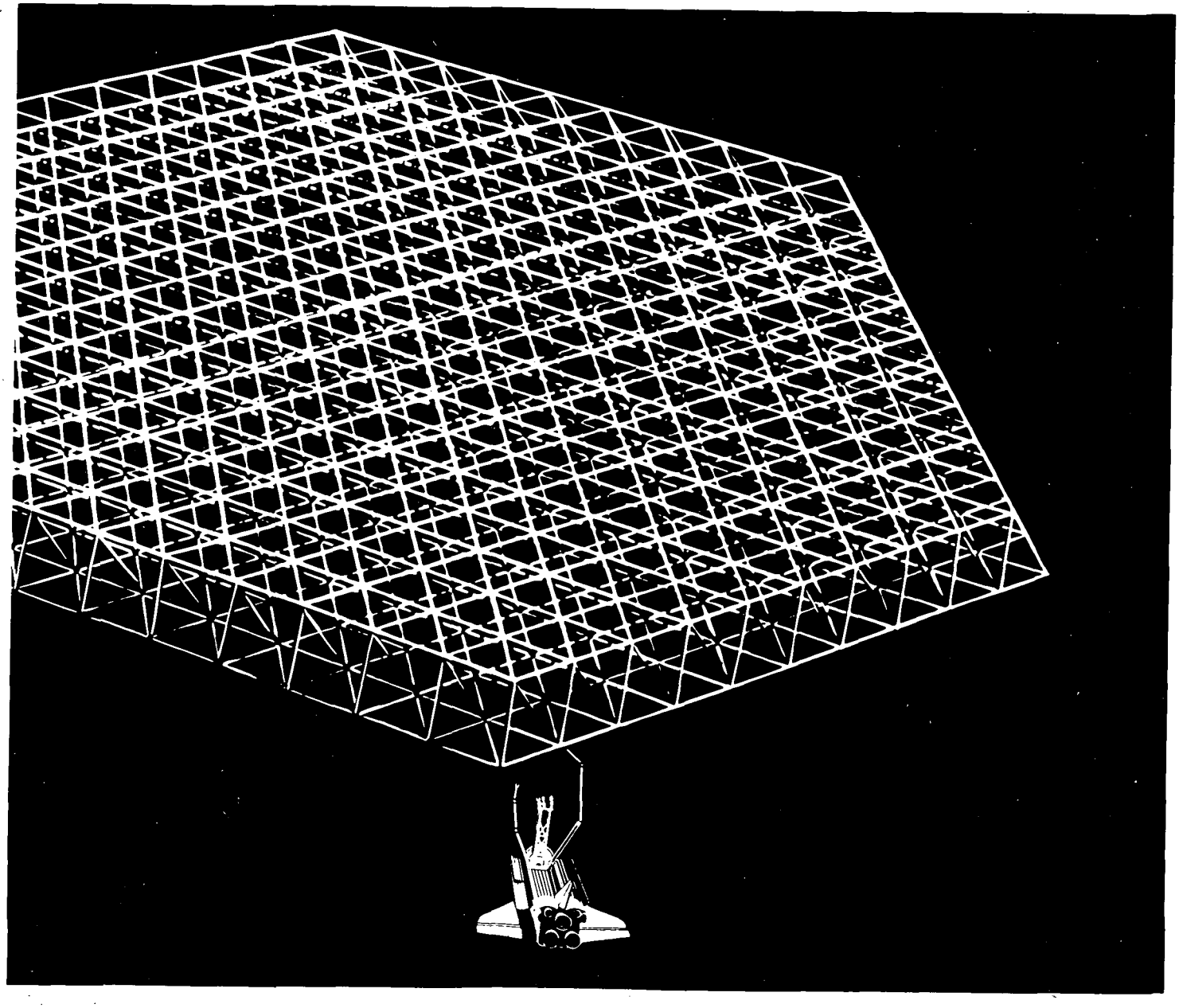
NASA

Technology for Large Space Systems

A Bibliography
with Indexes

NASA SP-7046(18)
June 1988



NASA SP-7046(18)

TECHNOLOGY FOR LARGE SPACE SYSTEMS

A BIBLIOGRAPHY WITH INDEXES

Supplement 18

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 July 1 and December 31, 1987 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 569 reports, articles and other documents announced between July 1, 1987 and December 31, 1987 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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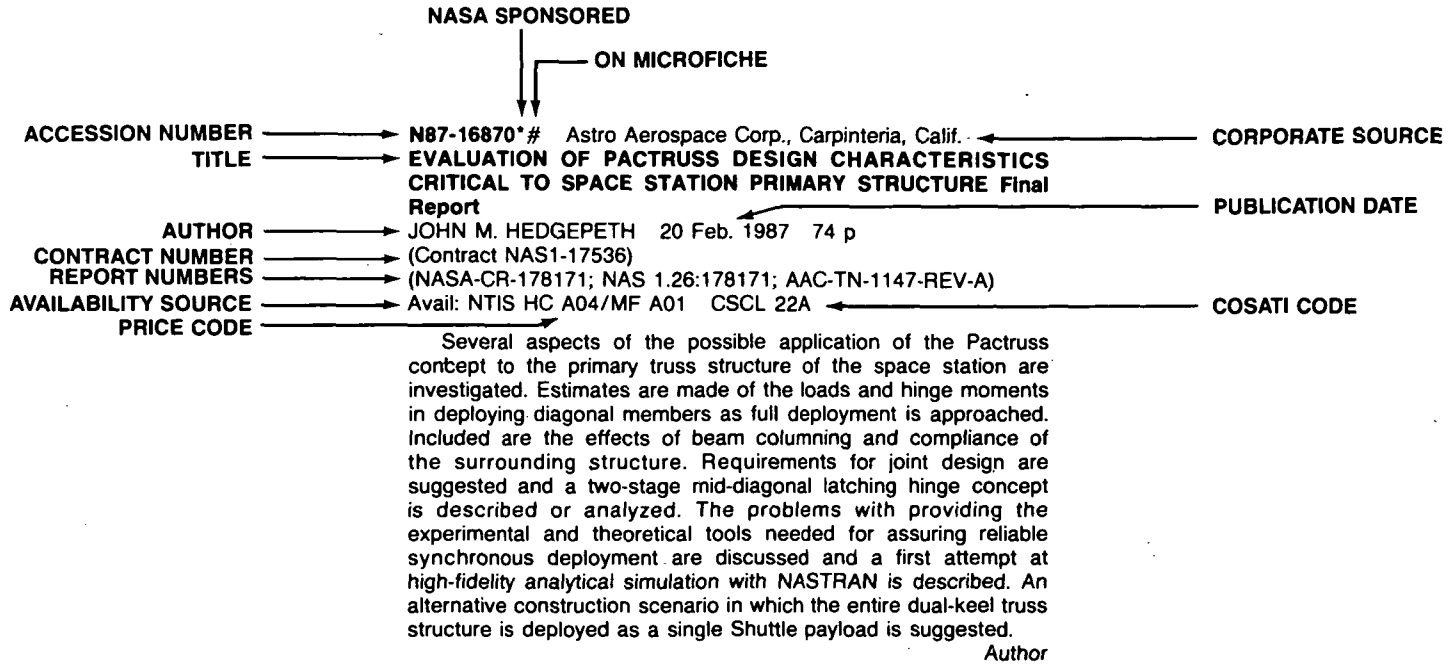
TYPICAL REPORT CITATION AND ABSTRACT



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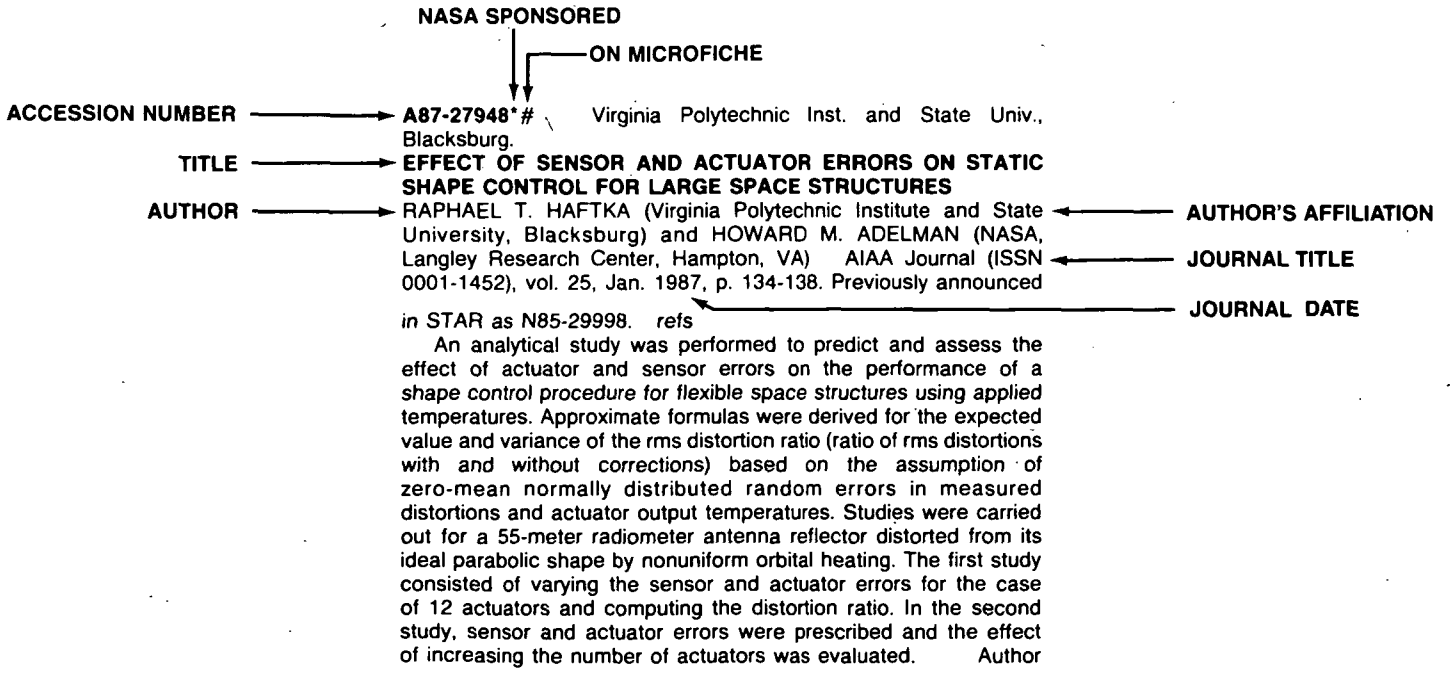

TECHNOLOGY FOR LARGE SPACE SYSTEMS

A Bibliography (Suppl. 18)

JUNE 1988

01

SYSTEMS

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

A87-32017* National Aeronautics and Space Administration, Washington, D.C.
SPACE RESEARCH - AT A CROSSROADS
FRANK B. MCDONALD (NASA, Washington, DC) Science (ISSN 0036-8075), vol. 235, Feb. 13, 1987, p. 751-754. refs

Efforts which must be expended if U.S. space research is to regain vitality in the next few years are discussed. Small-scale programs are the cornerstone for big science projects, giving both researchers and students a chance to practice the development of space missions and hardware and identify promising goals for larger projects. Small projects can be carried aloft by balloons, sounding rockets, the Shuttle and ELVs. It is recommended that NASA continue the development of remote sensing systems, and join with other government agencies to fund space-based materials science, space biology and medical research. Increased international cooperation in space projects is necessary for affording moderate to large scale missions, for political reasons, and to maximize available space resources. Finally, the establishment and funding of long-range goals in space, particularly the development of the infrastructure and technologies for the exploration and colonization of the planets, must be viewed as the normal outgrowth of the capabilities being developed for LEO operations. M.S.K.

A87-32534
AN ENCLOSED HANGAR CONCEPT FOR LARGE SPACECRAFT SERVICING AT SPACE STATION
YOSHIAKI OHKAMI, KOHTARO MATSUMOTO, TAKASHI KIDA (National Aerospace Laboratory, Chofu, Japan), TAKASHI IIDA (Ministry of Posts and Telecommunications, Radio Research Laboratory, Koganei, Japan), and JIRO SAKAI (Ohbayashi Corp., Tokyo, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1939-1944. refs

Two configurations for a large inflatable enclosed-space pressurized hangar being designed as a Space Station element for the purpose of providing a working area for semi-EVA spacecraft servicing are discussed. The hangar will be large enough to enable crews to assemble, measure, and repair such large structures as a 10-m class antenna planned for the Large Antenna Assembly and Measurement Experiment to be performed at the Japanese Experiment Module at the Space Station. A brief feasibility study on the large structure, the skin materials, and the operations management is presented with emphasis placed on the maintenance of pressure and temperature and the volume of the required air, identifying some technology problems that need to be resolved. I.S.

A87-32537
EURECA - A FIRST STEP TOWARDS THE SPACE STATION
ROBERT MORY (ESA, Paris, France) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1957-1963.

The European Retrievable Carrier (Eureca) is designed for Shuttle launch to LEO, self-boost to a 525 km orbit, 6-9 mos on-station, then return to LEO for Orbiter retrieval. Eureca will provide a long-duration undisturbed 0.00001 g environment, reusable hardware (up to five times), and high power and mass capability for the payload. The design includes the SPAS truss structure, the Spacelab cooling system, bubble memory and a modular attitude control system. Two 7 m solar arrays will furnish 1 kW continuous (1.5 kW peak) power backed up to NiCd batteries. Orbit transfer will be achieved with redundant hydrazine-fueled boosters, and data transmission is to be by relay through the Olympus satellite to ESOC headquarters. The progression of missions envisioned and scheduled for Eureca includes baseline experiments, microgravity research, astronomy, solar physics, and earth remote sensing. Eventually, the Eureca design will be used for coorbiting and noncoorbiting platforms as part of the Space Station system. M.S.K.

A87-32644
HUBBLE SPACE TELESCOPE SATELLITE SERVICING
W. E. JONES (Lockheed Missiles and Space Co., Inc., Huntsville, AL) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 14 p.
(SAE PAPER 861796)

The Hubble Space Telescope (HST) is the first satellite designed from the outset to accommodate servicing in space. Astronauts will have access to and be able to replace scientific instruments, guidance sensors, batteries, solar panels, computers, reaction wheels, etc., all configured as orbital replacement units (ORU). The HST outer shell has been fitted with 225 ft of handrails and 31 foot restraint receptacles. ORU fasteners were designed to permit facile disconnection and connection by astronauts wearing bulky spacesuits. Servicing is to be on regular 3 yr intervals, with retrieval and release from the Orbiter bay to take place at the 320 n. mi. operational orbit of the HST. The projected retrieval, link-up, repair and release procedures, hierarchical priority scheduling approach, and space support equipment to be carried on the Orbiter are explored. M.S.K.

A87-32667* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
ROLE OF THE MANNED MANEUVERING UNIT FOR THE SPACE STATION
C. E. WHITSETT (NASA, Johnson Space Center, Houston, TX) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 18 p. refs
(SAE PAPER 861834)

The performance specifications to be realized in the Manned Maneuvering Unit (MMU) for Space Station operations will be the culmination of design efforts which began during the Gemini project. The types of MMUs which have been built and tested over the past two decades are described, including handheld, jet shoe, and initial rigid backpack configurations. Efforts to enhance the control laws and human factors aspects of the Skylab MMU to

meet long-duration, flexible use Space Station requirements are summarized, noting the successes and deficiencies with the Shuttle MMU. The design requirements which must be met to allow the Space Station MMU to be used to perform rescue, transportation, inspection, assembly, contingency, and programmatic missions are explored. M.S.K.

A87-32747* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
SOLAR ARRAY FLIGHT DYNAMIC EXPERIMENT
RICHARD W. SCHOCK (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Guidance and control 1986; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 1-5, 1986 . San Diego, CA, Univelt, Inc., 1986, p. 351-365. Previously announced in STAR as N87-12581.
(AAS PAPER 86-050)

The purpose of the Solar Array Flight Dynamic Experiment (SAFDE) is to demonstrate the feasibility of on-orbit measurement and ground processing of large space structures dynamic characteristics. Test definition or verification provides the dynamic characteristic accuracy required for control systems use. An illumination/measurement system was developed to fly on Space Shuttle flight STS-31D. The system was designed to dynamically evaluate a large solar array called the Solar Array Flight Experiment (SAFE) that had been scheduled for this flight. The SAFDE system consisted of a set of laser diode illuminators, retroreflective targets, an intelligent star tracker receiver and the associated equipment to power, condition, and record the results. In six tests on STS-41D, data was successfully acquired from 18 retroreflector targets and ground processed, post flight, to define the solar array's dynamic characteristic. The flight experiment proved the viability of on-orbit test definition of large space structures dynamic characteristics. Future large space structures controllability should be greatly enhanced by this capability. Author

A87-33048
PLANNING FOR UNANTICIPATED SATELLITE SERVICING TELEOPERATIONS
JOHN R. RICE, JOHN P. YORCHAK, and CRAIG S. HARTLEY (Martin Marietta Corp., Denver, CO) IN: Human Factors Society, Annual Meeting, 30th, Dayton, OH, Sept. 29-Oct. 3, 1986, Proceedings. Volume 2 . Santa Monica, CA, Human Factors Society, 1986, p. 870-874. refs

The role that man will play in the space-based servicing of satellites will change with standardization and automation of such operations. If history is any indication, man cannot be completely removed from servicing duties because unanticipated servicing operations occasionally will require his direct intervention and control through either extra-vehicular activities (EVA) or teleoperations. As a result, certain minimum user-system interface capabilities must be maintained, no matter how sophisticated future technology becomes. This paper discusses research related to some of the basic human factors problems that will probably always have an impact on space-based teleoperated servicing operations. The implicit warning is that future advanced systems must implement solutions to these problems if humans are to provide effective backup support. Furthermore, it is believed that there are several critical gaps in the present knowledge of teleoperator human factors that must be closed before such backup operations can be effective. There is a danger that system developers may become so enamored of advanced teleoperator technology that they may fail to provide an adequate user/system interface for backup operations. Human factors issues discussed include: vision systems, control devices, and communication time delays.
Author

A87-33679#
ANALYSIS OF INTELSAT V FLIGHT DATA
T. RUSH, P. R. SCHRANTZ (COMSAT Laboratories, Clarksburg, MD), and B. AGRAWAL (INTELSAT, Washington, DC) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 253-257. COMSAT-INTELSAT-sponsored research.
(AIAA PAPER 87-0784)

This paper summarizes results of an extensive evaluation of the Intelsat V spacecraft flight data carried out by COMSAT Laboratories for INTELSAT. A structural loads data base for the Intelsat V was assembled including actual flight measurements, coupled loads analysis predictions, and environmental test loads. The flight measurements incorporate both accelerometer and strain gauge signals transmitted during eight Atlas/Centaur and two Ariane launches of the Intelsat V satellites. An evaluation of the loads data base placed primary emphasis on a comparison of coupled loads analysis predictions with statistically based flight loads. The predictions of axial acceleration at the spacecraft/launch vehicle interface were found to be accurate. However, the lateral loads predicted by the coupled loads analysis were overly conservative. Several discrepancies between the structural analysis and the flight measurements have been revealed. The influence of the spacecraft's dynamic characteristics on interface motions can be readily observed in the data. Author

A87-36759
AUTOMATED RECOGNITION, ISOLATION, AND ELIMINATION OF ERRORS, AS EXEMPLIFIED IN THE EUROPEAN RETRIEVABLE CARRIER EURECA [AUTOMATISCHE ERKENNUNG, ISOLIERUNG UND BEHEBUNG VON FEHLERN, DARGESTELLT AM BEISPIEL VON 'EURECA', DEM EUROPEAN RETRIEVABLE CARRIER]
ROLF STEINHARD (MBB-ERNO Raumfahrttechnik GmbH, Bremen, West Germany) IN: Yearbook 1986 I; DGLR, Annual Meeting, Munich, West Germany, Oct. 8-10, 1986, Reports . Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1986, p. 58-65. In German.
(DGLR PAPER 86-120)

Basic requirements, possibilities, restrictions, and practical solutions involved in the implementation of an automatic system for recognizing, isolating, and eliminating errors in autonomous spacecraft are discussed using the European Retrievable Carrier Eureca as an example. The errors are discussed as they apply to the Eureca subsystems for electrical power, telemetry and telecommand, thermal control, data handling, attitude and orbit control, microgravity measurement, and software. C.D.

A87-36763
HIGH-ACCURACY LABORATORY TESTS ON AN ORBITAL MICROGRAVITY SYSTEM [HOCHGENAUE LABORTESTS AN EINEM ORBIT-MIKROGRAVITATIONSSYSTEM]
DIETER KARL JOOS (Industrieanlagen-Betriebsgesellschaft mbH, Ottobrunn, West Germany) IN: Yearbook 1986 I; DGLR, Annual Meeting, Munich, West Germany, Oct. 8-10, 1986, Reports . Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1986, p. 98-105. In German.
(DGLR PAPER 86-173)

Laboratory tests which provide highly accurate calibrations of the Eureca microgravity measurement system are described. The microgravitational environment which Eureca will experience is summarized, and the microgravity acceleration meter which will be aboard Eureca is briefly described. The problems encountered in the laboratory function and accuracy tests are discussed, and their solutions are presented. These tests increased the measurement accuracy up to + or - 10 to the -7th, an accuracy sufficient to provide a reliable reference. C.D.

A87-38754* Management and Technical Services Co., Houston, Tex.
CONCEPTS FOR THE EVOLUTION OF THE SPACE STATION PROGRAM
ROGER B. MICHAUD, LADONNA J. MILLER (GE Management and Technical Services Co., Houston, TX), and GARY R. PRIMEAUX (NASA, Johnson Space Center, Houston, TX) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 561-570. refs
(SAE PAPER 860972)

An evaluation is made of innovative but pragmatic waste management, interior and exterior orbital module construction, Space Shuttle docking, orbital repair operation, and EVA techniques applicable to the NASA Space Station program over the course of its evolution. Accounts are given of the Space Shuttle's middeck extender module, an on-orbit module assembly technique employing 'Pringles' stack-transportable conformal panels, a flexible *Shuttle/Space Station docking tunnel, an 'expandable dome' for* transfer of objects into the Space Station, and a Space Station dual-hatch system. For EVA operations, pressurized bubbles with articulating manipulator arms and EVA hard suits incorporating maneuvering, life support and propulsion capabilities, as well as an EVA gas propulsion system, are proposed. A Space Station ultrasound cleaning system is also discussed. O.C.

A87-38783
THE NEXT STEP FOR THE MMU - CAPABILITIES AND ENHANCEMENTS
LESLIE J. A. ROGERS (Martin Marietta Corp., Denver, CO) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 883-889.
(SAE PAPER 861013)

The Manned Maneuvering Unit (MMU) for untethered astronaut EVAs is a self-contained vehicle incorporating all electrical power, propulsion control, and display components required for such operations as satellite rendezvous, docking and stabilization, as well as the rescuing of crew members, satellite refueling and inspection, and assistance for on-orbit construction of space platforms. Attention is given to prospective improvements of MMU hardware to facilitate its use in Space Shuttle and NASA Space Station-related activities. These enhancements encompass a digital electronics assembly, a navigation aid, and a propellant tank kit. O.C.

A87-39594#
EUROPE PREPARES FOR MANNED ORBITED OPERATIONS
RUDI G. REICHERT Dornier Post (English Edition) (ISSN 0012-5563), no. 1, 1987, p. 44-47.

