 816 p.; vol. 2, 758 p.; vol. 3, 701 p. For individual items see A88-27302 to A88-27425.

Papers are presented on stochastic control, robotics, variable structure control, adaptive control, nonlinear process control, aerospace applications, estimation, and robust control via Lyapunov methods. Also considered are knowledge-based systems for control design, multitarget control of uncertain systems, multitarget tracking and sensor fusion, simulation in guidance and control systems, and computer science applications to control. Other topics include the decentralized control of large space structures, the modeling and control of solar energy processes, industrial applications of self-tuning and predictive control, and identification. Papers are also presented on state-space self-tuning control, synthesis techniques, the modeling of flexible structures, light-of-sight stabilization/tracking systems, order reduction, intelligent control systems, and energy systems analysis and control. R.R.

A88-31562
VIBRATION CONTROL AND ACTIVE VIBRATION SUPPRESSION; PROCEEDINGS OF THE ELEVENTH BIENNIAL CONFERENCE ON MECHANICAL VIBRATION AND NOISE, BOSTON, MA, SEPT. 27-30, 1987
D. J. INMAN, ED. (New York, State University, Buffalo) and J. C. SIMONIS, ED. (Southwest Research Institute, San Antonio, TX)

Conference sponsored by ASME. New York, American Society of Mechanical Engineers, 1987, 212 p. For individual items see A88-31563 to A88-31572.

Papers are presented on the theory of centrifugal pendulum vibration absorbers, the design of active damping in flexible structures, active damping of a Bernoulli-Euler beam via end point impedance control using distributed parameter techniques, and dynamics and control of a planar truss actuator. Also considered are active vibration control in a microgravity environment, a review of linear stochastic optimal control systems and applications, a recursive pole placement method for large flexible structures, and the vibration of a point-supported linear distributed system. Other topics include the nature of natural control, convergence properties of modal costs for certain distributed parameter systems, the design of an active magnetic bearing with a velocity observer, and morphological aspects of structural control. R.R.

A88-31573
THE ROLE OF DAMPING IN VIBRATION AND NOISE CONTROL; PROCEEDINGS OF THE ELEVENTH BIENNIAL CONFERENCE ON MECHANICAL VIBRATION AND NOISE, BOSTON, MA, SEPT. 27-30, 1987
L. ROGERS, ED. (USAF, Wright-Patterson AFB, OH) and J. C. SIMONIS, ED. (Southwest Research Institute, San Antonio, TX) Conference sponsored by ASME. New York, American Society of Mechanical Engineers, 1987, 296 p. For individual items see A88-31574 to A88-31607.

The present conference on vibration- and noise-control damping considers the design and analysis of passively damped large space structures, optimization methods for viscoelastic damping treatment design, the modal coupling of structures with complex storage moduli, the effectiveness of impact dampers for space applications, adaptive damping for spacecraft by temperature control, the harmonic response of nonproportionately damped structures, and a novel method for representing damping material properties. Also discussed are very high damping in very large space structures, an integrated approach to friction damper design, experimental techniques for damping capacity measurements in metal-matrix composites, damping in unidirectional graphite/metal composites, and fractional derivatives in the description of damping material and phenomena. O.C.

A88-32176
STRUCTURES, STRUCTURAL DYNAMICS AND MATERIALS CONFERENCE, 29TH, WILLIAMSBURG, VA, APR. 18-20, 1988, TECHNICAL PAPERS. PARTS 1, 2, & 3
Conference sponsored by AIAA, ASME, ASCE, and AHS. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. Pt. 1, 619 p.; pt. 2, 504 p.; pt. 3, 673 p. For individual items see A88-32177 to A88-32363.

Among the topics discussed are structural tailoring and feedback control synthesis, passive vibration control in composites, the stability characteristics of deformable aircraft, the structural efficiency of graphite/epoxy aircraft ribs, force-management technology development, parameter identification of discrete time series models for transient response prediction, the chaotic motion of a shallow arch, the sonic fatigue of stiffened panels, composite rotor blade modeling, and the prevention of free-edge delamination. Also treated are the postbuckling behavior of composites, aeroelastic tailoring for wings, active cooling design for a scramjet engine, the control of energy dissipation in structures, the bending of sandwich beams, minimum-weight aircraft structures, finite element models for composite shells, a unitized composite fuselage fuel tank, oblique hypervelocity impact phenomena, and damage-dependent material damping in laminated composites. O.C.