Manned space operations proposed by ESA are discussed. The development of a space suit system is examined in terms of its applications and life support system requirements. Consideration is given to the fabrication of manned maneuvering equipment and special test facilities for evaluating new equipment, and an air lock design. I.F.

A87-40328
THE EARTH IS ABOVE US [ZEMLIA NAD NAMI]
IURII NIKOLAEVICH GLAZKOV (Tsentr Podgotovki Kosmonavtov, USSR) Moscow, Izdatel'stvo Mashinostroenie, 1986, 120 p. In Russian.

The author, a former Soviet cosmonaut, describes his experience in the Soviet space program. The bulk of this book is devoted to the author's flight on Salyut-5 in 1977. Much of the work is of a philosophical nature, in which the author records his impressions of seeing the earth from space and meditates on the future of man and the planet. B.J.

A87-40353*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
ADVANCED TECHNOLOGY FOR THE SPACE STATION
MARK B. NOLAN and DENNIS A. STONE (NASA, Johnson Space Center, Houston, TX) IN: EASCON '86; Proceedings of the Nineteenth Annual Electronics and Aerospace Systems Conference, Washington, DC, Sept. 8-10, 1986 . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 24-32.

The goals and objectives of the Space Station Advanced Development Program are discussed. Data from tests and experiments in the areas of attitude control and stabilization, communications and tracking, data management systems, man systems, mechanisms, power systems, structures, thermal systems, and EVA are examined. The approaches used to implement these programs and for data transfer are described. The plans for the development of the Space Station are presented. I.F.

A87-41153#
THE CANADIAN ROBOTIC SYSTEM FOR THE SPACE STATION
DOUGLAS CASWELL (National Research Council of Canada, Ottawa) and DEV GOSSAIN (Spar Aerospace, Ltd., Remote Manipulator Systems Div., Toronto, Canada) AIAA, NASA, and USAF, Symposium on Automation, Robotics and Advanced Computing for the National Space Program, 2nd, Arlington, VA, Mar. 9-11, 1987. 6 p.
(AIAA PAPER 87-1677)

The general concept of the Mobile Servicing Center and the Special Purpose Dextrous Manipulator (SPDM), both of which are parts of the Space Station Mobile Servicing System, is described. The role of the SPDM in the assembly and maintenance of the Station and the servicing of payloads and other equipment is outlined. Planning activities for technology diffusion and exploitation of the terrestrial economy are also addressed. C.D.

A87-41218
RECONSTITUTING THE US SPACE PROGRAMME
JOHN M. LOGSDON (George Washington University, Washington, DC) Space Policy (ISSN 0265-9646), vol. 3, May 1987, p. 86-88.

Proposals to reconstitute the U.S. civilian space program are briefly discussed, with an emphasis on political and economic factors. The symbolic nature of the space program (as a way of demonstrating national power and technological competence) is found to be as important today as it was at the establishment of NASA in 1958 and at the inception of the Apollo program in 1961. It is argued that current NASA funding (about $9 billion per year) is sufficient for a space program comprising projects carefully selected to fulfill these symbolic aims. The elements of such a program include renewal of the technology base to assure access to space for all purposes, appropriate use of the Space Shuttle, a significant role for humans in space, a perceived future for space science and exploration, and a Space Station with broad international participation. T.K.

A87-41222
PRIORITIES AND POLICY ANALYSIS - A RESPONSE TO ALEX ROLAND
JOHN M. LOGSDON Space Policy (ISSN 0265-9644), vol. 3, May 1987, p. 112-114.

This response to Alex Roland's article, 'Priorities in space for the USA' (1987), argues that his analysis and conclusions are based on shaky historical evidence. Professor Roland's interpretation of NASA's priorities since 1959 is challenged, and it is pointed out that the manned spaceflight program has widespread support in the U.S. The most important issue, raised by the article but not treated extensively enough, is whether the pursuit of the widely accepted emphasis on manned spaceflight is a large-scale societal mistake. Author

A87-41572
TRENDS IN SPACE TRANSPORTATION
R. F. BRODSKY (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) and M. G. WOLFE (Aerospace Corp., Los Angeles, CA) (IAF, International Astronautical Congress on Space: New Opportunities for all People, 37th, Innsbruck, Austria, Oct. 4-11, 1986) Acta Astronautica (ISSN 0094-5765), vol. 16, 1987, p. 105-112.

An evaluation is made of emerging design trends in third-generation launch vehicle concepts being entertained in the U.S., Western Europe, and Soviet Union. Novel concepts encompass the horizontal-takeoff-and-landing SSTO, Space Shuttle-derived vehicles, and mammoth heavy lift vehicles. The projected performance capabilities and economic feasibility of these systems are compared. While civilian uses for these vehicles will encompass the extension of current communications and earth observation capabilities and the support of further planetary expeditions, military applications will be dominated by the requirements of the reconnaissance and communication tasks that will be included in the Strategic Defense Initiative system as well as by the constitution of a permanent weapons capability in space. O.C.

A87-43156
JAPAN'S SPACE DEVELOPMENT PROGRAMS FOR COMMUNICATIONS - AN OVERVIEW
TADAHISA MORI and TAKASHI IIDA (Ministry of Posts and Telecommunications, Tokyo, Japan) IEEE Journal on Selected Areas in Communications (ISSN 0733-8716), vol. SAC-5, May 1987, p. 624-629. refs

Japan now operates the communications satellite CS-2. A test communications satellite, CS-1, was launched in 1977, and CS-3 will be launched in 1988 as a successor to CS-2. In the area of mobile satellite communications development, Japan is proceeding with an experimental program, ETS-V/EMSS (Engineering Test Satellite-V/Experimental Mobile Satellite System), for which a satellite will be launched in 1987. A follow-up experimental ETS-VI program is planned and will be launched in 1992 as a 2000-kg weight class satellite. Japan has also begun an Experimental Platform Study as a step toward the Geostationary Communication Platform. This paper reviews and explains the scenario, activities, and objectives of satellite communications development in Japan. Author

A87-44375
SPACE THE NEXT TWENTY-FIVE YEARS
THOMAS R. MCDONOUGH (California Institute of Technology, Pasadena) New York, John Wiley and Sons, Inc., 1987, 250 p. refs

Prospects for the next 25 years of the U.S. space program are considered. Technical advances that may lead to lunar bases, the development of the Strategic Defense Initiative, interstellar travel, the use of robots in space, space stations, and new SETI methods are examined. Possible scientific missions to study the inner planets, Mars, the asteroids and comets, the outer planets, and the universe are discussed. C.D.

A87-44683
SOLAR POWER SATELLITES [SOLNECHNYE KOSMICHESKIE ENERGOSTANTSII]
VLADIMIR ALEKSANDROV GRILIKHES Leningrad, Izdatel'stvo Nauka, 1986, 182 p. In Russian. refs

The current status of research on the solar power satellite (SPS) concept is reviewed. Particular consideration is given to the development of microwave power transmission systems and to alternative SPS designs (thermal and photoelectric). Problems connected with the development of SPS systems are considered; these include problems of construction and transportation as well as ecological, social, and economic problems. B.J.

A87-45362*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACECRAFT AND MISSION DESIGN FOR THE SPACENUCLEAR POWERSYSTEM REFERENCE MISSION
WILLIAM D. DEININGER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and ROBERT J. VONDRA (W. J. Schafer Associates, Inc., Arlington, VA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 10 p. refs
(AIAA PAPER 87-2026)

The design and performance of a spacecraft employing arcjet nuclear electric propulsion, suitable for use in the Space Nuclear Power System Reference Mission, are outlined. The vehicle design is based on a 92 kW ammonia arcjet system operating at an I(sp) of 1050 s and an efficiency of 45 percent. The arcjet/gimbal system, power processing unit, and propellant feed-system are described. A 100 kW(e) space nuclear power system is assumed and the spacecraft mass is baselined at 5250 kg excluding the propellant, propellent feed system, and integrated chemical boost engine. A radiation/arcjet efflux diagnostics package is included in the performance analysis. Three mission scenarios are described and are capable of demonstrating the full capability of the space nuclear power source. The missions considered include power system deployment to possible SDI platform orbits and a spacecraft storage mission to an orbit of three times geosynchronous (GEO) with return to GEO corresponding to Delta V's between 7400 m/s, and 7900 m/s. This spacecraft meets the Reference Mission constraint of low developmental risk and is scaleable to power levels projected for future space platforms. Author

A87-46875
WE SHOULDN'T BUILD THE SPACE STATION NOW
ALEX ROLAND (Duke University, Durham, NC) Technology Review (ISSN 0040-1692), vol. 90, July 1987, p. 22, 23.

The present evaluation of the goals and resources of the U.S. space program notes that the construction of a Space Station enjoys only narrow support beyond NASA and the aerospace industry, in the scientific and engineering communities that would be expected to make the greatest use of it. In addition, it is argued that the first phase of Space Station construction will cost far in excess of the $13 billion estimated in April 1987 and be completed significantly later that the '1996 date projected. The Space Station is further alleged to constitute a drain on NASA funds that will starve more productive programs concerned with space science experimentation, and invite more intensive military participation and funding, thereby further complicating the already problematic legal aspects of space use. O.C.

A87-49593*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
WIND-TUNNEL PREFLIGHT TEST PROGRAM FOR AEROASSIST FLIGHT EXPERIMENT
WILLIAM L. WELLS (NASA, Langley Research Center, Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 151-163. refs
(AIAA PAPER 87-2367)

A proposed Aeroassist Flight Experiment (AFE) will simulate return from geosynchronous orbit to low-earth orbit to provide fundamental information about the hypersonic flow conditions surrounding aeroassisted orbital transfer vehicles (AOTV's). Future AOTV design must rely heavily on computational fluid dynamic (CFD) computer codes now under development, since the entry conditions are beyond the simulation capabilities of ground-based test facilities. However, existing codes and best available ground-based test facilities must provide for design of the AFE. The AFE ground-based test program provides data for calibration of existing and developing pertinent CFD codes. Confidence in code prediction capability increases with ability to predict forces and moments, pressure and heat-transfer distributions, shock shapes, and surface streamline directions. The ground-based test program provides these data over a wide range of hypersonic

test parameters. This paper describes the test program, models, facilities, and some representative results. Author

A87-53085
PROSPECTS FOR SPACE SCIENCE
CARL SAGAN (Cornell University, Ithaca, NY; Planetary Society, Pasadena, CA) IN: The human quest in space; Proceedings of the Twenty-fourth Goddard Memorial Symposium, Greenbelt, MD, Mar. 20, 21, 1986 . San Diego, CA, Univelt, Inc., 1987, p. 45-51; Discussion, p. 52-55.
(AAS PAPER 86-106)

The use of the space environment for astronomy and the study of the earth is examined. Particular attention is given to the exploration of the electromagnetic spectrum and the solar system. It is argued that it is necessary to complete the proposed missions to rendezvous with a comet and to send an entry probe into the atmosphere of Titan. The need for the development of a Space Station is discussed, and the benefits of manned versus unmanned missions are considered. The political, social, and economic benefits of a joint U.S./Soviet manned mission to Mars are also discussed. I.F.

A87-53916#
FROM EURECA-A TO EURECA-B
R. MORY (ESA, Directorate of Space Station and Platforms, Paris, France) ESA Bulletin (ISSN 0376-4265), no. 50, May 1987, p. 24-31.

The design and capabilities of Eureca, a free-flying carrier of space payloads to be launched and retrieved by the Space Shuttle, are described. Eureca is 2.3 m long, weighs 4000 kg at launch, and is supported in the bay by two trunnions and a keel fitting. Consideration is given to the thermal-control system, electrical subsystem, data-handling subsystem, attitude and orbit control subsystem, and orbital transfer assembly of Eureca. The first Eureca-A mission is to consist of microgravity experiments (material and life science) that require long-duration space exposure. The growth capabilities of Eureca-A, and the development of a platform with improved in-orbit capabilities and designed for other space science experiments are discussed. Eureca-B, a three-axis stabilized, retrievable carrier with orbital transfer capabilities, has been developed; the upgraded capabilities that Eureca-B should provide are examined. I.F.

A87-53917#
THE OLYMPUS UTILISATION PROGRAMME
C. D. HUGHES and P. BARTHOLOME (ESA, Communications Satellites Dept., Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 50, May 1987, p. 32-41.

Olympus, a proposed large communications satellite, consists of four payloads: the direct broadcast service, the specialized services, the 30/20 GHz advanced communications, and propagation. The configuration, use, and earth-segment hardware for each payload of Olympus are described. The role of the Utilization Board in coordinating the use of the four payloads is discussed. I.F.

N87-20340*# Bionetics Corp., Hampton, Va.
AN ADVANCED TECHNOLOGY SPACE STATION FOR THE YEAR 2025, STUDY AND CONCEPTS Contractor Report, May-Nov. 1986
M. J. QUEIJO, A. J. BUTTERFIELD, W. F. CUDDIHY, C. B. KING, and P. A. GARN Mar. 1987 191 p
(Contract NAS1-18267)
(NASA-CR-178208; NAS 1.26:178208) Avail: NTIS HC A09/MF A01 CSCL 22B

A survey was made of potential space station missions that might exist in the 2020 to 2030 time period. Also, a brief study of the current state-of-the-art of the major subsystems was undertaken, and trends in technologies that could impact the subsystems were reviewed. The results of the survey and study were then used to arrive at a conceptual design of a space station for the year 2025. Factors addressed in the conceptual design included requirements for artificial gravity, synergies between subsystems, and the use of robotics. Suggestions are made relative to more in-depth studies concerning the conceptual design and alternative configurations. Author

N87-20352*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
LARGE SPACE ANTENNAS: A SYSTEMS ANALYSIS CASE HISTORY
LLOYD S. KEAFER, comp. and U. M. LOVELACE, comp. Feb. 1987 19 p
(NASA-TM-89072; NAS 1.15:89072) Avail: NTIS HC A02/MF A01 CSCL 22B

The value of systems analysis and engineering is aptly demonstrated by the work on Large Space Antennas (LSA) by the NASA Langley Spacecraft Analysis Branch. This work was accomplished over the last half-decade by augmenting traditional system engineering, analysis, and design techniques with computer-aided engineering (CAE) techniques using the Langley-developed Interactive Design and Evaluation of Advanced Spacecraft (IDEAS) system. This report chronicles the research highlights and special systems analyses that focused the LSA work on deployable truss antennas. It notes developmental trends toward greater use of CAE techniques in their design and analysis. A look to the future envisions the application of improved systems analysis capabilities to advanced space systems such as an advanced space station or to lunar and Martian missions and human habitats. Author

N87-20356*# National Aeronautics and Space Administration, Washington, D.C. Materials and Structures Div.
FUTURE TRENDS IN SPACECRAFT DESIGN AND QUALIFICATION
SAMUEL L. VENNERI, BRANTLEY R. HANKS (National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.), and LARRY D. PINSON *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 9 p Jul. 1986
Avail: NTIS HC A12/MF A01 CSCL 22A

Material and structures issues that must be resolved in order to develop the technology data base needed to design and qualify the next generation of large flexible spacecraft are discussed. This invoves the development of new ground test and analysis methods and the conduct of appropriate instrumented in-space flight experiments for final verification. A review of present understanding of material behavior in the space environment arid identification of future needs is presented. The dynamic verification and subsequent qualification of a spacecraft structure currently rely heavily on ground-based tests, coupled with the verified analysis model. Future space structures, such as large antennas, Space Station and other large platforms, will be of sizes difficult to test using current ground test methods. In addition to size, other complex factors, such as low natural frequencies, lightweight construction and many structural joints, will also contribute significant problems to the test and qualification process in an Earth-gravity environment. These large spacecraft will also require new technology for controlling the configuration and dynamic deformations of the structures. Future trend in large flexible structures will also involve long-life design missions (10 to 20 years). In low earth orbit (LEO), materials will be subjected to repeated thermal cycles, ultraviolet radiation, atomic oxygen and vacuum. For high orbits such as geo-synchronous earth orbit (GEO), the materials will also be subjected to large doses of high energy electrons and protons. Understanding degradation and material stability over long-mission time periods will confront the designer with many issues that are unresolved today.

N87-20380*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
SOLAR ARRAY FLIGHT EXPERIMENT/DYNAMIC AUGMENTATION EXPERIMENT
LEIGHTON E. YOUNG and HOMER C. PACK, JR. Feb. 1987 72 p
(NASA-TP-2690; NAS 1.60:2690) Avail: NTIS HC A04/MF A01 CSCL 10A

This report presents the objectives, design, testing, and data analyses of the Solar Array Flight Experiment/Dynamic Augmentation Experiment (SAFE/DAE) that was tested aboard Shuttle in September 1984. The SAFE was a lightweight, flat-fold array that employed a thin polyimide film (Kapton) as a substrate for the solar cells. Extension/retraction, dynamics, electrical and thermal tests, were performed. Of particular interest is the dynamic behavior of such a large lightweight structure in space. Three techniques for measuring and analyzing this behavior were employed. The methodology for performing these tests, gathering data, and data analyses are presented. The report shows that the SAFE solar array technology is ready for application and that new methods are available to assess the dynamics of large structures in space. Author

N87-20570*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
STRUCTURES AND DYNAMICS DIVISION RESEARCH AND TECHNOLOGY PLANS FOR FY 1987 AND ACCOMPLISHMENTS FOR FY 1986
KAY S. BALES Mar. 1987 108 p
(NASA-TM-89141; NAS 1.15:89141) Avail: NTIS HC A06/MF A01 CSCL 20K

This paper presents the Objectives, FY 1987 Plans, Approach, and FY 1987 Milestones for the Structures and Dynamics Division's research programs. FY 1986 Accomplishments are presented where applicable. This information is useful in program coordination with other governmental organizations in areas of mutual interest. Author

N87-22551# General Accounting Office, Washington, D. C.
SPACE OPERATIONS: NASA'S USE OF INFORMATION TECHNOLOGY. REPORT TO THE CHAIRMAN, COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
Apr. 1987 67 p
(GAO/IMTEC-87-20; B-226577) Avail: NTIS HC A04/MF A01

An overview of the information technology that is critical to the missions of NASA are provided. Planning, development, and use of information for three areas (Space Transportation System, space stations, and unmanned space exploration) are discussed. B.G.

N87-22560# Committee on Appropriations (U.S. House).
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT-INDEPENDENT AGENCIES APPROPRIATIONS FOR 1988
Washington GPO 1987 1031 p Hearings before the Subcommittee on HUD-Independent Agencies of the Committee on Appropriations, 100th Congress, 1st Session, 7 Apr. 1987
(GPO-73-418) Avail: Subcommittee on HUD-Independent Agencies

The Federal Budget requests by the National Aeronautics and Space Administration for the Fiscal Year 1988 are discussed. These requests cover the expenditure for returning the Shuttle to flight status; commitments to the space station; space science and applications; space research and technology; space tracking and data systems; institutional programs; and construction and maintenance. B.G.

N87-22697# Lawrence Livermore National Lab., Calif.
TOWARD THE YEAR 2000: THE NEAR FUTURE OF THE AMERICAN CIVILIAN AND MILITARY SPACE PROGRAMS
L. L. WOOD and M. Y. ISHIKAWA Jan. 1987 10 p Presented at the 3rd National Space Symposium of the US Space Foundation, Colorado Springs, Colo., 20 Jan. 1987
(Contract W-7405-ENG-48)
(DE87-006467; UCRL-96258; CONF-870162-1) Avail: NTIS HC A02/MF A01

The basic features of the American civilian and military space programs at the end of this century are identified and their histories traced back to the present time, for the surprise-free scenario. Several of the more likely surprises are noted, and their probable impacts sketched. DOE

N87-22703*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
STATUS OF THE MAST EXPERIMENT
BRANTLEY R. HANKS, ANTHONY FONTANA, and JOHN L. ALLEN *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 29-56 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Many sophisticated mathematical control techniques for flexible structures have been devised. The basic problem is that most of them require a relatively accurate mathematical model of the system under control including the dynamics of both the structure and the control system components. Obtaining such a model for either subsystem traditionally has required great effort including a significant validation step based on test data. Because of the quantum increase in complexity over proven methods, promising techniques for the control of flexible structures must be validated in actual hardware experiments before committing to their use in actual spacecraft missions. The Mast experiment system serves as a focus for such validation. It is the first in a series of experiments under the Control of Flexible Structures (COFS) Program at the NASA Langley Research Center. The Mast experiment is a combination of ground tests, orbital flight test, and analysis of a deployable beam under the COFS program. It provides a vehicle for research in structures, structural dynamics, and control issues. Author

N87-22705*# Air Force Rocket Propulsion Lab., Edwards AFB, Calif.
IDENTIFICATION OF LARGE SPACE STRUCTURES: A STATE-OF-PRACTICE REPORT
In NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 85-98 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

An outline of this work is presented. It begins with a schematic flow diagram and a logical flow diagram of the identification process for large space structures (LSS). Next, the task is defined by a structure model definition. A matrix polynomial formulation with a node displacement equation and a state variable formulation with node displacement and velocities are outlined. Further outlined is the identification of LSS on orbit; modeling errors and uncertainties; verification and validation of model; and noise, computations, and data collection. E.R.

N87-22717*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
STATUS REPORT AND PRELIMINARY RESULTS OF THE SPACECRAFT CONTROL LABORATORY EXPERIMENT
JEFFREY P. WILLIAMS *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 359-398 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

The Spacecraft Control Laboratory Experiment (SCOLE) was conceived to provide a physical test bed for investigation of control techniques for large flexible spacecraft. The SCOLE problem is defined as two design challenges. The first challenge is to design control laws for a mathematical model of a large antenna attached to the space shuttle by a long flexible mast. The second challenge

is to design and implement a control scheme on a laboratory representation of the structure modelled in the first part. Control sensors and actuators are typical of those which the control designer would have to deal with on an actual spacecraft. The primary control processing computer is representative of the capacity and speed which may be expected in actual flight computers. A brief description is given of the laboratory apparatus along with some preliminary results of structural dynamics tests and actuator effectiveness tests. Author

N87-22722*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
SOLAR ARRAY FLIGHT DYNAMIC EXPERIMENT
RICHARD W. SCHOCK *In its* Structural Dynamics and Control Interaction of Flexible Structures p 487-504 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 10A

The purpose of the Solar Array Flight Dynamic Experiment (SAFDE) is to demonstrate the feasibility of on-orbit measurement and ground processing of large space structures' dynamic characteristics. Test definition or verification provides the dynamic characteristic accuracy required for control systems use. An illumination/measurement system was developed to fly on space shuttle flight STS-41D. The system was designed to dynamically evaluate a large solar array called the Solar Array Flight Experiment (SAFE) that had been scheduled for this flight. The SAFDE system consisted of a set of laser diode illuminators, retroreflective targets, an intelligent star tracker receiver and the associated equipment to power, condition, and record the results. In six tests on STS-41D, data was successfully acquired from 18 retroreflector targets and ground processed, post flight, to define the solar array's dynamic characteristic. The flight experiment proved the viability of on-orbit test definition of large space structures dynamic characteristics. Future large space structures controllability should be greatly enhanced by this capability. Author

N87-24240# Committee on Commerce, Science, and Transportation (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT
Washington GPO 1987 47 p A bill, S. 1164, referred to the Committee on Commerce, Science and Transportation, 100th Congress, 1st Session, 7 May 1987
(S-REPT-100-87) Avail: US Capitol, Senate Document Room

Appropriations for the National Aeronautics and Space Administration for research and development, space flight, control and data communication, construction of facilities, and research and program management are discussed. B.G.