N88-10084*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
SPACECRAFT 2000
Jul. 1986 236 p Workshop held in Cleveland, Ohio, 29-31 Jul. 1986
(NASA-CP-2473; E-3358; NAS 1.55:2473) Avail: NTIS HC A11/MF A01 CSCL 22B

The objective of the Workshop was to focus on the key technology area for 21st century spacecraft and the programs needed to facilitate technology development and validation. Topics addressed include: spacecraft systems; system development; structures and materials; thermal control; electrical power; telemetry, tracking, and control; data management; propulsion; and attitude control.

N88-10093*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
STRUCTURES AND MATERIALS WORKING GROUP REPORT
ROBERT TORCZYNER (Lockheed Missiles and Space Co., Sunnyvale, Calif.) and BRANTLEY R. HANKS *In* NASA-Lewis Research Center, Spacecraft 2000 p 117-134 Jul. 1986
Avail: NTIS HC A11/MF A01 CSCL 22B

The appropriateness of the selection of four issues (advanced materials development, analysis/design methods, tests of large flexible structures, and structural concepts) was evaluated. A cross-check of the issues and their relationship to the technology drivers is presented. Although all of the issues addressed numerous drivers, the advanced materials development issue impacts six out of the seven drivers and is considered to be the most crucial. The advanced materials technology development and the advanced design/analysis methods development were determined to be enabling technologies with the testing issues and development of structural concepts considered to be of great importance, although not enabling technologies. In addition, and of more general interest and criticality, the need for a Government/Industry commitment which does not now exist, was established. This commitment would call for the establishment of the required infrastructure to facilitate the development of the capabilities highlighted through the availability of resources and testbed facilities, including a national testbed in space to be in place in ten years. B.G.

N88-10094*# Grumman Aerospace Corp., Bethpage, N.Y.
THERMAL CONTROL WORKING GROUP REPORT
ROBERT HASLETT and E. THOMAS MAHEFKEY (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.) *In* NASA-Lewis Research Center, Spacecraft 2000 p 135-147 Jul. 1986
Avail: NTIS HC A11/MF A01 CSCL 22B

The Thermal Control Working Group limited its evaluation to issues associated with Earth orbiting and planetary spacecraft with power levels up to 50 kW. It was concluded that the space station technology is a necessary precursor but does not meet S/C 2000 needs (life, high heat flux, long term cryogenics, and survivability). Additional basic and applied research are required (fluid/materials compatibility and two phase system modeling). Scaling, the key issue, must define accelerated life test criteria. The two phase systems require 0g to 1 g correlation. Additional ground test beds are required and combined space environment tests of materials. B.G.

N88-10829*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
FOURTEENTH SPACE SIMULATION CONFERENCE: TESTING FOR A PERMANENT PRESENCE IN SPACE
JOSEPH L. STECHER, III, ed. 1986 435 p Conference held in Baltimore, Md., 3-6 Nov. 1986; sponsored by NASA, Inst. of Environmental Sciences, AIAA, and the American Society for Testing and Materials
(NASA-CP-2446; REPT-86B0561; NAS 1.55:2446) Avail: NTIS HC A19/MF A01 CSCL 22B

The Institute of Environmental Sciences Fourteenth Space Simulation Conference, Testing for a Permanent Presence in Space, provided participants a forum to acquire and exchange information on the state-of-the-art in space simulation, test technology, thermal simulation, and protection, contamination, and techniques of test measurements.