N87-24496*# National Aeronautics and Space Administration, Washington, D.C.
SPACE STATION: A PROGRAM OVERVIEW
JUDITH H. AMBRUS *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 579-590 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

An overview is presented of the NASA program for the development of the Space Station. A general representation of the initial Space Station complex is shown. The Space Station goals and program objectives are briefly reviewed, as well as the program schedule. An advanced development program and program management approach are also presented. E.R.

N87-24500*# National Aeronautics and Space Administration, Washington, D.C.
LARGE SPACE SYSTEMS TECHNOLOGY AND REQUIREMENTS
JAMES M. ROMERO *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 665-673 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

Only viewgraphs of this presentation are shown. Outlined are NASA's space emphasis, state of technology, space R&D funding trend and civil space technology initiative. Also given are Control/Structures Interaction Technology (CSTI) focus, program focus on driver missions, in-space technology experiments, and in-space R&T approach. E.R.

N87-24506*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
COFS 3 MULTIBODY DYNAMICS AND CONTROL TECHNOLOGY
ROBERT LETCHWORTH, PAUL E. MCGOWAN, and MARC J. GRONET (Lockheed Missiles and Space Co., Sunnyvale, Calif.) *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 757-765 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

One of the results from the model definition study showed that the maximum scale factor for a replica model is .25. This is dictated by the fixed dimensions of the Large Spacecraft Lab. Replica scaling laws were applied to simplified theoretical models of joints and the joint/tube/joint system. The practical interpretation of the results for the specific Space Station configuration under study yielded a number of conclusions which are briefly discussed. Detailed suspension analyses were conducted to evaluate the ability of the suspended scale model to emulate the dynamic behavior of the free-free Space Station. The results indicated only a slight preference for smaller scales. A candidate erectable Space Station joint was fabricated at full scale, 1/4 scale and 1/3 scale in order to assess the comparability of the scaled joints to the full scale behavior. Another important question discussed is how well the inherent damping characteristics of the scaled joints compare to those of the full scale joint. The preliminary definition study yielded three separate scale factor recommendations for the scale model. Author

N87-25024# Committee on Science, Space and Technology (U.S. House).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, FISCAL YEAR 1988
Washington GPO 1987 270 p Report on H.R. 2782 presented by the Committee on Science, Space and Technology to the Committee of the Whole House on the State of the Union, 100th Congress, 1st Session, 7 Jul. 1987
(H-REPT-100-204; GPO-69-356) Avail: NTIS HC A12/MF A01

Appropriations to the National Aeronautics and Space Administration (NASA) are reviewed for research and development; space flight, control, and data communications; construction of facilities, and research and development management. B.G.

N87-26174*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
REVIEW OF LOW EARTH ORBITAL (LEO) FLIGHT EXPERIMENTS
L. LEGER, B. SANTOSMASON, J. VISENTINE, and J. KUMINECZ *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 1-10 1 Jun. 1987
Avail: NTIS HC A09/MF A01 CSCL 22A

The atomic oxygen flux exposure experiments flown on Space Shuttle flights STS-5 and STS-8 are described along with the results of measurements made on hardware returned from the Solar Maximum repair mission (Space Shuttle flight 41-C). In general, these experiments have essentially provided for passive exposure of samples to oxygen fluences of approximately 1 to 3.5 x 10(20) atoms/sq cm. Atmospheric density is used to derive fluence and is dependent on solar activity, which has been on the decline side of the 11-year cycle. Thus, relatively low flight altitudes of less than 300 km were used to acquire these exposures. After exposure, the samples were analyzed using various methods ranging from mass loss to extensive scanning electron microscopy and surface analysis techniques. Results are summarized and implications for the space station are discussed. M.G.

N87-28975# Royal Netherlands Aircraft Factories Fokker, Amsterdam.
THE INMARSAT SOLAR ARRAY: THE FIRST ADVANCED RIGID ARRAY (ARA) TO FLY
PH. J. ZIJDEMANS *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 123-127 Nov. 1986
Avail: NTIS HC A21/MF A01

Design and verification of a project solar array from a generic concept are described. Part level and wing level testing prove that the rigid design option yields a viable and promising solar array family, capable of delivering 30 to 40 W/kg, 10 yr end of life, within the range of application of 1 to 4 kW. ESA

N87-28979# Royal Netherlands Aircraft Factories Fokker, Amsterdam.
THE FOKKER STRONGBACK SOLAR ARRAY
R. ZWANENBURG *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 151-157 Nov. 1986
Avail: NTIS HC A21/MF A01

The Strongback solar array with rigid solar panels offers a design solution for power levels up to 40 kW. The strongback array deploys the panels simultaneously in a synchronized way. The deployment is actuated by deployment springs. Deployment control and retraction is possible. High strength and stiffness in deployed condition is obtained by the preloaded truss-type structure. A life size model of 9 m length demonstrates the performances. ESA

N87-28988# Societe Nationale Industrielle Aerospatiale, Cannes (France).
AEROSPATIALE SOLAR ARRAYS, IN ORBIT PERFORMANCE
J. J. JUILLET, P. SAMSON, L. PELENC, G. HEESCHEN, and K. DETTLAFF (AEG-Telefunken, Wedel, West Germany) *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 213-221 Nov. 1986
Avail: NTIS HC A21/MF A01

Correlation between on-ground prediction and in-orbit mechanical and electrical behavior for Telecom-1, ARABSAT, and SPOT solar arrays is shown. When recorded during the deployment phases, the current growth curves allow a good correlation between mechanical models and flight data. Flight data and the performance predictions are well correlated, within the measurement and model accuracies after adjustment of the cell data with ground flasher test results. For geostationary (GEO) missions, transfer orbit degradation may be due to an equivalent radiation dosage lower than usually computed (5 EI3 e/sq cm). If so, mismatch and calibration losses may be neglected at BOL, for a nominal power output prediction, this being confirmed by SPOT 1 data analysis. Solar cell degradation due to radiation as observed at the beginning of missions seems to be compatible with an annual equivalent radiation dosage of 5 EI3 e/sq cm for GEO missions, and very low for low orbits. ESA

N87-29010# Lockheed Missiles and Space Co., Sunnyvale, Calif.
TEST RESULTS FROM THE SOLAR ARRAY FLIGHT EXPERIMENT
GARY F. TURNER and MIKE D. MENNING *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 365-372 Nov. 1986
Avail: NTIS HC A21/MF A01

The Solar Array Flight Experiment flown on STS-41D demonstrated the readiness of this technology and associated analytical tools to support advanced programs such as Space Station. The solar array, which measured 4.5 x 31.5 m, was successfully deployed and retracted several times during the mission, and electrical, mechanical, and dynamic performance was observed and measured, with excellent correlation with preflight predictions. ESA

N87-29024# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
SPACE 2000 IN EUROPE
K. REINHARTZ and H. STOEWER *In its* Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 451-459 Nov. 1986
Avail: NTIS HC A21/MF A01

European space programs including the Columbus space station, Ariane 5, Hermes, Cluster, XMM, Comet Nucleus Sample Return Mission, Infrared Heterodyne Spectroscopy Mission, the microgravity program, the communications program, data relay systems, navigation systems, and space commercialization are summarized. ESA

N87-29916*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
LEO AND GEO MISSIONS
ENRICO MERCANTI *In* NASA-Lewis Research Center, Space Electrochemical Research and Technology (SERT) p 9-14 Sep. 1987
Avail: NTIS HC A16/MF A01 CSCL 22A

The occurrence of the Challenger disaster in early 1986 caused a severe reevaluation of the space program. Plans already established had to be drastically revised and new plans had to be made. NASA created the Space Leadership Planning Group (SLPG) to formulate space mission plans covering a 50 year period based on Agency goals and objectives responsive to the National Commission on Space recommendations. An interim view of the status of SLPG plans for low altitude and geosynchronous missions is presented. Author

N87-30220# Committee on Appropriations (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
In its Department of Housing and Urban Development - Independent Agencies Appropriation Bill, 1988 p 64-73 6 Oct. 1987
Avail: NTIS HC A06/MF A01

The objectives of the NASA program of research and development are to extend the knowledge of the Earth, its space environment, and the universe; to expand the practical applications of space technology; to develop, operate, and improve unmanned space vehicles; to provide technology for improving the performance of aeronautical vehicles while minimizing the environmental effects and energy consumption; and to assure continued development of the aeronautics and space technology necessary to accomplish national goals. The appropriations necessary to accomplish these goals are examined. B.G.

N87-30221# Committee on Commerce, Science, and Transportation (U.S. Senate).
NASA AUTHORIZATION: AUTHORIZATION OF APPROPRIATIONS FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION FOR FISCAL YEAR 1988
Washington GPO 1987 471 p Hearings on S-Hrg-100-231 before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation, 100th Congress, 1st Session, 3, 19, 26 Feb.; 5 Mar. and 29 Apr. 1987 (GPO-73-245) Avail: NTIS HC A20/MF A01

Appropriations for the FY88 budget for NASA are examined. Prioritization of the four upcoming planetary missions-Galileo, Ulysses, Magellan, and the Mars Observer is discussed. Obstacles which delay the return of the shuttles to service and which delay the building of the space station are also discussed. B.G.

02

ANALYSIS AND DESIGN TECHNIQUES

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

A87-32075
EXPERT SYSTEMS IN SPACE
DAVID LEINWEBER (Inference Corp., Los Angeles, CA) IEEE Expert (ISSN 0885-9000), vol. 2, Spring 1987, p. 26-36. refs

The requirements of expert systems for monitoring and real-time control of processes on space platforms and the Space Station are described, along with a prototype system. Emphasis is on process intelligent control (PICON) written in Lisp, giving the expert system the capability of taking care of problems while maintaining operational continuity. Design criteria include rapid focusing on relevant sensors, fast data collection during critical events, analysis of the temporal history of sensor values, discerning the causes of anomalies from their effects through knowledge of the underlying process structure, and amenability to command sequence inputs. Techniques for using PICON to develop expert systems for specific roles and with the capability of interacting with other systems, for knowledge engineering, and to imbue the system with the ability to reason about data quality are explored. A sample application, control of the electrical power system for the Space Station, is outlined. M.S.K.

A87-32633
A SIMULATION CAPABILITY FOR FUTURE SPACE FLIGHT
RICHARD A. SKIDMORE and ROBERT PULLIAM (Martin Marietta Corp., Denver, CO) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 8 p.
(SAE PAPER 861784)

The limited number of laboratories which can simulate operations in space provide a critical engineering resource. Among these the Martin Marietta Space Operations Simulator Laboratory in Denver provides resources for real-time piloted flight and other human/machine simulations. Its facilities include a 6 degree-of-freedom (DOF), man-rated carriage with a 3 DOF target gimbal, which is computer driven to simulate flight in space. This system can simulate astronaut freeflight, or the relative motion of any two bodies in space. Other resouces include a manipulator arm, a neutral bouyancy tank, a Shuttle Orbiter aft flight deck mockup, and a large screenflight simulator. Recently developed is computer generated imagery for low cost space simulation, with 3-body motion, flexible body dynamics, and simulated handling of payloads at the Space Station. Advanced pilot consoles are used to control simulations and for control-display experiments. New resources are being developed. Author

A87-32655
AN ASSESSMENT OF RECENT ADVANCES IN MODELING AND CONTROL DESIGN OF SPACE STRUCTURES UNDER UNCERTAINTY
HAGOP V. PANOSSIAN (HR Textron, Inc., Valencia, CA) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 9 p. refs
(SAE PAPER 861818)

Uncertainty due to modeling approximations, random noise and tolerances in components, parametric and other errors in space structure modeling and control design create the need for stochastic representations. A short survey of different approaches to modeling of large flexible space structures under uncertainty is presented in the present article. Advantages and disadvantages of various modeling procedures for analysis and control design are briefly discussed and a novel approach is presented that incorporates statistical information in the best available mathematical model, and thus generates a realistic stochastic model for the structure. Moreover, difficulties relative to modeling, testing, validation, and verification in space structures are underlined and discussed. Author

A87-32658* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
STATIC SHAPE CONTROL FOR FLEXIBLE STRUCTURES
G. RODRIGUEZ and R. E. SCHEID, JR. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 16 p. NASA-supported research.
(SAE PAPER 861822)

An integrated methodology is described for defining static shape control laws for large flexible structures. The techniques include modeling, identifying and estimating the control laws of distributed systems characterized in terms of infinite dimensional state and parameter spaces. The models are expressed as interconnected elliptic partial differential equations governing a range of static loads, with the capability of analyzing electromagnetic fields around antenna systems. A second-order analysis is carried out for statistical errors, and model parameters are determined by maximizing an appropriate defined likelihood functional which adjusts the model to observational data. The parameter estimates are derived from the conditional mean of the observational data, resulting in a least squares superposition of shape functions obtained from the structural model. M.S.K.

A87-33560*# Old Dominion Univ., Norfolk, Va.
PRACTICAL IMPLEMENTATION OF AN ACCURATE METHOD FOR MULTILEVEL DESIGN SENSITIVITY ANALYSIS
DUC T. NGUYEN (Old Dominion University, Norfolk, VA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 76-87. NASA-supported research. refs
(AIAA PAPER 87-0718)

Solution techniques for handling large scale engineering optimization problems are reviewed. Potentials for practical applications as well as their limited capabilities are discussed. A new solution algorithm for design sensitivity is proposed. The algorithm is based upon the multilevel substructuring concept to be coupled with the adjoint method of sensitivity analysis. There are no approximations involved in the present algorithm except the usual approximations introduced due to the discretization of the finite element model. Results from the six- and thirty-bar planar truss problems show that the proposed multilevel scheme for sensitivity analysis is more effective (in terms of computer incore memory and the total CPU time) than a conventional (one level) scheme even on small problems. The new algorithm is expected to perform better for larger problems and its applications on the new generation of computer hardwares with 'parallel processing' capability is very promising. Author

A87-35718* Arizona State Univ., Tempe.
A HYBRID NONLINEAR PROGRAMMING METHOD FOR DESIGN OPTIMIZATION
S. D. RAJAN (Arizona State University, Tempe) Journal of Structural Mechanics (ISSN 0360-1218), vol. 14, no. 4, 1986, p. 455-474. refs
(Contract NAG3-580)

Solutions to engineering design problems formulated as nonlinear programming (NLP) problems usually require the use of more than one optimization technique. Moreover, the interaction between the user (analysis/synthesis) program and the NLP system can lead to interface, scaling, or convergence problems. An NLP solution system is presented that seeks to solve these problems by providing a programming system to ease the user-system interface. A simple set of rules is used to select an optimization technique or to switch from one technique to another in an attempt to detect, diagnose, and solve some potential problems. Numerical examples involving finite element based optimal design of space trusses and rotor bearing systems are used to illustrate the applicability of the proposed methodology. Author

A87-44392
ORBITAL DEBRIS ENVIRONMENT RESULTING FROM FUTURE ACTIVITIES IN SPACE
SHIN-YI SU (National Central University, Chung-Li, Republic of China) (COSPAR and IAF, Plenary Meeting, 26th, Topical Meetings and Workshop on Cosmic Dust and Space Debris, 6th, Toulouse, France, June 30-July 11, 1986) Advances in Space Research (ISSN 0273-1177), vol. 6, no. 7, 1986, p. 109-117. refs

A long-term evolution of space debris environment has been simulated by a numerical model. Based on previously published results in many 50-year runs of the 'dynamic model', an 'average model' is derived to reduce the computation time in order to effectively simulate a very-long-term evolution of space debris environment. The evolution of space debris environment is examined with two different future space activities in LEO: (1) involving an increase of the yearly traffic input of new satellites by 2, 5, 10, 20, and 50 percent; and (2) placing ten large space structures of 100 meters diameter in the year 1995 at either 500-km or 1000-km altitude. The results indicate that in a 170-year span from 1983, every space activity listed above results in a rapid runaway of debris fluxes from objects of 4 mm or larger. Author

A87-50473#
SQUARE ROOT STATE ESTIMATOR FOR LARGE SPACE STRUCTURES
YAAKOV OSHMAN and DANIEL J. INMAN (New York, State University, Buffalo) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 617-627. refs
(AIAA PAPER 87-2389)

A square root Kalman filtering algorithm is developed for large space structures, which are modeled by second-order continuous-time finite dynamic models augmented by a discrete-time measurement process. The algorithm is based on the spectral decomposition of the estimation error covariance matrix into its V-Lambda factors, where V is the matrix whose columns are the covariance eigenvectors and Lambda is the diagonal matrix of eigenvalues. The filter consists of a continuous time-update stage and a discrete measurement update stage. In the time-update stage a weighted eigenvector matrix is used instead of using V directly, to avoid the inversion of the mass matrix during the numerical integration process. The measurement update is based on the Singular Valve Decomposition technique. Using the orthogonality property of the covariance eigenvectors, an orthogonalization step is optionally added at the exit from the time-update stage to enhance the filter accuracy. Author

A87-51793
DEVELOPMENT OF FULL SCALE DEPLOYABLE CFRP TRUSS FOR SPACE STRUCTURE
YOSHIAKI SAKATANI and TETSUYA YAMAMOTO (Mitsubishi Heavy Industries, Ltd., Nagoya Aircraft Works, Japan) IN: Composites '86: Recent advances in Japan and the United States; Proceedings of the Third Japan-U.S. Conference on Composite Materials, Tokyo, Japan, June 23-25, 1986 . Tokyo, Japan Society for Composite Materials, 1986, p. 693-700.

A design development program has been conducted for deployable truss structures that may serve as spacecraft platforms, antennas, or solar cell panels. The CFRP composite structural elements investigated as bases of these structures encompass hinged, sliding, and flexibly deformable types. The design chosen for structural performance testing employs CFRP tubing, bundled CFRP cable, and titanium alloy hub fittings. Attention is given to prospective synthetic aperture radar, solar cell panel, and sensor mast applications. O.C.

A87-51870
STRUCTURE AND DESIGN OF SPACECRAFT [KONSTRUKTSIIA I PROEKTIROVANIE KOSMICHESKIKH LETATEL'NYKH APPARATOV]
NIKOLAI IVANOVICH PANICHKIN, IURII VALENTINOVICH SLEPUSHKIN, VIACHESLAV PAVLOVICH SHINKIN, and NIKOLAI ALEKSANDROVI IATSYNIN Moscow, Izdatel'stvo Mashinostroenie, 1986, 344 p. In Russian. refs

The structure and the general principles of the design of spacecraft and launch vehicles are reviewed. In particular, attention is given to the fundamentals of the theory of jet propulsion and space flight mechanics, selection of the main design parameters of launch vehicles and spacecraft, design of manned spacecraft, and design of spacecraft powerplants. The discussion also covers the selection of structural materials, strength analysis of structural elements, and design of specific spacecraft systems and components. V.L.

A87-52966#
IDENTIFICATION OF LARGE SPACE STRUCTURES - A FACTORIZATION APPROACH
TREVOR WILLIAMS (Kingston Polytechnic, Kingston-upon-Thames, England) (Guidance, Navigation and Control Conference, Williamsburg, VA, Aug. 18-20, 1986, Technical Papers, p. 296-302) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Sept.-Oct. 1987, p. 466-473. SERC-supported research. Previously cited in issue 23, p. 3426, Accession no. A86-47432. refs

N87-18878*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SENSITIVITY ANALYSIS FOR LARGE-SCALE PROBLEMS
AHMED K. NOOR and SANDRA L. WHITWORTH *In its* Sensitivity Analysis in Engineering p 357-374 Feb. 1987 Prepared in cooperation with George Washington Univ., Washington, D.C.
Avail: NTIS HC A16/MF A01 CSCL 20K

The development of efficient techniques for calculating sensitivity derivatives is studied. The objective is to present a computational procedure for calculating sensitivity derivatives as part of performing structural reanalysis for large-scale problems. The scope is limited to framed type structures. Both linear static analysis and free-vibration eigenvalue problems are considered. Author

N87-22718*# Boeing Aerospace Co., Seattle, Wash.
FLEXIBLE SPACECRAFT SIMULATOR
In NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 399-416 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 14B

Verification of control algorithms for flexible spacecraft can be done only through simulation and test; these are necessary to understand control/structure interaction (C/SI) sufficiently to design robust controllers for future spacecraft. The objective persued is to develop a low-cost facility which simulates the fundamental problem of C/SI; and to provide accessibility for designs so that experience can be gained in applying various multivariable control design methods to an actual structure. A test facility is being constructed with test elements that provide 3 rigid body and 6 flexible modes, all in the horizontal plane, with frequencies below 2.5 Hz. The control force actuator are on/off air jets with sensing by optical displacement sensors. Loop closure is provided by a digital computer with control algorithms designed using the IAC and MATRIX-X. E.R.

N87-22735*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
A TREETOPS SIMULATION OF THE HUBBLE SPACE TELESCOPE-HIGH GAIN ANTENNA INTERACTION
JOHN P. SHARKEY *In its* Structural Dynamics and Control Interaction of Flexible Structures p 881-902 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

Virtually any project dealing with the control of a Large Space Structure (LSS) will involve some level of verification by digital

computer simulation. While the Hubble Space Telescope might not normally be included in a discussion of LSS, it is presented to highlight a recently developed simulation and analysis program named TREETOPS. TREETOPS provides digital simulation, linearization, and control system interaction of flexible, multibody spacecraft which admit to a point-connected tree topology. The HST application of TREETOPS is intended to familiarize the LSS community with TREETOPS by presenting a user perspective of its key features. B.G.

N87-23683# California Univ., Berkeley. Electronics Research Lab.
AN INTEGRATED, OPTIMIZATION-BASED APPROACH TO THE DESIGN AND CONTROL OF LARGE SPACE STRUCTURES Final Technical Report, 1 Oct. 1983 - 30 Sep. 1986
ELIJAH POLAK, KARL S. PISTER, and ROBERT L. TAYLOR 30 Sep. 1986 10 p
(Contract AF-AFOSR-0361-83)
(AD-A179459; AFOSR-87-0402TR) Avail: NTIS HC A02/MF A01 CSCL 20K

This research was aimed at laying the groundwork for a long term project on the integrated, optimization-based design of large, flexible structures and their control systems. Research was carried out in four areas: (1) modeling the dynamic behavior of simple flexible structures; (2) development of a theory of nondifferentiable optimization algorithms for the solution of problems with max function type inequality constraints; (3) exploration of the use of optimization in optimization-based design of large, flexible structures and their control systems; and (4) interactive software for optimization-based control system design. GRA

N87-29002# Societe Nationale Industrielle Aerospatiale, Cannes (France). Div. Systemes Balistiques et Spatiaux.
COMPUTER SIMULATION OF DEPLOYMENT
CH. ROUX and P. FLAMENT *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 305-311 Nov. 1986
Avail: NTIS HC A21/MF A01

A solar array deployment analysis software, ADAMS, was developed. The ADAMS program improves predictability of dynamic phenomena during deployment; understanding of influences from component flexibilities during deployment; and inflight predictions (geometry, spacecraft motions). These enhance accuracy in optimizing mechanisms as to mechanical strength under deployment loads and latching shocks, motorization factors, and layout on solar array; and predicting all in-orbit deployment (including, possibly, failure) cases to make sure of no unexpected disturbances of spaceflight. Ground tests of deployment geometry can be eliminated. ESA

N87-29193# California Univ., Berkeley. Electronics Research Lab.
OPTIMIZATION-BASED DESIGN OF CONTROL SYSTEMS Final Report, 1 Jul. 1984 - 31 Dec. 1986
ELIJAH POLAK 26 Feb. 1987 4 p
(Contract AF-AFOSR-0250-84)
(AD-A182529; AFOSR-87-0860TR) Avail: NTIS HC A02/MF A01 CSCL 09B

A VAX 11/780 system has been expanded so as to facilitate the implementation of DELIGHT.MIMO, an interactive software system for the solution of optimal, worst case design of multivariable control systems. A SUN workstation - based system has been assembled for experiments in distributed computing for the optimal, integrated design of flexible structures and their control systems. GRA

03

STRUCTURAL CONCEPTS

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

A87-32548
STRUCTURE AND FUNCTION OF DEPLOYABLE TRUSS BEAM (DTB)
SEISHIRO KIBE, YOSHINORI FUJIMORI (National Aerospace Laboratory, Tokyo, Japan), KUNIHIKO KAWAKAMI, TATSUYA HAMAGUCHI, MASAYUKI TOMITA (Mitsubishi Electric Corp., Amagasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 2035-2040.