N88-11702 Centre National d'Etudes Spatiales, Toulouse (France).
SPACE ENVIRONMENT TECHNOLOGY
Apr. 1987 751 p Partly in FRENCH and ENGLISH Lecture course presented in Toulouse, France, Apr. 1986
(ISBN-2-85428-170-5; ISSN-0766-1002; ETN-87-90631) Avail: CEPADUES-Editions, Toulouse, France

Lectures presented at the conference are presented. Areas of discussion are: Space plasma physics; the solar wind; and solar terrestrial interactions. Earth orbital environment, spacecraft charging and electrostatic discharges, and satellite design to overcome environmental effects were also discussed. ESA

N88-13375# RADEX, Inc., Carlisle, Mass.
ANALYSIS OF GEOPHYSICAL DATA BASES AND MODELS FOR SPACECRAFT INTERACTIONS Final Technical Report, Aug. 1983 - Oct. 1986
J. N. BASS, N. A. BONITO, K. G. COTTRELL, R. J. ECKHARDT, and W. J. MCNEIL 31 Oct. 1986 276 p
(Contract F19628-83-C-0105)
(AD-A184809; AFGL-TR-86-0221) Avail: NTIS HC A13/MF A01 CSCL 04A

This contract supported on-going as well as planned research into environments and spacecraft interactions in near space. The major projects are summarized. Models and geophysical data bases were investigated for spacecraft charging, shuttle contamination, electrostatic particle pushing codes, beam-plasma interaction in emitting probes, and magnetospheric dynamics. Adiabatic invariance of trapped particles, fluxgate magnetometer simulation and falling sphere accelerometers. In support of the CRRES project, a data management plan has been provided, and a graphics capability developed for the SPAN network. Software development was involved in all phases, using CYBER, VAX and RIDGE computers. GRA

N88-14855*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)/AMERICAN SOCIETY FOR ENGINEERING EDUCATION (ASEE) SUMMER FACULTY FELLOWSHIP PROGRAM, 1987. VOLUME 1 Final Reports
WILLIAM B. JONES, ed. (Texas A&M Univ., College Station.) and STANLEY H. GOLDSTEIN, ed. Nov. 1987 326 p Program held in Houston, Tex., 1987; sponsored by NASA, Johnson Space Center, Houston, Tex. and Texas A/M Univ., College Station
(Contract NGT-44-001-800)
(NASA-CR-172009-VOL-1; NAS 1.26:172009-VOL-1) Avail: NTIS HC A15/MF A01 CSCL 05A

The objective of the NASA/ASEE program were: (1) to further the professional knowledge of qualified engineering and science faculty members; (2) to stimulate an exchange of ideas between participants and NASA; (3) to enrich and refresh the research and teaching activities of participants' institutions; and (4) to contribute to the research objectives of the NASA centers. Each faculty fellow spent 10 weeks at Johnson Space Center engaged in a research project commensurate with his/her interests and background and worked in collaboration with a NASA/JSC colleague. A compilation is presented of the final reports on the research projects done by the fellows during the summer of 1987. This is volume 1 of a 2 volume report.

N88-14874*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)/AMERICAN SOCIETY FOR ENGINEERING EDUCATION (ASEE) SUMMER FACULTY FELLOWSHIP PROGRAM, 1987. VOLUME 2 Final Reports
WILLIAM B. JONES, JR., ed. (Texas A&M Univ., College Station.) and STANLEY H. GOLDSTEIN, ed. Nov. 1987 332 p Program held in Houston, Texas, 1987; sponsored by NASA, Johnson Space Center, Houston and Texas A/M Univ., College Station
(Contract NGT-44-001-800)
(NASA-CR-172009-VOL-2; NAS 1.26:172009-VOL-2) Avail: NTIS HC A15/MF A01 CSCL 05A

The 1987 Johnson Space Center (JCS) National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship program was conducted by Texas A and M University and JSC. The 10-week program was operated under the auspices of ASEE. The basic objectives of the program are: to further the professional knowledge of qualified engineering and science faculty members; to stimulate an exchange of ideas between participants and NASA; to enrich and refresh the research and teaching activities of participants' institutions; and to contribute to the research objective of the NASA Centers. This document is a compilation of the final reports on the research projects done by the faculty fellows during the summer of 1987.