This paper describes the concept study of the deployable truss beam (DTB) and the development of its key parts (i.e., two types of latches). DTB will be applicable to the common facility of the Space Station and as a supportive bench for specific missions, for it can provide the adequate field of view, cut off contamination from/to the Space Station core and enlarge the working area. The Solar Energy Concentration System, the Large Antenna assembly, and Tether Boomerang systems are supposed to be prospective missions for DTB. Author

A87-33632#
NEW CONCEPTS OF DEPLOYABLE TRUSS UNITS FOR LARGE SPACE STRUCTURES
KIYOSHI TAKAMATSU (Fuji Heavy Industries, Ltd., Tochigi, Japan), JUNJIRO ONODA (Tokyo, University, Japan), and KEN HIGUCHI (Tokyo University of Electrical Engineering, Saitama, Japan) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 695-704. refs
(AIAA PAPER 87-0868)

Concepts of two types of newly proposed deployable hexahedral truss units are presented. One of them, which is called Sliding Hinge Double Fold (SHDF), is the concept which is suitable for the application to the macroscopic two- or three-dimensional structures, while the other, which is called Sliding Hinge Single Fold (SHSF), for the application to the macroscopic one dimensional structures. Comparative study with existing deployable concepts indicates that both concepts can achieve almost the same or in some cases better packaging efficiency with fewer mechanisms for the truss to be folded. Function models were fabricated and tested to demonstrate the kinematic consistency of the concepts. Feasibility study of the application of SHDF to a large antenna structure is also performed. The finite element calculations were carried out to investigate effects of some design parameters on dynamic characteristics of two-dimensional platforms consisting of SHDF. Author

A87-33635#
DESIGN CONSIDERATIONS FOR A ONE-KILOMETER ANTENNA STICK
JANET E. FREEMAN (Hughes Aircraft Co., Space and Communications Group, El Segundo, CA) and CHARLES D. BABCOCK (California Institute of Technology, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 722-727.
(AIAA PAPER 87-0871)

Truss design equations for a large space structure are developed, using beam theory, from position knowledge accuracy requirements imposed on the structure. The maximum allowable spacing between position sensing points on the structure can be

found by iteration. The underlying static structural analysis assumes a uniform transverse acceleration acting on the structure. Calculations for the design of a three-longeron truss are demonstrated for a satellite antenna stick with a required position knowledge accuracy of 0.5 cm. Author

A87-33636*# California Inst. of Tech., Pasadena.
IDENTIFICATION OF THE ZERO-G SHAPE OF A SPACE BEAM
GARY J. BALAS and CHARLES D. BABCOCK (California Institute of Technology, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 728-736. Research supported by the California Institute of Technology and NASA.
(AIAA PAPER 87-0872)

This paper develops an approach for identifying the 0-g shape of a beam/column in a 1-g environment. The determination of the 0-g shape is accomplished by a combination of experiment and analysis. A prototype large space structure beam/column is scaled to laboratory size to demonstrate that the 0-g shape of the structure can be accurately determined in a ground based experiment. Information obtained from the 0-g shape experiment is also used to experimentally measure the stiffness of the beam model. Author

A87-34467#
ALTERNATIVE METHODS TO FOLD/DEPLOY TETRAHEDRAL OR PENTAHEDRAL TRUSS PLATFORMS
JUNJIRO ONODA (Tokyo, University, Japan) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Mar.-Apr. 1987, p. 183-186. refs

Deployable tetrahedral and pentahedral truss platforms call for designs minimizing the number of central joints that must be provided with weight-increasing lock mechanisms; this requires the reduction of the number of struts to be folded, extended or contracted. The methods presented accomplish this goal with a 50-percent reduction in total strut number, by making the number of members to be folded or elongated average six per unit module. In addition, the number of face members to be folded or elongated is decreased to one-third that of a conventional truss platform. O.C.

A87-35327
REDUCED MODELING AND ANALYSIS OF LARGE REPETITIVE SPACE STRUCTURES VIA CONTINUUM/DISCRETE CONCEPTS
KUMAR K. TAMMA and KONG C. SAW (West Virginia University, Morgantown) Computers and Structures (ISSN 0045-7949), vol. 25, no. 3, 1987, p. 321-333. refs

The paper describes reduced modeling/analysis approaches for repetitive lattice configurations with emphasis on tetrahedral-type space structures although the basic concepts can be extended to general repetitive lattice structures as well. The approach is based on transforming the actual configuration to a significantly reduced discrete configuration using scaling transformations and constitutive properties derived via the concept of equivalent continuum. The approach seeks to model/analyze the much simpler and reduced configurations, and transformations and extrapolation/interpolation procedures are utilized to relate back the response to that of the significantly complex actual configurations. The effectiveness and accuracy of the approach is demonstrated via comparisons with detailed analysis of the actual models. Response due to geometric non-linear effects are also evaluated. The overall results obtained are in good agreement with the approach offers potential for further extension. Author

A87-37853
AUTOMATIC GENERATION OF STOCHASTICALLY DOMINANT FAILURE MODES FOR LARGE-SCALE STRUCTURES
YOSHISADA MUROTSU, SATOSHI MATSUZAKI, and HIROO OKADA (Osaka Prefecture, University, Sakai, Japan) JSME International Journal (ISSN 0913-185X), vol. 30, Feb. 1987, p. 234-241. refs

This paper proposes a branch-and-bound technique which generates stochastically dominant structural failure modes by using a lower bound of the complete failure path probability. Combinatorial properties of the failure paths are clarified and it is shown that there are many complete failure paths in a large-scale structure with a high degree of redundancy. Then, in order to reduce the number of computations, heuristic operations are applied to the branch-and-bound algorithm. Finally, the validity of the heuristic operations is demonstrated through numerical examples. Author

A87-38601* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
COMPOSITE TUBES FOR THE SPACE STATION TRUSS STRUCTURE
DAVID E. BOWLES and DARREL R. TENNEY (NASA, Langley Research Center, Hampton, VA) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 414-428. refs

The reference configuration of NASA's Space Station includes a large truss structure to support the various modules and solar arrays. This truss structure will be constructed from tubular members approximately 2 in. in diameter and up to 23 ft in length. The important design considerations for this structure are light weight, high stiffness, dimensional stability, and long-term durability. Continuous graphite fiber reinforced polymer matrix composite materials can meet the structural requirements, and are leading candidates for the tubular truss members. However, there are concerns regarding the durability of composites during the long-term exposure to atomic oxygen and thermal cycling that will be encountered during the Space Station service life. This paper discusses space environmental factors and their effect on composite materials, and provides estimates of the changes in mechanical and thermal properties of composites exposed to long-term Space Station conditions. The effect of low velocity impact and handling damage on composite tube properties is also discussed. Author

N87-21994*# Astro Aerospace Corp., Carpinteria, Calif.
STRUCTURAL CONCEPTS FOR LARGE SOLAR CONCENTRATORS Final Report
JOHN M. HEDGEPETH and RICHARD K. MILLER Washington NASA 1987 66 p
(Contract NAS1-17536)
(NASA-CR-4075; NAS 1.26:4075) Avail: NTIS HC A04/MF A01 CSCL 10A

The Sunflower large solar concentrator, developed in the early 1970's, is a salient example of a high-efficiency concentrator. The newly emphasized needs for solar dynamic power on the Space Station and for large, lightweight thermal sources are outlined. Existing concepts for high efficiency reflector surfaces are examined with attention to accuracy needs for concentration rates of 1000 to 3000. Concepts using stiff reflector panels are deemed most likely to exhibit the long-term consistent accuracy necessary for low-orbit operation, particularly for the higher concentration ratios. Quantitative results are shown of the effects of surface errors for various concentration and focal-length diameter ratios. Cost effectiveness is discussed. Principal sources of high cost include the need for various dished panels for paraboloidal reflectors and the expense of ground testing and adjustment. A new configuration is presented addressing both problems, i.e., a deployable Pactruss backup structure with identical panels installed on the structure after deployment in space. Analytical results show that with reasonable pointing errors, this new concept is capable of concentration ratios greater than 2000. Author

N87-22269# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Unternehmensbereich Apparate.
STRESS AND DEFORMATION ANALYSIS OF LIGHTWEIGHT COMPOSITE STRUCTURES
KARL PFEIFER and JOERG BODE Oct. 1986 17 p Presented at the 37th International Astronautical Congress, Innsbruck, Austria, 4-11 Oct. 1986 Previously announced in IAA as A87-15939
(MBB-UD-489/86; IAF-86-212; ETN-87-99930) Avail: ISSUING ACTIVITY

The influence of thermal stress and deformation on curved beams and shells, particularly for the reflector shells of spacecraft antennas, is reviewed. It is shown that the antenna contour distortions can be minimized by thermal expansion coefficients close to zero for all parts, or be a combination of vertical and horizontal displacements which deform the whole shell within the original contour. ESA

N87-22712*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
VERIFICATION OF LARGE BEAM-TYPE SPACE STRUCTURES
CHOON-FOO SHIH, JAY C. CHEN, and JOHN A. GARBA *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 247-254 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

The verification approach of large beam type space structures is verified. The proposed verification approach consists of two parts. The first part is to remove the gravity effect on the tested substructure and to identify the on-orbit dynamic characteristics of the substructure by using the measurements of the ground test. A scaling law is also established to define the critical length of the structure which can be tested in 1-g field without incurring a buckling problem. The second part is to develop an adequate scaling law to extrapolate the dynamic characteristics of the prototype structure by using results from the substructure. The verification approaches are demonstrated on two typical structural configurations, the feed support structure of a wrap-rip antenna and a candidate shuttle flight experiment. The results indicate that it is practical to verify the on-orbit dynamic characteristics of these structures by using the proposed approach. Author

N87-22725*# Boeing Aerospace Co., Seattle, Wash.
EQUIVALENT BEAM MODELING USING NUMERICAL REDUCTION TECHNIQUES
J. M. CHAPMAN and F. H. SHAW *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 567-594 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

Numerical procedures that can accomplish model reductions for space trusses were developed. Three techniques are presented that can be implemented using current capabilities within NASTRAN. The proposed techniques accomplish their model reductions numerically through use of NASTRAN structural analyses and as such are termed numerical in contrast to the previously developed analytical techniques. Numerical procedures are developed that permit reductions of large truss models containing full modeling detail of the truss and its joints. Three techniques are presented that accomplish these model reductions with various levels of structural accuracy. These numerical techniques are designated as equivalent beam, truss element reduction, and post-assembly reduction methods. These techniques are discussed in detail. E.R.

N87-24501*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DESIGN, CONSTRUCTION, AND UTILIZATION OF A SPACE STATION ASSEMBLED FROM 5-METER ERECTABLE STRUTS
MARTIN M. MIKULAS, JR. and HAROLD G. BUSH *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 675-699 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The primary characteristics of the 5-meter erectable truss is presented, which was baselined for the Space Station. The relatively large 5-meter truss dimension was chosen to provide a deep beam for high bending stiffness yet provide convenient mounting locations for space shuttle cargo bay size payloads which are approx. 14.5 ft (4.4 m) in diameter. Truss nodes and quick attachment erectable joints are described which provide for evolutionary three dimensional growth and for simple maintenance and repair. A mobile remote manipulator system is described which is provided to assist in station construction and maintenance. A discussion is also presented of the construction of the Space Station and the associated extravehicular active (EVA) time.
Author

N87-25349*# Astro Aerospace Corp., Carpinteria, Calif.
DESIGN, DEVELOPMENT AND FABRICATION OF A DEPLOYABLE/RETRACTABLE TRUSS BEAM MODEL FOR LARGE SPACE STRUCTURES APPLICATION Final Report
LOUIS R. ADAMS Jun. 1987 64 p
(Contract NAS1-18013)
(NASA-CR-178287; NAS 1.26:178287; AAC-TN-1150-REV-A)
Avail: NTIS HC A04/MF A01 CSCL 22B

The design requirements for a truss beam model are reviewed. The concept behind the beam is described. Pertinent analysis and studies concerning beam definition, deployment loading, joint compliance, etc. are given. Design, fabrication and assembly procedures are discussed. Author

N87-25492* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DEPLOYABLE GEODESIC TRUSS STRUCTURE Patent
MARTIN M. MIKULAS, JR., inventor (to NASA), MARVIN D. RHODES, inventor (to NASA), and J. WAYNE SIMONTON, inventor (to NASA) 7 Jul. 1987 9 p Filed 20 Feb. 1986 Supersedes N86-24867 (24 - 15, p 2443)
(NASA-CASE-LAR-13113-1; US-PATENT-4,677,803; US-PATENT-APPL-SN-831371; US-PATENT-CLASS-52-646; US-PATENT-CLASS-52-108; US-PATENT-CLASS-52-632; US-PATENT-CLASS-182-152) Avail: US Patent and Trademark Office CSCL 13I

A deployable geodesic truss structure which can be deployed from a stowed state to an erected state is described. The truss structure includes a series of bays, each bay having sets of battens connected by longitudinal cross members which give the bay its axial and torsional stiffness. The cross members are hinged at their mid point by a joint so that the cross members are foldable for deployment or collapsing. The bays are deployed and stabilized by actuator means connected between the mid point joints of the cross members. Hinged longerons may be provided to also connect the sets of battens and to collapse for stowing with the rest of the truss structure.
Official Gazette of the U.S. Patent and Trademark Office

N87-25576*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
COLLECT LOCK JOINT FOR SPACE STATION TRUSS Patent Application
CLARENCE J. WESSELSKI, inventor (to NASA) 1 Apr. 1987 19 p
(NASA-CASE-MSC-21207-1; US-PATENT-APPL-SN-032818)
Avail: NTIS HC A02/MF A01 CSCL 13K

A lock joint for a space station has a plurality of struts joined together in a predetermined configuration by node point fittings. The fittings have removable inserts therein. The lock joint has an elongated housing connected at one end to a strut. A split-fingered collet is mounted within the housing for movement reciprocally therein. A handle on the housing is connected to the collet for moving the collet into the insert where the fingers of the collet expand to lock the joint to the fitting. NASA

N87-25586*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
BI-STEM GRIPPING APPARATUS Patent Application
FRED G. SANDERS, inventor (to NASA) 3 Jun. 1987 13 p
(NASA-CASE-MFS-28185-1; US-PATENT-APPL-SN-056930)
Avail: NTIS HC A02/MF A01 CSCL 13I

This invention relates to devices which grip cylindrical structures and more particularly to a device which has three arcuate gripping members having frictional surfaces for gripping and compressing a bi-stem. The bi-stem gripping apparatus is constructed having a pair of side gripping members, and an intermediate gripping member disposed between them. Sheets of a gum stock silicone rubber with frictional gripping surfaces are bonded to the inner region of the gripping members and provide frictional engagement between the bi-stem and the apparatus. A latch secures the gripping apparatus to a bi-stem, and removable handles are attached, allowing an astronaut to pull the bi-stem from its cassette. A tethering ring on the outside of the gripping apparatus provides a convenient point to which a lanyard may be attached. NASA

N87-25606*# Lockheed Missiles and Space Co., Sunnyvale, Calif.
PRELIMINARY DESIGN, ANALYSIS, AND COSTING OF A DYNAMIC SCALE MODEL OF THE NASA SPACE STATION Final Report
M. J. GRONET, E. D. PINSON, H. L. VOQUI, E. F. CRAWLEY, and M. R. EVERMAN (AEC-ABLE Engineering Co., Inc., Goleta, Calif.) Washington NASA Jul. 1987 208 p
(Contract NAS1-18229)
(NASA-CR-4068; NAS 1.26:4068; LMSC-F177633) Avail: NTIS HC A10/MF A01 CSCL 20K

The difficulty of testing the next generation of large flexible space structures on the ground places an emphasis on other means for validating predicted on-orbit dynamic behavior. Scale model technology represents one way of verifying analytical predictions with ground test data. This study investigates the preliminary design, scaling and cost trades for a Space Station dynamic scale model. The scaling of nonlinear joint behavior is studied from theoretical and practical points of view. Suspension system interaction trades are conducted for the ISS Dual Keel Configuration and Build-Up Stages suspended in the proposed NASA/LaRC Large Spacecraft Laboratory. Key issues addressed are scaling laws, replication vs. simulation of components, manufacturing, suspension interactions, joint behavior, damping, articulation capability, and cost. These issues are the subject of parametric trades versus the scale model factor. The results of these detailed analyses are used to recommend scale factors for four different scale model options, each with varying degrees of replication. Potential problems in constructing and testing the scale model are identified, and recommendations for further study are outlined. Author

N87-25805# Massachusetts Inst. of Tech., Cambridge. Space Systems Lab.
DEVELOPMENT OF INTELLIGENT STRUCTURES USING FINITE CONTROL ELEMENTS IN A HIERARCHIC AND DISTRIBUTED CONTROL SYSTEM Final Report, 15 May 1985 - 14 Jan. 1986
DAVID W. MILLER, BENJAMIN A. WARD, EDWARD F. CRAWLEY, and WILLIAM WIDNALL 12 Jan. 1987 324 p
(Contract F49620-84-K-0010)
(AD-A179711; MIT-SSL-1-87; AFOSR-87-0560TR) Avail: NTIS HC A14/MF A01 CSCL 22B

Conclusions are drawn from the theoretical optimization of inertial reaction devices. Three different optimization procedures yielded almost identical absorber designs providing confidence in the tuning process. The optimal passive components of the control actuator were found to be equal to those of the optimal absorber. This allows passive damping to be added without significant mass penalty. When using an inertial device to increase damping in several modes, it is desirable to tune the frequency of the device to the lowest mode and adjust the damping accordingly. Experimentally, an inertial reaction device was used effectively as both a passive vibration absorber and a control actuator, passively tuned as an absorber, verifying the results of the tuning analysis that stated that passive tuning compliments active control. This dual purpose device resulted in a mass savings, increased modal controllability, and reduced target mode disturbance transmission. Additional passive damping increases gain margin for feedback systems that are conditionally stable and allows a form of passive damping enhancement in the event of control system failure. These space realizable experiments were found to be important in determining performance limitations due to instrumentation instabilities, friction in relative motion actuators, and actuator saturation at low frequencies. Uniformity in the positive definite, dual feedback matrix allowed better performance before the onset of instrumentation. GRA

N87-26075# Erno Raumfahrttechnik G.m.b.H., Bremen (West Germany).
DEVELOPMENT OF EXPERIMENTAL/ANALYTICAL CONCEPTS FOR STRUCTURAL DESIGN VERIFICATION Final Report
E. HORNUNG, K. ECKHARDT, E. ERBEN, E. HUENERS, N. NIEDBAL, H. OERY, and H. GLASER Paris, France ESA Feb. 1985 139 p
(Contract ESTEC-5166/82-NL-PB(SC))
(ESA-CR(P)-2340; ETN-87-99991) Avail: NTIS HC A06/MF A01

Spacecraft structure analytical and test verification methods were reviewed. It is concluded that in general adequate verification capabilities exist to provide the required level of confidence in spacecraft projects. When optimal verification procedures are performed in a project low safety margins might be sufficient for the realization of the project. However, the employment of minimum safety margins, i.e., margins as requested by the launcher authorities, is not encountered in practice in the space industry because of user uncertainty as to launcher loads. To improve spacecraft design and verification activities better knowledge is required for launcher loads as they arise in reality. The recording of flight responses and loads during launch is essential for an overall improvement of design and verification activities. Such activities allow the employment of representative safety margins, and eliminate excessive margins currently employed to cover load uncertainties. ESA

N87-26085*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
EXPERIMENTAL EVALUATION OF SMALL-SCALE ERECTABLE TRUSS HARDWARE
DAVID M. MCGOWAN and MARK S. LAKE Jun. 1987 15 p
(NASA-TM-89068; NAS 1.15:89068) Avail: NTIS HC A02/MF A01 CSCL 22B

To aid in the prediction of the dynamic behavior of the space station, a one-tenth scale dynamic test model is to be constructed of commercially available, small scale truss hardware. Tests have been performed to determine the axial stiffness characteristics and failure loads of the truss joint. A parametric study has shown that the stiffness of the joint increases as the attachment bolt torque value is increased. Furthermore, at torque values equal to or higher than 250 in-lbs, hysteresis in the load-deflection curve is essentially eliminated. Also, the joint stiffness remained relatively constant between specimens. The effective stiffness of a joint subassembly tested is 76 percent that of the strut. Tensile and compressive failure occurred in the region of the bonded plug, with lower failure loads corresponding to compressive loadings. Author

N87-27260*# Old Dominion Univ., Norfolk, Va. Dept. of Civil Engineering.
SUBSTRUCTURE ANALYSIS USING NICE/SPAR AND APPLICATIONS OF FORCE TO LINEAR AND NONLINEAR STRUCTURES Progress Report, period ending 30 Jun. 1987
ZIA RAZZAQ, VENKATESH PRASAD, SIVA PRASAD DARBHAMULLA, RAVINDER BHATI, and CAI LIN Aug. 1987 129 p
(Contract NAG1-438)
(NASA-CR-180317; NAS 1.26:180317) Avail: NTIS HC A07/MF A01 CSCL 20K

Parallel computing studies are presented for a variety of structural analysis problems. Included are the substructure planar analysis of rectangular panels with and without a hole, the static analysis of space mast, using NICE/SPAR and FORCE, and substructure analysis of plane rigid-jointed frames using FORCE. The computations are carried out on the Flex/32 MultiComputer using one to eighteen processors. The NICE/SPAR runstream samples are documented for the panel problem. For the substructure analysis of plane frames, a computer program is developed to demonstrate the effectiveness of a substructuring technique when FORCE is enforced. Ongoing research activities for an elasto-plastic stability analysis problem using FORCE, and stability analysis of the focus problem using NICE/SPAR are briefly summarized. Speedup curves for the panel, the mast, and the frame problems provide a basic understanding of the effectiveness of parallel computing procedures utilized or developed, within the domain of the parameters considered. Although the speedup curves obtained exhibit various levels of computational efficiency, they clearly demonstrate the excellent promise which parallel computing holds for the structural analysis problem. Source code is given for the elasto-plastic stability problem and the FORCE program.
Author

N87-27713* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
PRELOADED SPACE STRUCTURAL COUPLING JOINTS Patent
MARVIN D. RHODES, inventor (to NASA) 4 Aug. 1987 10 p Filed 30 Jul. 1986 Supersedes N86-21630 (24 - 23, p 3565
(NASA-CASE-LAR-13489-1; US-PATENT-4,684,156; US-PATENT-APPL-SN-890445; US-PATENT-CLASS-285-27; US-PATENT-CLASS-285-31; US-PATENT-CLASS-285-86; US-PATENT-CLASS-285-373; US-PATENT-CLASS-285-421; US-PATENT-CLASS-403-341) Avail: US Patent and Trademark Office CSCL 22B

A coupling device for tubular members of large truss structures with a locking collar being the only moving part is described. Each tubular member is constructed with an end bell section that has a belled flange with a mating face, and a necked area which is smaller in diameter than the tubular members to be joined. A split ring is affixed to each tubular member and is constructed so that when two tubular members are laterally moved into axial alignment and the collar is rotated over it, the split ring loads the joint with axial forces by pressing the belled flange mating surfaces together, and a preloading force is provided by the collar mating with a taper on the outside of the split rings. All free play is thereby removed by preloaded force. A major object is to provide an ability to remove and replace individual tubular members without disturbing other structural parts of a truss structure. An additional anticipated use of this joint is to couple high pressure fluid lines.
Official Gazette of the U.S. Patent and Trademark Office

N87-28581*# Boeing Aerospace Co., Seattle, Wash.
SPACE STATION INTEGRATED WALL DESIGN AND PENETRATION DAMAGE CONTROL Final Report
A. R. CORONADO, M. N. GIBBINS, M. A. WRIGHT, and P. H. STERN Jul. 1987 257 p
(Contract NAS8-36426)
(NASA-CR-179165; NAS 1.26:179165; D180-30550-1) Avail: NTIS HC A12/MF A01 CSCL 22B

A methodology was developed to allow a designer to optimize the pressure wall, insulation, and meteoroid/debris shield system of a manned spacecraft for a given spacecraft configuration and threat environment. The threat environment consists of meteoroids and orbital debris, as specified for an arbitrary orbit and expected lifetime. An overall probability of no penetration is calculated, as well as contours of equal threat that take into account spacecraft geometry and orientation. Techniques, tools, and procedures for repairing an impacted and penetrated pressure wall were developed and tested. These techniques are applied from the spacecraft interior and account for the possibility of performing the repair in a vacuum. Hypervelocity impact testing was conducted to: (1) develop and refine appropriate penetration functions, and (2) determine the internal effects of a penetration on personnel and equipment.
Author

N87-28582*# Boeing Aerospace Co., Seattle, Wash.
SPACE STATION INTEGRATED WALL DESIGN AND PENETRATION DAMAGE CONTROL. TASK 3: THEORETICAL ANALYSIS OF PENETRATION MECHANICS Final Report
M. D. BJORKMAN, J. D. GEIGER, and E. E. WILHELM Jul. 1987 150 p
(Contract NAS8-36426)
(NASA-CR-179166; NAS 1.26:179166; D180-30550-2) Avail: NTIS HC A07/MF A01 CSCL 22B

The efforts to provide a penetration code called PEN4 version 10 is documented for calculation of projectile and target states for the impact of 2024-T3 aluminum, R sub B 90 1018 steel projectiles and icy meteoroids onto 2024-T3 aluminum plates at impact velocities from 0 to 16 km/s. PEN4 determines whether a plate is perforated by calculating the state of fragmentation of projectile and first plate. Depth of penetration into the second to n sup th plate by fragments resulting from first plate perforation is determined by multiple cratering. The results from applications are given.
Author

N87-28973# Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost. Space Div.
EURECA APPLICATION OF THE RETRACTABLE ADVANCED RIGID ARRAY (RARA) SOLAR ARRAY
J. DEKAM *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 105-114 Nov. 1986 Avail: NTIS HC A21/MF A01

A reusable, retractable solar array for low Earth orbit free flyers was designed. The design can be applied for power up to 10 kW, but can be extended. The rigid concept allows for a simple and therefore reliable and cost effective design. A high design flexibility with respect to wing lay out and interface is featured. It will be applied on EURECA in a 5 kW version.
ESA

N87-28986# Societe Nationale Industrielle Aerospatiale, Cannes (France).
SPOT SOLAR ARRAY IN-ORBIT DEPLOYMENT RESULTS EVALUATION
PH. BOBO *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 203-206 Nov. 1986 Avail: NTIS HC A21/MF A01

The design and deployment sequence of the SPOT satellite flexible solar array are recalled. The analysis tools whereby in-orbit behavior can be retrieved are described. Results from telemetry deliveries are presented and evaluated to derive solar generator flight data. Performances are compared to predictions or simulations. The performance budget shows good performance-prediction correlation, increasing confidence level for this solar array subsystem, three specimens of which are in production.
ESA

N87-29006# Indian Space Research Organization, Bangalore.
DESIGN AND FABRICATION OF STRETCHED ROHINI SATELLITE-1 SOLAR ARRAY
N. SRINIVASAMURTHY, M. SUDHAKAR, B. L. AGRAWAL, and A. U. GOPALAN (Indian Space Research Organization, Trivandrum.) *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 333-342 Nov. 1986
Avail: NTIS HC A21/MF A01

The SROSS satellites solar array studies and selected configuration are described. Mission demands are such that spinning and three axis stabilized satellites are required. A single bus satellite design catering to both types of mission requirements was envolved, imposing severe constraints on the solar array design. The satellite structure is an octagonal cylinder. The eight deployed panels are stowed against the corresponding body mounted fixed panels. The deployed panels contain cell on both sides and each deployed panel makes an angle of 135 deg with the corresponding body mounted panel when deployed. A modification in this configuration is to distribute the deployable panels on each end of the octagon. The SROSS satellites require 96 W raw power for 3 axis stabilized versions, 66 W for spinners. ESA

N87-29012# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
THE EXTENDABLE AND RETRACTABLE MAST AS SUPPORTING TOOL FOR RIGID SOLAR ARRAYS
M. SCHMID *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 377-383 Nov. 1986
Avail: NTIS HC A21/MF A01

The Extendable and Retractable Mast (ERM) was developed to deploy and retract large foldable structures like solar arrays. By adequate choice of the interfaces between solar array and ERM it is possible to deploy, position, and retract large rollable or foldable, rigid, or flexible solar arrays up to the 40 m deployment range. Since for the attachment of rollable and foldable solar arrays only a tip and base interface on the ERM is necessary, different configurations providing intermediate attachment points along the mast were investigated to deploy and retract rigid solar array panels also. ESA

N87-29700# *Foster-Miller Associates, Inc., Waltham, Mass.*
NET-SHAPE TUBULAR STRUCTURES FROM ORDERED POLYMERS Final Report, 15 Nov. 1986 - 12 Jun. 1987
RICHARD W. LUSIGNEA and JAMES L. RACICH 12 Jun. 1987 80 p
(Contract N00014-86-C-0849)
(AD-A183867; NAV-0849-FM-8690) Avail: NTIS HC A05/MF A01 CSCL 11B

Ordered polymers can be used to make very lightweight, high modulus tubes with near-zero coefficient of thermal expansion (CTE) in the axial direction. These tubes and joints will be the building blocks of SDI space structures. Net-shape processing will produce thin-walled (0.050 in. or less) tubes with the proper orientation built in by a special extrusion process combined with interpenetrating network (IPN) materials which provide reinforcement at a submicron level. Ordered polymer tubes were extruded with controlled biaxial orientation and IPN materials were produced using sol-gel glass processing methods. The combination of controlled microstructure orientation and reinforcement at the molecular level produces a new form of materials with outstanding properties, tailorability, and rapid fabrication. GRA

N87-29859*# AEC-Able Engineering Co., Inc., Goleta, Calif.
FOLDING, ARTICULATED, SQUARE TRUSS
ROBERT M. WARDEN *In* NASA-Lyndon B. Johnson Space Center, The 21st Aerospace Mechanisms Symposium p 1-17 May 1987
Avail: NTIS HC A16/MF A01 CSCL 13I

A larger, stronger deployable boom was developed to handle the requirements of larger, heavier payloads in space. The main components of the boom and its deployer are described and their functions explained. Desirable features of the boom are identified and physical properties are reported. Author

04

STRUCTURAL AND THERMAL ANALYSIS

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

A87-32175*# Texas A&M Univ., College Station.
DETERMINATION OF THE CROSS-SECTIONAL TEMPERATURE DISTRIBUTION AND BOILING LIMITATION OF A HEAT PIPE
G. P. PETERSON (Texas A & M University, College Station) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 1, April 1987, p. 189-192.
(Contract NAS8-4496)

A computer model is developed and verified which is capable of determining the cross-sectional temperature distribution within a heat pipe with an attached radiator fin; such heat pipes would be plugged into contact heat exchangers designed to carry heat from a space station habitation module to the radiator elements through a centralized fluid loop. The model can furnish information for determining the susceptibility of the monogroove heat pipe to boiling, as well as the location and magnitude of that boiling. O.C.

A87-32336* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
VALIDATION OF LARGE SPACE STRUCTURES BY GROUND TESTS
B. K. WADA, C. P. KUO, and R. J. GLASER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 465-474. refs
(Contract NAS7-918)

The paper presents concepts designed to validate, through the use of ground tests, mathematical models of continuous type structures and structures comprised of interconnecting subsystems. For continuous-type structures, a multiple boundary condition test approach is considered in which the basic idea is to perform a large number of tests using artificial boundary conditions from which good ground test data can be obtained. The test ensures an arbitrarily large number of test data for use in the validation and updating of the mathematical model. Another approach, applicable to structures comprised of subsystems, involves the identification of significant structural elements for the system dynamic model which are not validated by standard modal tests of the subsystems. K.K.

A87-32339
MODEL STUDY OF SIMPLEX MASTS
MICHIHIRO NATORI, MASAMORI SAKAMAKI, KORYO MIURA (Tokyo, University, Japan), KAKUMA OKAZAKI (Japan Aircraft Manufacturing Co., Ltd., Yokohama, Japan), and MASAKI TABATA (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 489-496. refs

Large deformation properties of longerons and spacers of a coilable lattice mast for space applications are investigated. Some small models for laboratory experiments are manufactured and tested to get a fundamental understanding of the mechanism of a coilable lattice mast. Deformation patterns of a mast at each deployment stage are clearly shown, and the effects of material stiffness are also investigated. Author

A87-32340
DESIGN CONSIDERATION OF MECHANICAL AND DEPLOYMENT PROPERTIES OF A COILABLE LATTICE MAST
K. OKAZAKI, S. SATO, A. OBATA (Japan Aircraft Manufacturing Co., Ltd., Yokohama, Japan), M. NATORI, and K. MIURA (Tokyo, University, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 497-502.

An analytical approach is presented to extract suitable values of elements for fundamental design of coilable lattice masts. The large deflection of each element in the transition zone makes the analysis difficult. In this paper, deploying mode analyses using strain energy calculations with some reasonable assumptions based on experimental results are presented. Author

A87-32368
THERMAL VERIFICATION METHOD FOR LARGE SIZED SPACECRAFT
SATOSHI HAYASHIGUCHI, TATSUSABURO NAKAMURA (Kawasaki Heavy Industries, Ltd., Technical Institute, Akashi, Japan), AKIRA OHNISHI, and TOMONAO HAYASHI (Tokyo, University, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 697-702.

Space exploration in recent years has made possible the transport of a large payload with a large-sized vehicle, motivated by the advent of the Shuttle, which is encouraging the use of space for a host of new activities. As it becomes difficult to make a thermal balance test on the full scale necessary for thermal design with the enlargement of spacecraft, thermal balance test by a divided module is preferable and an experiment was conducted to develop this method. The modular test method divides a spacecraft into plural modules and makes a thermal balance test for each module, to evaluate the thermal design of a full-scale spacecraft. It arises in this method that a part of each divided module makes another heat exchange between its divided face and the chamber shroud. To solve this, a method of simulating the quantity of radiative heat exchange between each module by means of an infrared panel was adopted. In order to confirm the propriety of this modular test method, a thermal balance test using a simple box-shaped model was made, and good agreement was attained between the estimated temperature of the full-scale model obtained from the modular test method and the measured temperature of the full-scale model. Author

A87-32370
DEVELOPMENT OF FLUID LOOP SYSTEM FOR SPACECRAFT
MASAO FURUKAWA, YASUO NAKAMURA, RYOUICHI IMAI (National Space Development Agency of Japan, Sakura), TAKAHIRO KOMATSU, KIYOSHI TANAKA (NEC Corp., Yokohama, Japan) et al. IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 711-716.

This paper describes experimental results on the stability of temperature control for a single-phase fluid loop system being developed for possible use of a large geostationary satellite and a free-flyer. The developed model has 200 W of heat removal capacity and a weight of 20 Kg. As a result of temperature control via a bypass valve, the temperature of the cold plates arranged in series can be controlled within + or 3.0 C, and, in case of cold plates arranged in parallel, control is within + or - 3.5 C. Author

A87-32405
THERMAL DEFORMATION AND ELECTRICAL DEGRADATION OF ANTENNA REFLECTOR WITH TRUSS BACKSTRUCTURE
KOHEI OHATA and TAKEHIKO KOBAYASHI (Nippon Telegraph and Telephone Public Corp., Yokosuka Electrical Communications Laboratory, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 955-960.

A large high-precision reflector required for 20/30 GHz multibeam on-board antennas is investigated. A reflector with a truss back-structure constructed of CFRP is expected to have good performance in suppression of excessive thermal deformations in space. The thermal deformation characteristics of this antenna are estimated both experimentally and analytically. The effects of the deformation on electrical performance are analyzed, giving special attention to the multibeam applications. It is observed that the periodic deformation has a pronounced effect on sidelobe level. Author

A87-32662
DEVELOPMENT STATUS OF A TWO-PHASE THERMAL MANAGEMENT SYSTEM FOR LARGE SPACECRAFT
TIMOTHY J. BLAND, ING-YOMN CHEN, and DAVID G. C. HILL (Sundstrand Corp., Rockford, IL) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 9 p.
(SAE PAPER 861828)

Design features and results from testing of a prototype components of a two-phase thermal management system (TPTMS) for the Space Station are summarized. The TPTMS is comprised of an evaporator (heat addition) loop and a condenser (heat rejection) loop, both of which interface through a rotary fluid management device (RFMD). System functions which are to transfer heat from the Station to space through radiators are described, noting methods which keep the RFMD hot end at a constant temperature to control the liquid temperatures inside the evaporator. The TPTMS has been configured to accommodate growth loads to avoid the need for future capacity upgrades. Results are provided from tests of prototype RFMD, condenser and back pressure regulator valve. The assembled prototype is to undergo hypergravity and microgravity flight tests on a KC-135 aircraft. M.S.K.

A87-32666* Hughes Aircraft Co., Torrance, Calif.
HIGH CAPACITY DEMONSTRATION OF HONEYCOMB PANEL HEAT PIPES
H. J. TANZER, M. R. CERZA, JR. (Hughes Aircraft Co., Torrance, CA), and J. B. HALL (NASA, Langley Research Center, Hampton, VA) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 18 p. refs
(SAE PAPER 861833)

High capacity honeycomb panel heat pipes were investigated as heat rejection radiators on future space platforms. Starting with a remnant section of honeycomb panel measuring 3.05-m long by 0.127-m wide that was originally designed and built for high-efficiency radiator fins, features were added to increase thermal transport capacity and thus permit test evaluation as an integral heat transport and rejection radiator. A series of subscale panels were fabricated and reworked to isolate individual enhancement features. Key to the enhancement was the addition of a liquid sideflow that utilizes pressure priming. A prediction model was developed and correlated with measured data, and then used to project performance to large, space-station size radiators. Results show that a honeycomb panel with 5.08-cm sideflow spacing and core modification will meet the design load of a 50 kW space heat rejection system. Author

A87-33564#
AN EQUIVALENT CONTINUUM ANALYSIS PROCEDURE FOR SPACE STATION LATTICE STRUCTURES
JOHN O. DOW and STEPHEN A. HUYER (Colorado, University, Boulder) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 110-122. refs
(AIAA PAPER 87-0724)

A procedure for determining the equivalent continuum properties of a structure composed of repeated patterns of discrete elements with both displacement and rotation coordinates is presented. These nodal coordinates are transformed to rigid body and strain gradient variables using a polynomial representation. The set of independent strain gradient variables is identified by inspection and depends on the geometry of the structure being modeled. The possibility of introducing errors by requiring the analyst to supply the strain gradient terms directly is eliminated. The procedure is applied to six example problems, including two in which the effect of structural damage on the stiffness characteristics of the structure is analyzed. The compactness of the procedure makes it particularly suited for the preliminary design stage and implementation on personal computers. Author

A87-33639#
EFFECT OF TRANSVERSE SHEARING FORCES ON BUCKLING AND POSTBUCKLING OF DELAMINATED COMPOSITES UNDER COMPRESSIVE LOADS
G. A. KARDOMATEAS and D. W. SCHMUESER (GM Research Laboratories, Warren, MI) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 757-765. refs
(AIAA PAPER 87-0877)

The deformation of delaminated composites under axial compression is analyzed by a one-dimensional beam-plate model. In this model, a formulation that accounts for the transverse shear effects is also presented. Using the perturbation technique, analytical solutions for the critical instability load and the postbuckling deflections are obtained. All possible instability modes, namely local delamination buckling, global plate buckling and coupled global and local (mixed) buckling are considered. Specific emphasis is placed on studying the transverse shear effects on both the critical load and the postcritical characteristics, as well as the influence of the geometry such as that of the location of the delamination across the thickness. The postbuckling solution is used in conjunction with a J-integral formulation to study the postcritical characteristics with respect to possible quasi-static extension of the delamination and the energy absorption capacity of a beam. Author

A87-33670*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SYSTEM IDENTIFICATION OF A TRUSS TYPE SPACE STRUCTURE USING THE MULTIPLE BOUNDARY CONDITION TEST (MBCT) METHOD
C. P. KUO and B. K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 172-176. refs
(AIAA PAPER 87-0746)

Experimental results on the application of the multiple boundary condition test (MBCT) method to experimental hardware have validated its usefulness in the ground testing of large flexible space structures. Excellant results were obtained with a beam with a uniform cross-section and with a beam consisting of two different cross-sections alternately located. The MBCT method is then applied to a 12 bay MAST type structure which is part of the NASA COFS program, and the cross-sectional area of the updated mathematical model was found to be within 4.5 percent of the true value. R.R.

A87-33757#
LOCALIZATION IN DISORDERED PERIODIC STRUCTURES
GLEN J. KISSEL IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 1046-1055. USAF-supported research. refs
(AIAA PAPER 87-0819)

Disorder in periodic structures is known to cause spatial localization of normal modes and attenuation of waves in all frequency bands. This paper uses a wave perspective to investigate these effects on one-dimensional periodic structures of interest to the engineer. Relevant work in the fields of solid state physics and mathematics is reviewed. A limit theorem for products of random matrices is exploited to calculate localization effects as a function of frequency. Localization is studied on two disordered periodic systems using both theoretical calculations and Monte Carlo simulations. The problem of localization in multiwave systems is briefly discussed. Author

A87-34469*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THERMAL DESIGN OF THE ACCESS ERECTABLE SPACE TRUSS
OBIE H. BRADLEY, JR. and RICHARD A. FOSS (NASA, Langley Research Center, Hampton, VA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Mar.-Apr. 1987, p. 188-192. Previously cited in issue 17, p. 2472, Accession no. A85-37658. refs

A87-36531* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
DESIGN CONSIDERATIONS FOR LONG-LIVED GLASS MIRRORS FOR SPACE
FRANK L. BOUQUET, CARL R. MAAG (California Institute of Technology, Jet Propulsion Laboratory, Pasadena), and PHILIP M. HEGGEN (Energy General, Menlo Park, CA) IN: Materials and optics for solar energy conversion and advanced lighting technology; Proceedings of the Meeting, San Diego, CA, Aug. 19-21, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 94-101. DOE-sponsored research. refs

Large mirrors intended for long-term operation in orbital space will have to retain high reflectance in the presence of contamination or destruction by high-energy particles, meteorites, and orbiting debris. These conditions require the use of low-energy outer surfaces that resist the buildup of contamination, the use of small mirror segments that restrict local damage and facilitate replacement, and the use of surface coatings that minimize the effects of atomic oxygen and/or charge buildup. The present recommendations are based on experience accumulated with terrestrial solar-concentrator mirror materials. O.C.

A87-38610* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
COMPOSITE SPACE ANTENNA STRUCTURES - PROPERTIES AND ENVIRONMENTAL EFFECTS
C. A. GINTY (NASA, Lewis Research Center, Cleveland, OH) and N. M. ENDRES (Sverdrup Technology, Inc., Middleburg Heights, OH) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 545-560. Previously announced in STAR as N87-16880. refs

The thermal behavior of composite spacecraft antenna reflectors has been investigated with the integrated Composites Analyzer (ICAN) computer code. Parametric studies have been conducted on the face sheets and honeycomb core which constitute the sandwich-type structures. Selected thermal and mechanical properties of the composite faces and sandwich structures are presented graphically as functions of varying fiber volume ratio, temperature, and moisture content. The coefficients of thermal expansion are discussed in detail since these are the

critical design parameters. In addition, existing experimental data are presented and compared to the ICAN predictions. Author

A87-38612
MEASURING THERMAL EXPANSION IN LARGE COMPOSITE STRUCTURES
GARY C. KRUMWEIDE, DAVID N. CHAMBERLIN, and EDDY A. DERBY (Composite Optics, Inc., San Diego, CA) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 572-582.

A unique laser/comparator measurement method is successfully adapted to the determination of the end-to-end coefficient of thermal expansion of a large telescope metering structure. Used principally for small coupon thermal expansion measurements, this light beam and movable optics technique has been scaled up to permit measurement of the actual structure to a resolution of 10 to the -7th in/in/deg F. Also discussed is real time design/analysis support during the test program to correct test set-up design problems and to modify the design of the telescope metering structure as indicated by test results. Author

A87-38725
THE CAPABILITIES OF EURECA THERMAL CONTROL FOR FUTURE MISSION SCENARIOS
B. SCHWARZ, K. BECKMANN, D. STUEMPEL (MBB-ERNO Raumfahrttechnik GmbH, Bremen, West Germany), and P. TAMBURINI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 225-233.
(SAE PAPER 860936)

Attention is given to the thermal control system configuration and functions of the European Retrievable Carrier (Eureca) spacecraft, which will be lofted into orbit by the NASA Space Shuttle in 1988 and is designed to perform a total of five free-flying missions of 6-month duration initially. Future missions, however, will entail extended lifetimes and a purely passive Thermal Control Subsystem design. The requirements of the Eureca Sophya solar region studies mission and Gretel X- and gamma-ray detection mission. O.C.

A87-38728
INFRARED TEST TECHNIQUE VALIDATION ON THE OLYMPUS SATELLITE
P. MESSIDORO and E. COLIZZI (Aeritalia S.p.A., Turin, Italy) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 259-268. refs
(SAE PAPER 860939)

The sheer size of the Columbus spacecraft and the presence of heat pipes on both of its radiators have suggested the present use of a spacecraft thermal model to assess the feasibility of IR testing. Data have been thus obtained which are pertinent to thermal control system design and both thermal and mathematical modelling. Attention is given to the test apparatus employed, the power control system used, and the characteristics of such IR test elements as IR sources, flux requirement definitions, outer surface property measurements, and the correlation methods applied to the test results. O.C.

A87-38734* United Technologies Corp., Windsor Locks, Conn.
REGENERABLE NON-VENTING THERMAL CONTROL SUBSYSTEM FOR EXTRAVEHICULAR ACTIVITY
GEORGE J. ROEBELEN, STEPHEN A. BAYES (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT), and B. MIKE LAWSON (NASA, Johnson Space Center, Houston, TX) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 345-355.
(SAE PAPER 860947)

Routine and complex EVAs call for more effective heat rejection systems in order to maximize mission productivity; an optimum EVA mobility unit (EMU) thermal control subsystem must require no expendables and introduce no contaminants into the environment, while conforming to minimum size limits and allowing easy regeneration. Attention is presently given to two thermal control subsystems, one of which can be integrated with the existing Space Shuttle Orbiter EMU to provide a 3-hour nonventing heat rejection capability, while the other can furnish the entire heat rejection capability requirement for an 8-hour Space Station EVA. O.C.