N88-15618*# Oakwood Coll., Huntsville, Ala. Dept. of Business and Information Systems Management.
THE FEASIBILITY OF USING TAE AS THE UIL FOR THE SPACE STATION AND FOR OTHER INTERNAL NASA TASKS AND PROJECTS
ESTHER NAOMI GILL *In* NASA. Marshall Space Flight Center, Research Reports: 1987 NASA/ASEE Summer Faculty Fellowship Program 22 p Nov. 1987
Avail: NTIS HC A99/MF E03 CSCL 09B

This description of the Transportable Applications Executive (TAE) is intended to serve to test the feasibility of its use as the Space Station User Interface Language (SSUIL). TAE was developed by the Space Data and Computing Division, Space and Earth Sciences Directorate of NASA/GSFC, and by Century Computing, Inc. in 1980. TAE is an executive program which ties a system of application programs into a single easily operated whole and supports users' operations of programs through a consistent friendly and flexible interactive user interface. TAE also supplies the interface between the user and the various application programs in a particular computer system. It appears to be an effective user interface for infrequent as well as for expert users. Author

N88-16428*# General Research Corp., Huntsville, Ala.
PROTOTYPE RESUPPLY SCHEDULER
STEVE TANNER, ANGI HUGHES, and JIM BYRD (United Space Boosters, Inc., Huntsville, Ala.) *In* NASA. Marshall Space Flight Center, Third Conference on Artificial Intelligence for Space Applications, Part 1 p 383-387 Nov. 1987
Avail: NTIS HC A18/MF A01 CSCL 09B

Resupply scheduling for the Space Station presents some formidable logistics problems. One of the most basic problems is assigning supplies to a series of shuttle resupply missions. A prototype logistics expert system which constructs resupply schedules was developed. This prototype is able to reconstruct feasible resupply plans. In addition, analysts can use the system to evaluate the impact of adding, deleting or modifying launches, cargo space, experiments, etc. Author

N88-16767# European Space Agency, Paris (France).
ESA BULLETIN NO. 25
BRUCE BATTRICK, ed. and DUC GUYENNE, ed. Feb. 1981 86 p
(ISSN-0376-4265; ETN-87-90517) Avail: NTIS HC A05/MF A01

The ESA convention; satellite assembly in geostationary orbit; Meteosat photographs of Karman vortex streets in the atmosphere; the Ariane 3 program; solar simulation; satellite power transmission to Earth; parallel processing utilization for remote sensing image processing; and training in satellite ground system operations are discussed.

N88-16777# European Space Agency, Paris (France).
PROCEEDINGS OF THE ESA WORKSHOP ON CO-ORBITING PLATFORM ELEMENTS (COPE)
T. DUC GUYENNE, ed. Sep. 1987 71 p Workshop held in Noordwijk, Netherlands, 7-8 Apr. 1987 Original contains color

illustrations
(ESA-SP-1093; ISSN-0379-6566; ETN-88-91413) Avail: NTIS HC A04/MF A01

Solid Earth, land, ocean, ice, and atmosphere observation from space; spaceborne space science; Columbus Space Station; and microgravity experiments were discussed. ESA

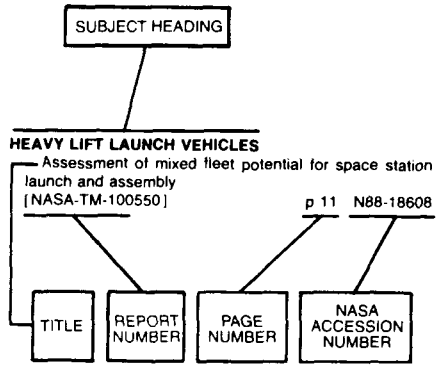
N88-19484# European Space Agency, Paris (France).
PROCEEDINGS OF THE 1ST EUROPEAN IN-ORBIT OPERATIONS TECHNOLOGY SYMPOSIUM
E. J. ROLFE, ed. Nov. 1987 497 p Symposium held in Darmstadt, Fed. Republic of Germany, 7-9 Sep. 1987; sponsored by ESA and DGLR
(ESA-SP-272; ISSN-0379-6566; ETN-88-91971) Avail: NTIS HC A21/MF A01

In-orbit scenarios; orbital rendezvous and docking; orbital assembly and servicing; spacecraft design; robotics; artificial intelligence and expert systems; ground simulation and modeling; teleoperation; and technology demonstration were discussed. ESA