A87-38739
THE DEVELOPMENT OF AN EVA UNIVERSAL WORK STATION
MILES MOFFATT and FRED ABELES (Grumman Corp., Bethpage, NY) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 397-403.
(SAE PAPER 860952)

The design requirements for a Space Station-associated EVA Universal Work Station (UWS) which will reduce the overhead costs accruing to multiple trips to and from work sites while increasing crew safety, are discussed. The requirements are established by the variety of work sites and many different EVA tasks, which are characterizable in terms of EVA duration, job performance requirements, work envelope considerations, and translation times. As a result of mission analyses, several design recommendations are made for the EVA UWS system; setup and breakdown time at the work site is noted to be greatly reduced by implementing dedicated work stations at areas of frequent EVA. Tools stored on the UWS, and procedures that are assessed via display system, allow the astronauts to perform the required tasks productively and autonomously. O.C.

A87-38743
QUALITY MONITORING IN TWO-PHASE HEAT TRANSPORT SYSTEMS FOR LARGE SPACECRAFT
A. A. M. DELIL (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 439-452. refs
(SAE PAPER 860959)

Two-phase heat transport systems are currently considered for the thermal management of future large power spacecraft. The monitoring of the quality, being the relative vapor mass content, of the two-phase mixture at various locations in the system, is valuable - possibly indispensable - for the proper operation of such a system. This paper reviews concepts for quality monitoring. Only a few concepts turn out to be suitable for spacecraft applications. Promising concepts are based on the capacitance, sonic velocity and index of refraction. These concepts are described and quantitatively analyzed. Applicability, advantages, restrictions and some hardware aspects are discussed. Author

A87-38760
ENHANCED EVAPORATIVE SURFACE FOR TWO-PHASE MOUNTING PLATES
M. G. GROTE, J. A. STARK, and E. C. TEFFT, III (McDonnell Douglas Corp., Saint Louis, MO) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 617-626.
(SAE PAPER 860979)

An enhancement method for a grooved, evaporative surface for two-phase mounting plates which could be used in two-phase thermal control systems, such as that on the proposed Space Station is presented. An aluminum plate is machined with fine, rectangular grooves (39 grooves/cm). This grooved surface is then enhanced by an inexpensive process called Ivadizing, during which aluminum is vapor-deposited onto the surface, forming a slightly porous coating on the area between the grooves. The resulting surface has a much larger evaporative heat transfer coefficient and capillary pumping ability than that of plain rectangular grooves. Tests of this plate with R-11 showed improvement in evaporative heat transfer coefficient by a factor of 4. Analytic studies show that this enhanced surface should have at least three times the capillary pumping capacity of the rectangular grooved surface.
Author

A87-38776
OPTIMIZATION OF HEAT REJECTION SUBSYSTEM FOR SOLAR DYNAMIC BRAYTON CYCLE POWER SYSTEM
RICHARD PEARSON and DAVID DABROWSKI (Grumman Aerospace Corp., Bethpage, NY) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 805-815.
(SAE PAPER 860999)

A closed Brayton cycle (CBC) powerplant is under consideration for the Space Station Solar Dynamic Power System; attention is presently given to the weight, volume and cost optimization of the CBC's heat rejection system, on whose performance the power generation efficiency of the entire apparatus is strongly dependent. An analysis of the effects of varying system parameters on the radiator area and weight requirement indicates that radiator area is strongly dependent on radiator physical design. Radiator size depends on the arrangement, size, and design point heat rejection of the radiator panels, as well as such radiator properties as fin effectiveness, emissivity, and absorptivity. O.C.

A87-43003#
SPACE STATION ACTIVE THERMAL CONTROL SYSTEM MODELLING
ROSEMARY SCHMIDT and ERIC GUSTAFSON (Grumman Aerospace Corp., Space Systems Div ., Bethpage, NY) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 8 p.
(AIAA PAPER 87-1468)

This paper describes a unique thermal modelling method that was devised to model the Grumman design of the Space Station Active Thermal Control System (ATCS). The ATCS utilizes a two-phase thermal bus for acquiring and transporting heat to heat pipe radiators, which reject the waste heat to space. The mathematical modelling and analysis of these systems required the development of new modelling methods. The SINDA thermal analyzer program was used for the modelling, but since this program has no two-phase flow analysis capability, several additional routines were developed. These routines were then used in conjunction with the SINDA thermal analyzer for modelling the two-phase flow in the thermal bus. This work was performed for NASA as part of the Space Station Work Package 2 phase B study. Author

A87-43014#
THE BENEFIT OF PHASE CHANGE THERMAL STORAGE FOR SPACECRAFT THERMAL MANAGEMENT
M. S. BUSBY and S. J. MERTESDORF (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 8 p. refs
(AIAA PAPER 87-1482)

This paper discusses the applications of thermal storage in spacecraft which are beneficial for weight savings. Tools are developed which allow a thermal system designer to perform preliminary thermal performance and weight trades on systems with thermal storage and those without. Thermal storage module designs which achieve high performance are also discussed. Analysis is performed to assess the impact of two heating profiles representative of typical spacecraft missions: a pulse power profile and the absolute value of a sinusoidal profile. The pulse power profile is typical of surveillance spacecraft dissipation and the sinusoidal profile represents solar heating. Using the tools developed in the paper, it was found that thermal storage can be valuable in reducing the system weight for pulsed heating with short pulse duration and for solar heating with short orbit periods.
Author

A87-43059*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
LIQUID DROPLET RADIATOR DEVELOPMENT STATUS
K. ALAN WHITE, III (NASA, Lewis Research Center, Cleveland, OH) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 21 p. Previously announced in STAR as N87-20353. refs
(AIAA PAPER 87-1537)

Development of the Liquid Droplet Radiator (LDR) is described. Significant published results of previous investigators are presented, and work currently in progress is discussed. Several proposed LDR configurations are described, and the rectangular and triangular configurations currently of most interest are examined. Development of the droplet generator, collector, and auxiliary components are discussed. Radiative performance of a droplet sheet is considered, and experimental results are seen to be in very good agreement with analytical predictions. The collision of droplets in the droplet sheet, the charging of droplets by the space plasma, and the effect of atmospheric drag on the droplet sheet are shown to be of little consequence, or can be minimized by proper design. The LDR is seen to be less susceptible than conventional technology to the effects of micrometeoroids or hostile threats. The identification of working fluids which are stable in the orbital environments of interest is also made. Methods for reducing spacecraft contamination from an LDR to an acceptable level are discussed. Preliminary results of microgravity testing of the droplet generator are presented. Possible future NASA and Air Force missions enhanced or enabled by a LDR are also discussed. System studies indicate that the LDR is potentially less massive than heat pipe radiators. Planned microgravity testing aboard the Shuttle or space station is seen to be a logical next step in LDR development. Author

A87-43082#
CALORIMETRIC MEASUREMENTS OF THERMAL CONTROL SURFACES AT GEOSYNCHRONOUS ORBIT
C. C. ANDERSON and M. M. HATTAR (Aerojet ElectroSystems Co., Azusa, CA) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 10 p. refs
(AIAA PAPER 87-1571)

Calorimeter data for up to 18,000 equivalent sun-hours are presented for a number of satellite thermal control surfaces. Solar absorptance values as a function of time were collected at geosynchronous orbit on samples of zinc orthotitanate paint, silver-alumina-silica, silvered Teflon, aluminized Teflon, silica cloth, and clean second-surface mirrors. Over 6000 equivalent sun-hours of calorimeter data were also collected on precontaminated second-surface mirror samples (also on orbit). Comparisons of both sets of collected data are made with previously published

calorimeter data including that from radiator surfaces on the same satellite from which the samples data was obtained. A useful collection of solar absorptance degredation equations is the result. These equations are of major significance in predicting satellite useful life. Author

A87-44830*# Washington Univ., Seattle.
RADIATION HEAT TRANSFER CALCULATIONS FOR SPACE STRUCTURES
A. F. EMERY, O. JOHANSSON, and A. ABROUS (Washington, University, Seattle) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 7 p. refs
(Contract NAG1-41)
(AIAA PAPER 87-1522)

A method is presented for the computation of radiant heat flux between arbitrary surfaces which permits a user defined level of accuracy. The method can be applied to directionally dependent surface properties, specular radiation, or solar illumination, and ensures conservation of energy. The method is compared with others to demonstrate its value. Author

A87-46682
EVALUATION OF THE INFRARED TEST METHOD FOR THE OLYMPUS THERMAL BALANCE TESTS
MARC DONATO, JERRY GREEN, DANY ST-PIERRE (Spar Aerospace, Ltd., Ste-Anne-de-Bellevue, Canada), and MURRAY REEVES (David Florida Laboratory, Ottawa, Canada) Journal of Environmental Sciences (ISSN 0022-0906), vol. 30, May-June 1987, p. 45-49. Research supported by the Canadian Department of Communications and Olympus Program.

The present work reports on the performance of the infrared test techniques developed and used for the thermal balance testing of the Olympus spacecraft thermal model. Developments in the area of computer software, radiometers, and temperature measurement systems are presented. The power control and data acquisition systems are detailed. A summary of the test results shows that temperature differences between test and predictions are in agreement within the values obtained in past programs for an uncorrelated mathematical model. Author

A87-48341
A BASIS CHANGE STRATEGY FOR THE REDUCED GRADIENT METHOD AND THE OPTIMUM DESIGN OF LARGE STRUCTURES
K. T. JOSEPH (Indian Space Research Organization, Vikram Sarabha, Space Centre, Trivandrum, India) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 24, July 1987, p. 1269-1281. refs

The paper proposes a basis change strategy within the reduced gradient method for optimization under linear constraints. It ensures a nonsingular basis matrix at every iteration. The same strategy can reliably be used within the generalized reduced gradient method for optimization under nonlinear constraints. This method is applied to the minimum weight design of large structures under displacement and stress constraints, exploiting the sparsity of the constraint Jacobian matrix. Author

A87-50157#
DESIGN OF A BEACON RECEIVING SYSTEM FOR THE OLYMPUS SATELLITE
ERKKI SALONEN (Helsinki University of Technology, Espoo, Finland) IN: International Beacon Satellite Symposium on Radio Beacon Contribution to the Study of Ionization and Dynamics of the Ionosphere and to Corrections to Geodesy and Technical Workshop, Oulu, Finland, June 9-14, 1986, Proceedings. Part 2 . Oulu, Finland, University of Oulu, 1986, p. 359-365. refs

The main features of the design of the propagation measurement system for the 12.5, 20, and 30 GHz Olympus 1 satellite beacons are described. Progress being made at the Metsaehovi Radio Research Station in Finland is discussed. The main goals of the propagation measurement are to collect statistics of attenuation, scintillation, and crosspolarization events. The propagation payload of Olympus 1 is discussed as well as the choice of the frequency for the main phase-locked loop, the antenna and feed system, and data acquisition. K.K.

N87-20353*# National Aeronautics and Space Administration. *Lewis Research Center, Cleveland, Ohio.*
LIQUID DROPLET RADIATOR DEVELOPMENT STATUS
K. ALAN WHITE, III 1987 28 p Prepared for presentation at the 22nd Thermophysics Conference, Honolulu, Hawaii, 8-10 Jul. 1987; sponsored by AIAA
(NASA-TM-89852; E-3510; NAS 1.15:89852) Avail: NTIS HC A03/MF A01 CSCL 22B

Development of the Liquid Droplet Radiator (LDR) is described. Significant published results of previous investigators are presented, and work currently in progress is discussed. Several proposed LDR configurations are described, and the rectangular and triangular configurations currently of most interest are examined. Development of the droplet generator, collector, and auxiliary components are discussed. Radiative performance of a droplet sheet is considered, and experimental results are seen to be in very good agreement with analytical predictions. The collision of droplets in the droplet sheet, the charging of droplets by the space plasma, and the effect of atmospheric drag on the droplet sheet are shown to be of little consequence, or can be minimized by proper design. The LDR is seen to be less susceptible than conventional technology to the effects of micrometeoroids or hostile threats. The identification of working fluids which are stable in the orbital environments of interest is also made. Methods for reducing spacecraft contamination from an LDR to an acceptable level are discussed. Preliminary results of microgravity testing of the droplet generator are presented. Possible future NASA and Air Force missions enhanced or enabled by a LDR are also discussed. System studies indicate that the LDR is potentially less massive than heat pipe radiators. Planned microgravity testing aboard the Shuttle or space station is seen to be a logical next step in LDR development. Author

N87-20361*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
STRUCTURAL QUALIFICATION OF LARGE SPACECRAFT
BEN K. WADA *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 19 p Jul. 1986
Avail: NTIS HC A12/MF A01 CSCL 22A

Over the past twenty-five (25) years of the space program, the major challenge in the structural qualification of the primary structure has shifted from conducting a test that simulated the environment to accurately predicting the structural member loads in flight. Once the flight loads are avaliable, a number of different test methods are used to qualify the structure by subjecting it to the proper loads. The qualification challenge for future large spacecraft will be to adequately predict its dynamic characteristic in space to assure that it can be controlled to meet the mission objectives. A new test concept that may allow acquisition of modal data by ground tests for verification of mathematical models of large flexible space structures which can't be ground tested by conventional methods is discussed. Author

N87-21021*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ANALYSIS OF ON-ORBIT THERMAL CHARACTERISTICS OF THE 15-METER HOOP/COLUMN ANTENNA
GREGORY C. ANDERSEN, JEFFERY T. FARMER, and JAMES GARRISON (Rensselaer Polytechnic Inst., Troy, N.Y.) Mar. 1987 33 p
(NASA-TM-89137; NAS 1.15:89137) Avail: NTIS HC A03/MF A01 CSCL 22B

In recent years, interest in large deployable space antennae has led to the development of the 15 meter hoop/column antenna. The thermal environment the antenna is expected to experience during orbit is examined and the temperature distributions leading to reflector surface distortion errors are determined. Two flight orientations corresponding to: (1) normal operation, and (2) use in a Shuttle-attached flight experiment are examined. A reduced element model was used to determine element temperatures at

16 orbit points for both flight orientations. The temperature ranged from a minimum of 188 K to a maximum of 326 K. Based on the element temperatures, orbit position leading to possible worst case surface distortions were determined, and the subsequent temperatures were used in a static finite element analysis to quantify surface control cord deflections. The predicted changes in the control cord lengths were in the submillimeter ranges.
Author

N87-21206* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
MEASUREMENT APPARATUS AND PROCEDURE FOR THE DETERMINATION OF SURFACE EMISSIVITIES Patent
HANS-JUERGEN C. BLUME, inventor (to NASA) 24 Feb. 1987 18 p Filed 3 Dec. 1985 Supersedes N86-24880 (24 - 15, p 2445)
(NASA-CASE-LAR-13455-1; US-PATENT-4,645,358; US-PATENT-APPL-SN-804040; US-PATENT-CLASS-374-9; US-PATENT-CLASS-250-341; US-PATENT-CLASS-374-122)
Avail: US Patent and Trademark Office CSCL 20N

A method and apparatus for independently determining the electromagnetic surface emissivity of a material is developed. This is particularly useful in the design of large deployable space antennas employing mesh membrane surfaces. The system is a closed one with respect to unwanted or uncorrelated radiation outside the system. The present embodiment comprises a radiometer connected to a horn antenna, a test section sealed to the horn antenna and a cryogenically cooled matched load (cryoload) exposed to the interior of the system. The material is enclosed in a convection test chamber within a test section, heated within a test chamber and allowed to radiate within the system such that a component of the radiation energy of the material is measured by the radiometer in terms of brightness temperature. The matched load serves as the stabilizing source of uncorrelated radiation within the system by radiating at a constant cryogenic temperature. The actual physical temperature of the material is also measured during the heating process. Brightness temperature over divided by physical temperature for the same time period is the emissivity of the material according to a derivation of the Raleigh-Jeans approximation for an ideal system free from all uncorrelated radiation.
Official Gazette of the U.S. Patent and Trademark Office

N87-21995*# General Electric Co., Philadelphia, Pa. Astro-Space Div.
THE MULTI-DISCIPLINARY DESIGN STUDY. A LIFE CYCLE COST ALGORITHM
R. R. HARDING, J. M. DURAN, and R. R. KAUFFMAN May 1987 107 p
(Contract NAS1-18032)
(NASA-CR-178192; NAS 1.26:178192; GE-DOC-87SDS-024)
Avail: NTIS HC A06/MF A01 CSCL 22B

Life-cycle cost (LCC) is investigated as a comprehensive design criterion for two major interrelated spacecraft subsystems, Controls and Structures. A Multi-Disciplinary Design Tool (MDDT) is developed to evaluate the sensitivity of LCC to subsystem design parameters. Major costs addressed are: non-recurring; launch; ground support; maintenance; expendables; and software. Examples and results from the MDDT are described, including a structural optimization study between different truss designs; a solar array feathering trade for a minimal drag configuration during umbra; and the cost of active control of a flexible structure is compared against the cost of passive damping using visco-elastic material.
Author

N87-22704*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
LARGE SPACE STRUCTURES GROUND EXPERIMENT CHECKOUT
HENRY B. WAITES *In its* Structural Dynamics and Control Interaction of Flexible Structures p 57-84 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

NASA Marshall Space Flight Center has developed a facility in which closed loop control of Large Space Structures (LSS) can be demonstrated and verified. The main objective of the facility is to verify LSS control system techniques so that on-orbit performance can be ensured. The facility consists of an LSS test article or payload which is connected to a 3-axis angular pointing mount assembly that provides control torque commands. The angular pointing mount assembly is attached to a base excitation system which will simulate disturbances most likely to occur for Orbiter and DOD payloads. The control computer contains the calibration software, the reference systems, the alignment procedures, the telemetry software, and the control algorithms. The total system is suspended in such a fashion that the LSS test article has the characteristics common to all LSS.
Author

N87-22711*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
CONSIDERATIONS IN THE DESIGN AND DEVELOPMENT OF A SPACE STATION SCALE MODEL
PAUL E. MCGOWAN *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 215-246 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Preliminary work at Langley Research Center (LaRC) related to the design, analysis and testing of a space station scale model is reviewed. Included are some rationale for focusing the scale model program on space station and the utilization of the model to achieve the program objectives. In addition, some considerations involved in designing a dynamics scale model, such as ground test facilities, sub-scale component fabrication and model replication vs. simulation are presented. Finally, some related research areas currently ongoing at LaRC in support of scale model development are discussed.
Author

N87-22713*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
VERIFICATION OF FLEXIBLE STRUCTURES BY GROUND TEST
BEN K. WADA and C. P. KUO *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 255-274 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

The validation of math models of large space structures (LSS) by ground tests is attempted. Concepts for two types of LSS are presented: continuous type and linked subsystems. It was concluded that ground test which simulate space conditions are not entirely reliable, that there should be an integration of testing and analyses, which then should be validated with laboratory and flight experiments.
E.R.

N87-22749*# Boeing Aerospace Co., Seattle, Wash.
EXPERIMENTAL CHARACTERIZATION OF DEPLOYABLE TRUSSES AND JOINTS
R. IKEGAMI, S. M. CHURCH, D. A. KEINHOLZ, and B. L. FOWLER (CSA Engineering, Inc., Palo Alto, Calif.) *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1271-1288 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

The structural dynamic properties of trusses are strongly affected by the characteristics of joints connecting the individual beam elements. Joints are particularly significant in that they are often the source of nonlinearities and energy dissipation. While the joints themselves may be physically simple, direct measurement is often necessary to obtain a mathematical description suitable for inclusion in a system model. Force state mapping is a flexible, practical test method for obtaining such a description, particularly

when significant nonlinear effects are present. It involves measurement of the relationship, nonlinear or linear, between force transmitted through a joint and the relative displacement and velocity across it. An apparatus and procedure for force state mapping are described. Results are presented from tests of joints used in a lightweight, composite, deployable truss built by the Boeing Aerospace Company. The results from the joint tests are used to develop a model of a full 4-bay truss segment. The truss segment was statically and dynamically tested. The results of the truss tests are presented and compared with the analytical predictions from the model. Author

N87-24510*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
GROUND TEST OF LARGE FLEXIBLE STRUCTURES
BEN K. WADA *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 831-850 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

Many future mission models require large space (LSS) which have accurate surfaces and/or the capability of being accurately aligned. If ground test approaches which will provide adequate confidence of the structrual performance to the program managers are not developed, many viable structural concepts may never be utilized. The size and flexibility of many of the structural concepts will preclude the use of the current ground test methods because of the adverse effects of the terrestrial environment. The challenge is to develop new test approaches which will provide confidence in the capability of LSS to meet performance requirements prior to flight. The activities on ground testing of LSS are described. Since some of the proposed structural systems cannot be tested in entirety, a coordinated ground test analytical model program is required to predict structural performance in space. Several concepts of ground testing under development are addressed. Author

N87-24520*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
LARGE SPACE STRUCTURES TESTING
HENRY WAITES and H. EUGENE WORLEY Jun. 1987 22 p
(NASA-TM-100306; NAS 1.15:100306) Avail: NTIS HC A02/MF A01 CSCL 22B

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 facilites 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 Government Agencies in joint endeavors. Author

N87-26205*# Lockheed Missiles and Space Co., Palo Alto, Calif.
SPACECRAFT RAM GLOW AND SURFACE TEMPERATURE Abstract Only
G. R. SWENSON, S. B. MENDE, and E. J. LLEWELLYN (Saskatchewan Univ., Saskatoon.) *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 169 1 Jun. 1987
Avail: NTIS HC A09/MF A01 CSCL 22B

Space shuttle glow intensity measurements show large differences when the data from different missions are compared. In particular, on the 41-G mission the space shuttle ram glow was observed to display an unusually low intensity. Subsequent investigation of this measurement and earlier measurements suggest that there was a significant difference in temperature of the glow producing ram surfaces. The highly insulating properties coupled with the high emissivity of the shuttle tile results in surfaces that cool quickly when exposed to deep space on the night side of the orbit. The increased glow intensity is consistent with the hypothesis that the glow is emitted from excited NO2. The excited NO2 is likely formed through three body recombination (OI + NO + M = NO2*) where ramming of OI interacts with weakly surface bound NO. The NO is formed from atmospheric OI and NI which is scavenged by the spacecraft moving through the atmosphere. It is postulated that the colder surfaces retain a thicker layer of NO thereby increasing the probability of the reaction. It has been found from the glow intensity/temperature data that the bond energy of the surface bound precursor, leading to the chemical recombination producing the glow, is approximately 0.14 eV. A thermal analysis of material samples of STS-8 was made and the postulated temperature change of individual material samples prior to the time of glow measurements above respective samples are consistent with the thermal effect on glow found for the orbiter surface. Author

N87-26365*# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronatuics and Astronautics.
JOINT NONLINEARITY EFFECTS IN THE DESIGN OF A FLEXIBLE TRUSS STRUCTURE CONTROL SYSTEM
MATHIEU MERCADAL Dec. 1986 164 p
(Contract NAG1-126)
(NASA-CR-180633; NAS 1.26:180633; SSL-22-86) Avail: NTIS HC A08/MF A01 CSCL 20K