N88-20235*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
WORKSHOP ON TECHNOLOGY DEVELOPMENT ISSUES FOR THE LARGE DEPLOYABLE REFLECTOR (LDR)
KENJI NISHIOKA, ed. Feb. 1986 118 p Workshop held in Asilomar, Calif., 17-22 Mar. 1985
(NASA-CP-2407; A-85394; NAS 1.55:2407) Avail: NTIS HC A06/MF A01 CSCL 03B

The results of the 2nd Large Deployable Reflector (LDR) Technology Review Workshop held at Asilomar, California, March 17 to 22, 1985, are summarized. The workshop was convened to update LDR Technology status and to revise as necessary the results for the first LDR Workshop held in June 1982. There were some 100 participants representing government agencies, industry, and universities. This Workshop's goal was to assess, identify, and set priorities for the LDR technology issues based on requirements identified in the first workshop. Four high-priority technology areas were identified: (1) mirror materials and construction; (2) sensing and controls; (3) system-simulation and modeling capability; and (4) submillimeter instruments. The results of the workshop were used to provide a list of technolgy issues for the development of a technology initiatives plan for the LDR by NASA's Office of Aeronautics and Space Technology. Author

Typical Subject Index Listing



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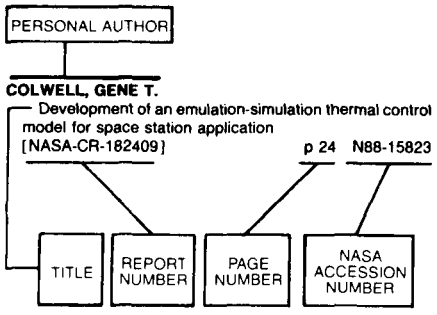

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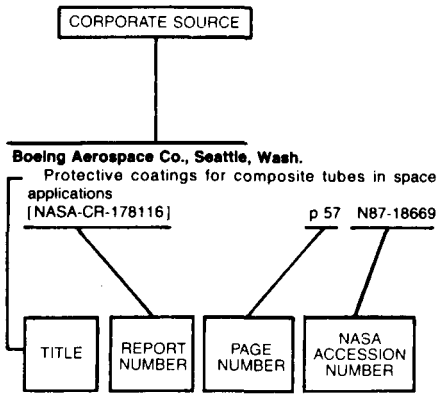

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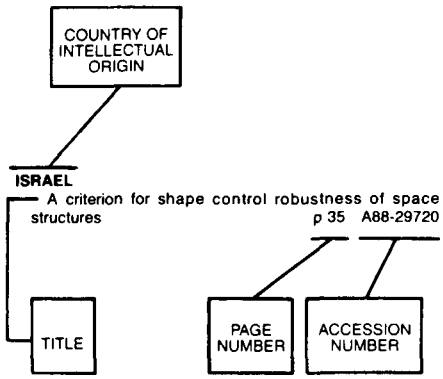

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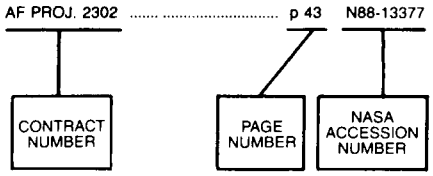

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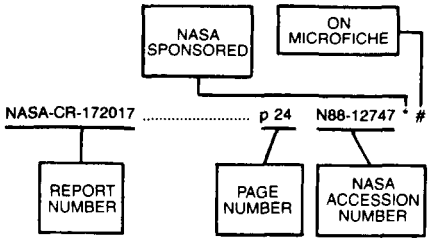

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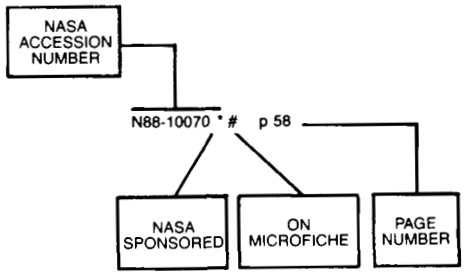

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16. Abstract

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