Nonlinear effects are introduced in the dynamics of large space truss structures by the connecting joints which are designed with rather important tolerances to facilitate the assembly of the structures in space. The purpose was to develop means to investigate the nonlinear dynamics of the structures, particularly the limit cycles that might occur when active control is applied to the structures. An analytical method was sought and derived to predict the occurrence of limit cycles and to determine their stability. This method is mainly based on the quasi-linearization of every joint using describing functions. This approach was proven successful when simple dynamical systems were tested. Its applicability to larger systems depends on the amount of computations it requires, and estimates of the computational task tend to indicate that the number of individual sources of nonlinearity should be limited. Alternate analytical approaches, which do not account for every single nonlinearity, or the simulation of a simplified model of the dynamical system should, therefore, be investigated to determine a more effective way to predict limit cycles in large dynamical systems with an important number of distributed nonlinearities. Author

N87-26429*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADVANCED PHOTOVOLTAIC SOLAR ARRAY DESIGN. ASSESSMENT
PAUL STELLA and JOHN SCOTT-MONCK *In* NASA. Lewis Research Center, Space Photovoltaic Research and Technology 1986. High Efficiency, Space Environment and Array Technology p 145-150 Jun. 1987
Avail: NTIS HC A16/MF A01 CSCL 10B

The Advanced Photovoltaic Solar Array (APSA) program seeks to bring to flight readiness a solar array that effectively doubles the specific power of the Solar Array Flight Experiment/Solar Electric Propulsion (SAFE/SEP) design that was successfully demonstrated during the Shuttle 41-D mission. APSA is a critical intermediate milestone in the effort to demonstrate solar array technologies capable of 300 W/kg and 300 W/square m at beginning of life (BOL). It is not unreasonable to anticipate the development of solar array designs capable of 300 W/kg at BOL for operational power levels approx. greater than 25 kW sub e. It is also quite reasonable to expect that high performance solar arrays capable of providing at least 200 W/kg at end of life for most orbits now being considered by mission planners will be realized in the next decade. Author

N87-26968# Naval Postgraduate School, Monterey, Calif.
COMPUTER SIMULATION OF A ROTATIONAL SINGLE-ELEMENT FLEXIBLE SPACECRAFT BOOM M.S. Thesis
ROBERT S. LAUFENBERG Mar. 1987 91 p
(AD-A181798) Avail: NTIS HC A05/MF A01 CSCL 22B

The requirement to develop a space based remote ocean sensing platform exists within the Department of the Navy. This project models a satellite subsystem with structural flexibility utilizing the Equivalent Rigid Link System (ERLS). Dynamic analysis with computer simulation is presented for a simple flexible boom rotating in three dimensions with and without a point mass at the boom tip. Author (GRA)

N87-28584# IIT Research Inst., Chicago, Ill.
SPACE STABLE THERMAL CONTROL COATINGS Final Report, Sep. 1983 - Dec. 1986
R. J. MELL and Y. HARADA May 1987 177 p
(Contract F33615-83-K-5099)
(AD-A182796; IITRI-M06124-F; AFWAL-TR-87-4010) Avail: NTIS HC A09/MF A01 CSCL 11C

An important aspect of satellite operation in a space environment is thermal control design. Various coatings having desired optical properties have been used to achieve passive thermal control of different spacecraft. IITRI's S13G/LO coating has found widespread use in a number of missions for 15 years. The source of binder material for S13G/LO, however, is now unavailable and there is a continuing need on various spacecraft missions for this type of coating. This report covers research to develop and qualify a material having the same or improved optical and physical properties as S13G/LO. The coating was to display desirable and reliable behavior in a space environment. The study has resulted in a material designated, S13G/LO-1, which exhibits properties as good as, or somewhat better than the original S13G/LO. Environment, Satellite Thermal Control, Radiation Effects, Material Outgassing, Silicone Resin. GRA

N87-28968# AEG-Telefunken, Wedel (West Germany).
AMOC: AN ALTERNATIVE MODULE CONFIGURATION FOR ADVANCED SOLAR ARRAYS IN LOW EARTH ORBITS
JUERGEN W. KOCH *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 63-70 Nov. 1986 Sponsored by ESTEC
Avail: NTIS HC A21/MF A01

A module concept, based on bifacial Si-solar cells, which also convert Earth albedo radiation to obtain an additional power gain was developed. Tests comprising 15,000 LEO-thermal cycles of real modules, irradiation tests, static load tests, and vibration tests with a fold stack in 2 configurations were conducted. The results show that the chosen design (bifacial cell, transparent substrate, long life interconnector) can meet LEO-mission requirements for extended lifetime. ESA

N87-29860*# Toshiba Corp., Kanagawa (Japan). Research and Development Center.
THE DESIGN AND DEVELOPMENT OF A TWO-DIMENSIONAL ADAPTIVE TRUSS STRUCTURE
FUMIHIRO KUWAO, SHOICHI MOTOHASHI, MAKOTO YOSHIHARA, KENICHI TAKAHARA, and MICHIHIRO NATORI (Tokyo Univ., Japan) *In* NASA-Lyndon B. Johnson Space Center, The 21st Aerospace Mechanisms Symposium p 19-34 May 1987
Avail: NTIS HC A16/MF A01 CSCL 13I

The functional model of a two dimensional adaptive truss structure which can purposefully change its geometrical configuration is introduced. The details of design and fabrication such as kinematic analysis, dynamic characteristics analysis and some test results are presented for the demonstration of this two dimensional truss concept. Author

N87-29865*# Rockwell International Corp., Downey, Calif. Space Station Systems Div.
THE DESIGN AND DEVELOPMENT OF A MOBILE TRANSPORTER SYSTEM FOR THE SPACE STATION REMOTE MANIPULATOR SYSTEM
THOMAS W. CARROLL *In* NASA-Lyndon B. Johnson Space Center, The 21st Aerospace Mechanisms Symposium p 93-101 May 1987
Avail: NTIS HC A16/MF A01 CSCL 05H

The analyses, selection process, and conceptual design of potential candidate Mobile Transporter (MT) systems to move the Space Station Remote Manipulator System (SSRMS) about the exposed faces of the Space Station truss structure are described. The actual requirements for a manipulator system on the space station are discussed, including potential tasks to be performed. The SSRMS operating environment and control methods are analyzed with potential design solutions highlighted. Three general categories of transporter systems are identified and analyzed. Several design solution have emerged that will satisfy these requirements. Their relative merits are discussed, and unique variations in each system are rated for functionality. Author

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.

A87-32117
CONTROL OPERATIONS IN ADVANCED AEROSPACE SYSTEMS
WILLIAM R. GRAHAM (R&D Associates, Marina Del Rey, CA) (IFAC, Symposium on Control of Distributed Parameter Systems, Los Angeles, CA, June 30-July 2, 1986) IEEE Control Systems Magazine (ISSN 0272-1708), vol. 7, Feb. 1987, p. 3-8.

Distributed parameter control systems being studied by NASA for use in advanced aerospace systems are described. A 15 m diam antenna that will be deployed in space from a 2 cu m box has 96 control cables for controlling the shape of the antenna. Appropriate near- and far-field tests are needed for tuning the shape of the antenna on-orbit. The Space Station will be dynamically stabilized, damped and pointed with a high degree of accuracy, performed to a high degree by automated systems that adapt to a growing structure. Self-diagnosis is also a necessary feature of future EVA equipment and telerobotics, the latter assuming greater importance in a Rover for exploring the surface of Mars. The concepts are being implemented in the X-29 forward swept wing aircraft, the electronics of the Hubble Space Telescope, and in studies of the national aerospaceplane. M.S.K.

A87-32120
SPACE STRUCTURE VIBRATION MODES - HOW MANY EXIST? WHICH ONES ARE IMPORTANT?
PETER C. HUGHES (Toronto, University, Downsview, Canada) IEEE Control Systems Magazine (ISSN 0272-1708), vol. 7, Feb. 1987, p. 22-28. refs
(Contract NSERC-A-4183)

Basic concepts of vibration modes analysis are re-evaluated to demonstrate techniques for discerning between significant physical vibration modes and mathematical models of modes. Generic integral equations are defined for the modal coefficients of momentum and angular momentum. When applied to a complex structure, the equations are solved by convergence of finite element calculations, i.e., an approximation is made. The calculations are a numerical equivalent of exact solutions to partial differential equations, but do not extend to 'absurd' orders of modes. Low frequency modes are identified as the important modes. Error indices are discussed for truncating the number of modes that

must be considered, noting that frequency is not the only parameter of importance in modal selection. M.S.K.

A87-32229#
ROBUST CONTROLLER DESIGN USING FREQUENCY DOMAIN CONSTRAINTS
R. D. HEFNER (Aerospace Corp., El Segundo, CA) and D. L. MINGORI (California, University, Los Angeles) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Mar.-Apr. 1987, p. 158-165. refs

This paper describes a method for designing a controller with improved robustness with respect to truncated flexible modes. The approach involves minimization of a quadratic performance index subject to constraints in the frequency domain. The frequency domain criteria are chosen so as to sufficiently attenuate the high frequency response of the full dynamic system while attempting to maintain the overall performance of the closed-loop system. The resulting constraint relationships are cast into a functional minimization framework and parameter optimization techniques are used to determine the solution. Author

A87-32235*# Old Dominion Univ., Norfolk, Va.
ROBUST CONTROLLER SYNTHESIS FOR A LARGE FLEXIBLE SPACE ANTENNA
N. SUNDARARAJAN (Old Dominion University Research Foundation, Norfolk, VA), S. M. JOSHI, and E. S. ARMSTRONG (NASA, Langley Research Center, Hampton, VA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Mar.-Apr. 1987, p. 201-208. refs

The linear-quadratic Gaussian/loop-transfer-recovery method is used to synthesize a fine-pointing control system for a large space antenna. A finite-element model for the 122-m hoop/column antenna is employed, and a compensator, utilizing attitudes sensors and torque actuators, is designed which achieves pointing performance while maintaining stability robustness to unmodeled dynamics. Inclusion of the rigid-body modes plus the first three elastic modes is found to be necessary to achieve a 0.1-rad/s bandwidth. Results are obtained by employing a modification of the standard robustness recovery procedure, which reduces the conservative nature of the design methodology. Performance degradation is encountered due to the presence of unavoidable invariant zeros within the design bandwidth. Author

A87-32236*# Johns Hopkins Univ., Laurel, Md.
CONFIGURATION TRADEOFFS FOR THE SPACE INFRARED TELESCOPE FACILITY POINTING CONTROL SYSTEM
A. J. PUE, K. STROHBEHN, and J. W. HUNT (Johns Hopkins University, Laurel, MD) (Guidance, Navigation and Control Conference, Snowmass, CO, Aug. 19-21, 1985, Technical Papers, p. 73-82) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Mar.-Apr. 1987, p. 209-215. NASA-sponsored research. Previously cited in issue 22, p. 3241, Accession no. A85-45885. refs

A87-32334
PREDICTION OF RANDOM VIBRATIONAL RESPONSES OF A LARGE SPACECRAFT IN ACOUSTIC ENVIRONMENT BY BLPF METHOD
HIDEHIKO MITSUMA (National Space Development Agency of Japan, Tokyo), SHOJI MAEKAWA, TORU ITO (Kawasaki Heavy Industries, Ltd., Kakamigahara, Japan), TOSHIAKI TAKAHASHI, YUJI KUBOTA (Toshiba Corp., Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 449-454.

The prediction of the random responses of a large model spacecraft consisting of honeycomb sandwich panels and component mass dummies to a reverberant acoustic field is studied using the Band-Limited Power Flow (BLPF) method. This method has the same characteristics as the Statistical Energy Method (SEM) in the high frequency domain and is applicable to prediction in the low frequency domain. The predictive results are compared with experimental ones, and good agreement is found. It is concluded that the BLPF method is effective for random response prediction for spacecraft. C.D.

A87-32335
STRUCTURAL DESIGN AND COMPONENT TESTS OF LARGE GEOSTATIONARY SATELLITE BUS
HIDEHIDO MITSUMA, KUNIO NAKAMARU (National Space Development Agency of Japan, Tokyo), MASATAKA YAMAMOTO, KAZUMI OKUDA, and RYOICHI IMAI (National Space Development Agency of Japan, Tsukuba Space Center, Sakura) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 455-464.

This paper presents the results of the structural design and major component tests of the Large Geostationary Satellite Bus for the application satellites in the 1990s. The satellite main structure is composed of a panel assembly. The mission, bus, and AKE tank support structures of the satellite are modularized. Author

A87-32337* Howard Univ., Washington, D. C.
A REVIEW OF MODELLING TECHNIQUES FOR THE OPEN AND CLOSED-LOOP DYNAMICS OF LARGE SPACE SYSTEMS
PETER M. BAINUM (Howard University, Washington, DC) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 475-482. Research supported by Howard University and Nippon Telegraph and Telephone Public Corp. refs
(Contract NSG-1414)

This paper reviews the steps in the development of mathematical models that can be used to simulate the in-orbit dynamic behavior of large flexible systems. A general continuum formulation is compared with the hybrid coordinate formulation and also a finite element representation of the total system. A review of structural analysis routines emphasizes the use of computer generated graphics to help understand the different modal elastic shape functions of complex systems. Numerical techniques employed to synthesize shape and attitude control laws are summarized. Finally, the modeling of environmental disturbance torques due to the interaction of solar radiation pressure on vibrating and thermally deflected systems is discussed. Author

A87-32338
TRANSIENT DYNAMICS OF ORBITING FLEXIBLE STRUCTURAL MEMBERS
V. J. MODI and A. M. IBRAHIM (British Columbia, University, Vancouver, Canada) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 483-488.
(Contract NSERC-67-1547)

Using a relatively general formulation procedure, this paper reviews complex interactions between deployment, attitude dynamics, and flexural rigidity for configurations representing deployment of beam and tether type appendages. The results suggest substantial influence of the flexibility, deployment velocity, initial conditions, and appendage orientation on the response, and under critical combinations of parameters the system can become unstable. The information has relevance to the design of control systems for: (1) the next generation of communication satellites; (2) the Orbiter based experiments such as SAFE (Solar Array Flight Experiment), SCOLE (Structural COntrol Laboratory Experiment), STEP (Structural Technology Exeriment Program), and the NASA/CNR tethered subsatellite system; as well as (3) the evolutionary transient and postconstruction operational phases of the proposed Space Station. Author

A87-32341
DEPLOYABLE SURFACE TRUSS CONCEPTS AND TWO-DIMENSIONAL ADAPTIVE STRUCTURES
MICHIHIRO NATORI, KORYO MIURA (Tokyo, University, Japan), and HIROSHI FURUYA (Nagoya University, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 503-508. refs

Various conceptual considerations for both flat and curved deployable truss structures based on the collapsible transformations of polyhedral truss elements are presented from the viewpoint of geometry. Various deployable octet elements are investigated for systematic interpretations of deployable surface truss structures. The new possibility for two-dimensional adaptive structures with controllable geometry is also studied. Author

A87-32440
LOCAL CONTROL FOR LARGE SPACE STRUCTURES
TAKASHI KIDA, ISAO YAMAGUCHI, and YOSHIAKI OHKAMI (National Aerospace Laboratory, Chofu, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1231-1236. refs

This paper describes the decentralized local control of a class of large space structures consisting of multirigid bodies that are connected through hinges. The formulation and the controller design are performed for each subbody independently from other contiguous bodies. For a simple two-body system, connective stability bounds are obtained when the local controller is designed by the pole placement method and by cost optimization. Author

A87-32441
A CONSIDERATION TO VIBRATION CONTROL FOR A LARGE SPACE STRUCTURES
ETSUJIRO SHIMEMURA (Waseda University, Tokyo, Japan), TERUO FUJIWARA, TADASHI ADACHI, HIDEHIKO TAMAOKI, and SHINTARO KAWAGUCHI (Nissan Motor Co., Ltd., Tokyo, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1237-1241.

The control problem of flexible space structures is one of the key technologies for the Space Station. This paper presents one approach to damp the vibration of the flexible structure using active control. The selection of the control method, modeling of the structure, and the control law are discussed. Computer simulation is performed to investigate the effects of control parameters. Numerical results show the improvement of the damping of the system and existence of the optimal point in control parameters. Author

A87-32442
FLEXIBILITY CONTROL OF TORSIONAL VIBRATIONS OF A LARGE SOLAR ARRAY
TOSHIO FUKUDA, HIDEMI HOSOGAI (Tokyo University of Science, Japan), NOBUYUKI YAJIMA (Ministry of International Trade and Industry, Mechanical Engineering Laboratory, Tsukuba, Japan), and FUMIHITO ARAI IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1243-1248. refs

This paper describes modeling and control methods for torsional vibration of flexible solar arrays. The eigenvalues and eigenfunctions for this distributed parameter system are solved both mathematically and numerically under the consideration of the inertia momentum of the supported rigid attachment. A differential solar cells sensor consisting of a pair of adjacent solar cells is proposed as a new type of sensor to measure the attitude and torsional vibrations of flexible solar arrays. To eliminate noises in the sensor outputs, the Kalman filtering method is employed. A proposed mode estimation method, based on this linear optimal filter, is show to give good results. The control method employing the optimal control theory, based on the quadratic performance index approach, is also shown to suppress the torsional vibration of the flexible array. Author

A87-32443
TWO-TIME-SCALE DESIGN OF ROBUST CONTROLLERS FOR LARGE STRUCTURE SYSTEMS
M. SUZUKI (Nagoya University, Japan), T. NARUSE (Daido Institute of Technology, Nagoya, Japan), Y. ANDO (Nagoya Municipal Industrial Research Institute, Japan), and S. KURACHI IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1249-1254.

The two time-scale design method of the singular perturbation system is decribed. The design method is used to determine the robust control design for large structure systems; the method is applied to the vibration control of a flexible beam. The advantages of the singular perturbation method for determining the robust stabilization control for large structure systems are discussed. I.F.

A87-32444
VIBRATION CONTROL FOR A LINKED SYSTEM OF FLEXIBLE STRUCTURES
TOSHIO FUKUDA (Tokyo University of Science, Japan) and MASAHIRO ISOGAI IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1255-1260. refs

A vibration control is proposed for a linked flexible system by allocating actuators at the joint of the linkage between the adjacent flexible structure and controlling these actuators, so that the coupled vibrations should be decreased. In order to derive the dynamics of such a linked system, first a flexible structure with the rigid bodies at each end is modeled by the bending vibration equation. Then, a decoupled control is shown based on these dynamics. In the experiments simulating the two-dimensional space environment, each joint at which flexible structures are supported is floated by air, so that there is no friction force from the ground to the floating joint and vice versa. Some experimental results are shown to demonstrate the effect of the proposed method. Author

A87-32446
PRECISE POINTING CONTROL OF FLEXIBLE SPACECRAFT
TOSHIO KASHIWASE, MASAO INOUE, KATSUHIKO YAMADA, and KAZUO TSUCHIYA (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1267-1272.

A control system for the antenna pointing and the attitude control of the main body of a flexible communication satellite is proposed. The designing of the controller is described. The performance of the developed controller is evaluated experimentally. The experimental results are compared with numerical simulations of closed loop performances. Good correlation between the experimental and theoretical data is observed. I.F.

A87-32447
A PRELIMINARY STUDY ON A LINEAR INERTIAL ACTUATOR FOR LSS CONTROL
TAKASHI KIDA, ISAO YAMAGUCHI, OSAMU OKAMOTO, YOSHIAKI OHKAMI (National Aerospace Laboratory, Chofu, Japan), YOSHIHARU SHIMAMOTO (Toshiba Corp., Research and Development Center, Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1273-1278.

This paper describes some characteristics of a laboratory model of a linear inertial actuator developed for large space structure damping augmentation. The actuator has the capability of performing direct velocity feedback control to a class of large

space structures, without causing control/observation spillover. A fundamental hardware experiment has been performed to demonstrate its capability and to clarify some basic aspects relating to hardware modeling. Author

A87-32448
CONTROL OF FLEXIBLE SOLAR ARRAYS WITH CONSIDERATION OF THE ACTUATOR DYNAMICS OF THE REACTION WHEEL
TOSHIO FUKUDA, HIDEMI HOSOGAI (Tokyo University of Science, Japan), and NOBUYUKI YAJIMA (Ministry of International Trade and Industry, Mechanical Engineering Laboratory, Sakura, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1279-1284. refs

This paper describes a control method to suppress such coupled vibrations and other interfering effects between a flexible solar array and a reaction wheel employed as an actuator. Based on the modal control, the dynamics of the overall system are obtained by taking into account the dynamics of the flexible array and the dynamics of the reaction wheel. The vibration measurement is carried out by employing the differential solar cells, which can measure the deflection angles, and the vibrational modes can be estimated. The control performance is evaluated by the sums of the squares of both the actuator consumption energy and the strain gauge output. The settling time of the system is dependent on the size of the reaction wheel employed here. Author

A87-32639
MOVER II - A COMPUTER PROGRAM FOR VERIFYING REDUCED-ORDER MODELS OF LARGE DYNAMIC SYSTEMS
J. D. CHROSTOWSKI and T. K. HASSELMAN (Engineering Mechanics Associates, Inc., Torrance, CA) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 14 p. USAF-supported research. refs
(SAE PAPER 861790)

This paper introduces a computer code for model verification of linear dynamic systems. Presentation is made within the broader context of system identification, and the many alternatives available for implementing a code. Practical considerations of the system identification process are discussed first. Alternative methods are reviewed and a classification system for existing as well as nonexisting methods is proposed. Finally, a rationale for the selection of a particular modeling approach, type of measurement data, and estimation algorithm is discussed. Although MOVER II was not specifically designed for large space structures, its capabilities fulfill many of the needs now recognized as important in the verification of reduced-order models. Prior application involving extensive use of substructuring and coordinate reduction is discussed. Author

A87-32657* California Univ., Los Angeles.
INTEGRATED CONTROL/STRUCTURE DESIGN AND ROBUSTNESS
A. ADAMIAN and J. S. GIBSON (California, University, Los Angeles) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 10 p. refs
(Contract JPL-957114)
(SAE PAPER 861821)

When a flexible structure is to be controlled actively, optimum performance is obtained by integrated, or simultaneous, design of the structure and the controller, as opposed to the common practice of designing the structure independently of control consideration and then designing a controller for a fixed structure. The primary design objective from the structural point of view usually is to minimize weight, while the control design objectives depend on the application. An important requirement for a practical control system is robustness with respect to uncertain plant parameters. This paper discusses simultaneous control/structure design when the overall design objective combines the weight of the structure and the robustness of the closed-loop control system. For numerical optimization, robustness is represented by the sensitivity of the closed-loop eigenvalues with respect to uncertain parameters. An example illustrates the optimal design of a flexible structure along with a robust compensator. Author

A87-32729
THE MAST FLIGHT SYSTEM DYNAMIC CHARACTERISTICS AND ACTUATOR/SENSOR SELECTION AND LOCATION
J. W. SHIPLEY and D. C. HYLAND (Harris Corp., Melbourne, FL) IN: Guidance and control 1986; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 1-5, 1986 . San Diego, CA, Univelt, Inc., 1986, p. 31-49.
(AAS PAPER 86-003)

The NASA Mast Flight System (MFS), which will serve as a test bed for the development of validation methodology for large space structures (LSS) and the accompanying control design methodology, is described. MFS will consist of a deployable/retractable truss beam 60 m or greater in length with a 100 kg tip mass, the latter being included to couple the first torsional mode with either the first or second bending mode. The system will include the capability of parameter alterations to change the modal frequency spacing and couple modes geometrically in a controlled manner. The design criteria for the MFS to ensure that the tests are valid for larger structures, cost-effective to perform, and harmonious with Orbiter operations are delineated. The designs, placement and operations of the linear dc motor actuators to achieve the mission goals are summarized. M.S.K.

A87-32730
LOW-AUTHORITY CONTROL THROUGH PASSIVE DAMPING
RUSSELL N. GEHLING (Martin Marietta Corp., Denver, CO) IN: Guidance and control 1986; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 1-5, 1986 . San Diego, CA, Univelt, Inc., 1986, p. 51-69. refs
(Contract F33615-82-C-3222)
(AAS PAPER 86-004)

Results are presented from a study of active and passive damping application to the Representative System Article (RSA) developed under the Passive and Active Control of Space Structures (PACOSS) program of Martin Marietta. Three control approaches are presented and demonstrated on a truncated model of the RSA. The approaches are active control alone via modal space control, passive damping alone, and low authority passive-active control. Results demonstrate that passive damping reduces the requirements for an active control system in terms of the number of control system components and the complexity of the control algorithm. This leads to simpler, more robust control systems which are likely to be more reliable and less expensive. Author

A87-32732* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE SOFTMOUNTED INERTIALLY REACTING POINTING SYSTEM (SIRPNT)
SAMUEL W. SIRLIN and ROBERT A. LASKIN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Guidance and control 1986; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 1-5, 1986 . San Diego, CA, Univelt, Inc., 1986, p. 85-105. refs
(AAS PAPER 86-007)

A softmounted inertially reacting pointing system differs from traditional gimbal-based pointing system architecture in that: (1) the primary pointing control actuator does not need to apply torques on the basebody, and hence will not interact in a destabilizing way with basebody flexibility, and (2) the connection of the payload with the basebody is via a soft, low frequency structure, which acts as a two-way low pass filter for disturbances. Planar, linear analysis of a preliminary design of such a pointing system using the piezoelectric polymer material PVF2 as an active element in the softmount is presented demonstrating the potential performance in disturbance rich environments such as Space Station. Author

A87-32819
CRITICAL LENGTH FOR STABLE ELONGATED ORBITING STRUCTURES
N. N. GORKAVYI, A. I. MOROZOV, and A. M. FRIDMAN (AN SSSR, Astronomicheskii Sovet, Moscow, USSR) (Zhurnal Tekhnicheskoi Fiziki, vol. 56, June 1986, p. 1210-1213) Soviet Physics - Technical Physics (ISSN 0038-5662), vol. 31, June 1986, p. 711-713. Translation. refs

The stabilizing effects of rigidity combined with tension are analyzed and the critical length for a stable section of rod lying tangent to the orbit are calculated. An example of elastic Euler instability for three-dimensional orbiting objects is provided. It is shown that, in large orbiting systems, the lengths of the rods tangent to the orbit and perpendicular to the orbital plane must satisfy certain conditions if they are to be stable. The precise form of these conditions depends on both the rigidity and tension on the rods. K.K.

A87-33557#
ASTROS - A MULTIDISCIPLINARY AUTOMATED STRUCTURAL DESIGN TOOL
D. J. NEILL, E. H. JOHNSON (Northrop Corp., Aircraft Div., Hawthorne, CA), and R. CANFIELD (USAF, Wright Aeronautical Laboratories, Wright-Patterson, AFB, OH) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 44-53. refs
(Contract F33615-83-C-3232)
(AIAA PAPER 87-0713)

ASTROS (Automated Structural Optimization System) is a multidisciplinary software system that can be used in the preliminary design of aerospace structures. The approach being taken in this ongoing development project is to blend proven engineering tools into an efficient unified system through the use of a specifically designed software environment. ASTROS has reached a stage of development at which significant test cases have been performed which demonstrate the power and versatility of the system. This paper first presents background information that motivates the development of this new system, followed by a discussion of the engineering technologies that have been integrated into ASTROS. Emphasis is placed on some of the more novel features, such as the treatment of flutter constraints and the linking of physical design variables. Insight into how the software environment has been applied to implement the multidisciplinary design features is then followed by two representative test cases. Author

A87-33561*# Auburn Univ., Ala.
ANALYTICAL SOLUTIONS FOR STATIC ELASTIC DEFORMATIONS OF WIRE ROPES
K. KUMAR and J. E. COCHRAN, JR. (Auburn University, AL) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 88-92. refs
(Contract NAG8-532)
(AIAA PAPER 87-0720)

This paper develops closed-form solutions for extension of twisted wire ropes subjected to axial forces for two different end conditions. The analytical results are compared with the corresponding numerical results obtained by Costello and Phillips. A close agreement between the two establishes validity of the analytical solutions. Finally, an expression for the effective rigidity modulus of the wire ropes is obtained in terms of the helix angle and the number of helical wires in the rope for each of the two end conditions. Author

A87-33565*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
A LANCZOS EIGENVALUE METHOD ON A PARALLEL COMPUTER
SUSAN W. BOSTIC and ROBERT E. FULTON (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 123-134. refs
(AIAA PAPER 87-0725)

Eigenvalue analyses of complex structures is a computationally intensive task which can benefit significantly from new and impending parallel computers. This study reports on a parallel computer implementation of the Lanczos method for free vibration analysis. The approach used here subdivides the major Lanczos calculation tasks into subtasks and introduces parallelism down to the subtask levels such as matrix decomposition and forward/backward substitution. The method was implemented on a commercial parallel computer and results were obtained for a long flexible space structure. While parallel computing efficiency is problem and computer dependent, the efficiency for the Lanczos method was good for a moderate number of processors for the test problem. The greatest reduction in time was realized for the decomposition of the stiffness matrix, a calculation which took 70 percent of the time in the sequential program and which took 25 percent of the time on eight processors. For a sample calculation of the twenty lowest frequencies of a 486 degree of freedom problem, the total sequential computing time was reduced by almost a factor of ten using 16 processors. Author

A87-33573*# California Univ., Los Angeles.
CONTROL AUGMENTED STRUCTURAL SYNTHESIS WITH TRANSIENT RESPONSE CONSTRAINTS
R. A. MANNING and L. A. SCHMIT (California, University, Los Angeles) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 194-204. Research supported by General Motors Corp. refs
(Contract NSG-1490)
(AIAA PAPER 87-0749)

An integrated approach to the optimum design of control augmented structural systems is presented in which structural variables and control variables are changed simultaneously during the design process. Constraints are imposed on peak transient dynamic displacements and accelerations, static displacements, natural frequencies, and control system effort. Side constraints imposed on structural member sizes and control system thresholds and actuator output forces insure the generation of physically meaningful designs. Example problems are presented which bring out the benefits of simultaneous treatment of both the structural design variables and the control design variables. Author

A87-33588#
STRUCTURAL OPTIMIZATION WITH FREQUENCY CONSTRAINTS
R. V. GRANDHI (Wright State University, Dayton, OH) and V. B. VENKAYYA (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 322-333. USAF-supported research. refs
(AIAA PAPER 87-0787)

This paper presents a design optimization algorithm for structural weight minimization with multiple frequency constraints. An optimality criterion method based on uniform Lagrangian density for resizing and a scaling procedure to locate the constraint boundary were used in optimization. Multiple frequency constraints of equality and inequality types were addressed. The effectiveness of the algorithm was demonstrated by designing a number of truss structures with as many as four hundred and eighty nine design variables. The algorithm is extremely stable and in all cases the optimum designs were obtained in less than twenty iterations

regardless of the size of the structure and the number of design variables. Author

A87-33591#
ROBUSTNESS OPTIMIZATION OF STRUCTURAL AND CONTROLLER PARAMETERS
KYONG B. LIM (Virginia Polytechnic Institute and State University, Blacksburg) and JOHN L. JUNKINS (Texas A & M University, College Station) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 351-361. refs
(Contract F49620-86-K-0014)
(AIAA PAPER 87-0791)

A unified approach to structure and controller design optimization is presented showing several novel ideas in the definition and optimization of robustness for structures and structural controllers. A robustness bound due to Patel and Toda is developed using conditioning analysis of the closed loop eigenvalue problem. Homotopy and sequential linear programming algorithms are used, in lieu of conventional nonlinear programming, to implement these ideas for an illustrative example. The numerical results confirm the conservatism of the stability robustness bound for highly structured perturbations but nevertheless clearly support the hypothesis that maximizing the robustness measure does significantly increase the true robustness of a closed loop system. Author

A87-33610*# Tokyo Univ. (Japan).
SIMULTANEOUS STRUCTURE/CONTROL OPTIMIZATION OF LARGE FLEXIBLE SPACECRAFT
JUNJIRO ONODA (Tokyo, University, Japan) and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 501-507. refs
(Contract NAG1-224)
(AIAA PAPER 87-0823)

This paper presents an approach to the simultaneous optimal design of a structure and control system for large flexible spacecrafts based on realistic objective function and constraints. The weight or total cost of structure and control system is minimized subject to constraints on the magnitude of response to a given disturbance involving both rigid-body and elastic modes. A nested optimization technique is developed to solve the combined problem. As an example, simple beam-like spacecraft under a steady-state white-noise disturbance force is investigated and some results of optimization are presented. In the numerical examples, the stiffness distribution, the location of controller and the control gains are optimized. Direct feedback control and linear quadratic optimal control laws are used with both inertial and non-inertial disturbing force. It is shown that the total cost is sensitive to the overall structural stiffness so that a simultaneous optimization of the structure and control system is indeed useful. Author

A87-33613*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
OPTIMIZATION PROCEDURE TO CONTROL THE COUPLING OF VIBRATION MODES IN FLEXIBLE SPACE STRUCTURES
JOANNE L. WALSH (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 525-534. refs
(AIAA PAPER 87-0826)

As spacecraft structural concepts increase in size and flexibility, the vibration frequencies become more closely-spaced. The identification and control of such closely-spaced frequencies present a significant challenge. To validate system identification and control methods prior to actual flight, simpler space structures will be flown. To challenge the above technologies it will be necessary to design these structures with closely-spaced or coupled vibration modes. Thus there exists a need to develop a systematic method to design a structure which has closely-spaced vibration frequencies. This paper describes an optimization procedure which is used to design a large flexible structure to have closely-spaced vibration frequencies. The procedure uses a general-purpose finite-element analysis program for the vibration and sensitivity analyses and a general-purpose optimization program. Results are presented from two studies. The first study uses a detailed model of a large flexible structure to design a structure with one pair of closely-spaced frequencies. The second study uses a simple equivalent beam model of a large flexible structure to obtain a design with two pairs of closely-spaced frequencies. Author

A87-33633*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
QUASI-STATIC SHAPE ADJUSTMENT OF A 15 METER DIAMETER SPACE ANTENNA
W. KEITH BELVIN, CATHERINE L. HERSTROM (NASA, Langley Research Center, Hampton, VA), and HAROLD H. EDIGHOFFER (Edighoffer, Inc., Newport News, VA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 705-713. refs
(AIAA PAPER 87-0869)

A 15 meter diameter Hoop-Column antenna has been analyzed and tested to study shape adjustment of the reflector surface. The Hoop-Column antenna concept employs pretensioned cables and mesh to produce a paraboloidal reflector surface. Fabrication errors and thermal distortions may significantly reduce surface accuracy and consequently degrade electromagnetic performance. Thus, the ability to adjust the surface shape is desirable. The shape adjustment algorithm consisted of finite element and least squares error analyses to minimize the surface distortions. Experimental results verified the analysis. Application of the procedure resulted in a reduction of surface error by 38 percent. Quasi-static shape adjustment has the potential for on-orbit compensation for a variety of surface shape distortions. Author

A87-33634*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON ORBIT DAMAGE ASSESSMENT FOR LARGE SPACE STRUCTURES
JAY-CHUNG CHEN and JOHN A. GARBA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 714-721. refs
(Contract NAS7-918)
(AIAA PAPER 87-0870)

The need for monitoring the dynamic characteristics of large structural systems, for the purpose of assessing the potential degradation of structural properties, has been established. This paper develops a theory for assessing the occurrence, location, and extent of potential damage utilizing on-orbit response measurements. The feasibility of the method is demonstrated using a simple structural system as an example. Author

A87-33658*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
DYNAMICAL RESPONSE TO PULSE EXCITATIONS IN LARGE SPACE STRUCTURES
MICHAIL ZAK (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 31-39. refs
(Contract NAS7-918)
(AIAA PAPER 87-0710)

Finite dimensional approximations of large space structures as distributed parameter systems may lead to a loss of contribution of high frequencies to the dynamic response in case of impulsive

or concentrated loads. It is shown that the unmodeled part of this response can be represented by a system of thin pulses which propagate as characteristic waves. It is demonstrated that the dynamical response to such a system of pulses can be modeled by a system of equations with delay argument. Fundamental dynamical properties of this system such as Liapunov stability, structural stability, loss of periodicity and transition to ergodicity are analyzed in this study. The results are illustrated by examples. Author

A87-33665*# State Univ. of New York, Buffalo.
VIBRATION SUPPRESSION USING A CONSTRAINED RATE-FEEDBACK THRESHOLD CONTROL STRATEGY
D. C. ZIMMERMAN, 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, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 125-134. NASA-supported research. refs
(Contract NGT-33-183-801; NSF MEA-83-51807; AF-AFOSR-85-0220)
(AIAA PAPER 87-0741)

Quasi-closed form solutions are derived for the finite time, minimum force rate-feedback threshold controller to bring a system with or without known external disturbances back into an 'allowable' state manifold in finite time. The disturbances are assumed to be expandable in terms of Fourier series. The quasi-closed form solutions replace the solution of the two-point boundary value problem and definite integral constraints with the solution of algebraic equations and the calculation of matrix exponentials. Examples demonstrate the threshold control technique and compare the quasi-closed form solutions with MACSYMA generated exact solutions (for small system order) and with the numerical solution of the two-point boundary value problem. Author

A87-33667#
ADAPTIVE PLANAR TRUSS STRUCTURES AND THEIR VIBRATION CHARACTERISTICS
MICHIHIRO NATORI (Tokyo, University, Japan), KAZUO IWASAKI (National Aerospace Laboratory, Chofu, Japan), and FUMIHIRO KUWAO (Toshiba Corp., Aerospace Equipment Div., Kawasaki, Japan) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 143-151. refs
(AIAA PAPER 87-0743)

The structural concept of adaptive planar space truss structures is evaluated from the viewpoints of both geometrical adaptivity and dynamic characteristics. Some geometrical properties of a function model are also presented to demonstrate the effectiveness of the concept. Author

A87-33669#
AN IDENTIFICATION METHOD FOR FLEXIBLE STRUCTURES
NELSON G. CREAMER and JOHN L. JUNKINS (Texas A & M University, College Station) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1967 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 163-171. refs
(AIAA PAPER 87-0745)

A structural model identification method is developed for determination of the mass and stiffness matrices of an undamped structure along with the damping matrix of a lightly-damped structure. Utilizing measurements of natural frequencies, damping factors, and frequency response elements, a unique identification of the model is established through incorporation of the spectral decomposition of the frequency response function and the modal orthonormality conditions. Numerical simulations demonstrate the flexibility and potential of the proposed method. Author

A87-33687#
SOME APPROXIMATIONS FOR THE DYNAMICS OF SPACECRAFT TETHERS
A. H. VON FLOTOW (MIT, Cambridge, MA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 314-321. USAF-sponsored research. refs
(AIAA PAPER 87-0821)

The dynamics of typical tethered spacecraft systems are studied in an expository approximate way, with spectral separation invoked to reduce the dynamics of the system to a relatively fast vibrational motion which is decoupled from and superimposed upon the slow roll/yaw librations of the system. The fast tether vibrations occur with respect to a slowly varying quasi-equilibrium. The equilibrium shape of the tether is shown to be slightly nonlinear, and the small perturbations from this equilibrium are given by a system of linear partial differential equations. Nondimensional parameter groups which govern the character of the fast tether vibration are specified. R.R.

A87-33689*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
EXPERIENCE IN DISTRIBUTED PARAMETER MODELING OF THE SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) STRUCTURE
L. W. TAYLOR and D. S. NAIDU (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 330-343. refs
(AIAA PAPER 87-0895)

The Spacecraft Control Laboratory Experiment (SCOLE) configuration is used to compare exact and approximate solutions of the partial differential equations which define its structural dynamics. The need for a proof model for evaluating competing control laws demands that solutions be generated which not only exhibit accurate modal characteristics, but precise static deflections as well. Because precise pointing is required, the motion of the end bodies of the Shuttle-attached antenna must be known with great accuracy. Modal models are attractive because of their stable solutions but require hundreds of modes to obtain a static deflection accuracy of only one percent. Although proportional damping in bending agrees well with experimental results using the SCOLE experimental apparatus, modes which involve both torsion and bending differ significantly from proportional damping. A lumped mass model is used to generate exact static deflections, but only approximate modal characteristics. Asymptotic solutions to the distributed parameter system approximate very accurately the modal characteristics at high mode numbers. Ways are examined for refining the approximate solutions by applying a first-order variation and by employing singular perturbation techniques which are usually limited to ordinary differential equations. The most accurate solutions of the distributed parameter model of SCOLE are obtained by combining exact and asymptotic solutions. Author

A87-33706*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON THE CONTROL OF FLEXIBLE STRUCTURES BY APPLIED THERMAL GRADIENTS
D. L. EDBERG (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 544-550. refs
(AIAA PAPER 87-0887)

Thermal, elastic, and feedback analyses are applied to the case of a beam with a distributed thermal actuator. The actuator is capable of producing a thermal gradient across the section of

the beam. One candidate for such an actuator uses the Peltier effect, which appears in certain semiconductors. These devices act as heat pumps when a voltage is applied, causing a temperature gradient. It is shown that the thermal gradients can induce deflection in the beam. If the thermal gradients are applied in the proper sense to a vibrating beam, it is possible to increase the vibration damping exhibited by the structure. Experimental results are given for a cantilever beam, whose first vibrational mode damping ratio was increased from 0.81 to 7.4 percent with a simple lead compensation. Author

A87-33708*# Texas A&M Univ., College Station.
DYNAMIC RESPONSE OF A VISCOELASTIC TIMOSHENKO BEAM
S. KALYANASUNDARAM, D. H. ALLEN, and R. A. SCHAPERY (Texas A & M University, College Station) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 559-567. refs
(Contract NAG9-140)
(AIAA PAPER 87-0890)

The analysis presented in this study deals with the vibratory response of viscoelastic Timoshenko (1955) beams under the assumption of small material loss tangents. The appropriate method of analysis employed here may be applied to more complex structures. This study compares the damping ratios obtained from the Timoshenko and Euler-Bernoulli theories for a given viscoelastic material system. From this study the effect of shear deformation and rotary inertia on damping ratios can be identified. Author

A87-33709*# Boeing Aerospace Co., Seattle, Wash.
NONLINEAR TRANSIENT ANALYSIS OF JOINT DOMINATED STRUCTURES
J. M. CHAPMAN, F. H. SHAW, and W. C. RUSSELL (Boeing Aerospace Co., Seattle, WA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A . New York, American Institute of Aeronautics and Astronautics, 1987, p. 568-577.
(Contract NAS8-36420)
(AIAA PAPER 87-0892)

A residual force technique is presented that can perform the transient analyses of large, flexible, and joint dominated structures. The technique permits substantial size reduction in the number of degrees of freedom describing the nonlinear structural models and can account for such nonlinear joint phenomena as free-play and hysteresis. In general, joints can have arbitrary force-state map representations but these are used in the form of residual force maps. One essential feature of the technique is to replace the arbitrary force-state maps describing the nonlinear joints with residual force maps describing the truss links. The main advantage of this replacement is that the incrementally small relative displacements and velocities across a joint are not monitored directly thereby avoiding numerical difficulties. Instead, very small and 'soft' residual forces are defined giving a numerically attractive form for the equations of motion and thereby permitting numerically stable integration algorithms. The technique was successfully applied to the transient analyses of a large 58 bay, 60 meter truss having nonlinear joints. A method to perform link testing is also presented. Author

A87-33710#
SENSITIVITY OF DISTRIBUTED STRUCTURES TO MODEL ORDER IN FEEDBACK CONTROL
LEONARD MEIROVITCH and MARK A. NORRIS (Virginia Polytechnic Institute and State University, Blacksburg) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 578-587. refs
(Contract AF-AFOSR-83-0017)
(AIAA PAPER 87-0900)

Feedback controls generated on the basis of a discretized model are applied to the actual distributed system, and the corresponding closed-loop poles are obtained. The sensitivity of the distributed system to feedback controls is studied by examining the incremental change in the closed-loop poles corresponding to a reduction in the order of the discretized model. In the second form of the sensitivity study, closed-loop poles are plotted as the order of the discretized model varies. From a numerical model it is shown that feedback controls designed on the basis of low-order discretized models induce instability in the actual distributed structure. R.R.

A87-33711*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
POSITIVE POSITION FEEDBACK CONTROL FOR LARGE SPACE STRUCTURES
J. L. FANSON (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) and T. K. CAUGHEY (California Institute of Technology, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 588-598. refs
(AIAA PAPER 87-0902)

A new technique for vibration suppression in large space structures is investigated in laboratory experiments on a thin cantilever beam. This technique, called Positive Position Feedback, makes use of generalized displacement measurements to accomplish vibration suppression. Several features of Positive Position Feedback make it attractive for the large space structure control environment: The realization of the controller is simple and straightforward. Global stability conditions can be derived which are independent of the dynamical characteristics of the structure being controlled, i.e., all spillover is stabilizing. The method cannot be destabilized by finite actuator dynamics, and the technique is amenable to a strain-based sensing approach. The experiments control the first six bending modes of a cantilever beam, and make use of piezoelectric materials for actuators and sensors, simulating a piezoelectric active-member. The modal damping ratios are increased by factors ranging from 2 to 130. Author

A87-33712*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
SPILLOVER STABILIZATION AND DECENTRALIZED MODAL CONTROL OF LARGE SPACE STRUCTURES
EVA A. CZAJKOWSKI and ANDRE PREUMONT (Virginia Polytechnic Institute and State University, Blacksburg) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 599-609. refs
(Contract NAG1-603)
(AIAA PAPER 87-0903)

The stabilization of the neglected dynamics of the higher modes of vibration in large space structures is studied, and the influence of the structure of the plant noise intensity matrix of the Kalman-Bucy filter on the stability margin of the residual modes is shown. An optimization procedure uses information on the residual modes to minimize spillover of known residual modes while preserving robustness with respect to the unknown dynamics, and

the optimum plant noise intensity matrix is selected to maximize the stability margins of the residual modes and to properly place the observer poles. Examples for both centralized and decentralized control are considered. R.R.

A87-33713*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
A COMPARISON OF ACTIVE VIBRATION CONTROL TECHNIQUES - OUTPUT FEEDBACK VS OPTIMAL CONTROL
ZORAN N. MARTINOVIC, RAPHAEL T. HAFTKA, WILLIAM L. HALLAUER, JR., and GEORGE C. SCHAMEL, II (Virginia Polytechnic Institute and State University, Blacksburg) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 610-621. refs
(Contract NAG1-224)
(AIAA PAPER 87-0904)

The paper presents analytical and experimental comparison of two control laws for a laboratory structure designed to simulate large space structures. The first control law is the standard linear quadratic law, which is optimal but requires model reduction for practical implementation. The second control law is a new simple direct feedback control law designed to minimize control forces while guaranteeing stability. The optimal control law was found to be only slightly better than the direct feedback law even in terms of the quadratic performance index. Moreover, the optimal control law provided almost no margin of stability for the unmodeled modes while the direct feedback law provided significant stability margins to all modes. The above results were verified experimentally using a digital implementation of the control laws. Excellent agreement between the analytical prediction and experimental measurements was observed. Author

A87-33714*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
ACCURACY OF DERIVATIVES OF CONTROL PERFORMANCE USING A REDUCED STRUCTURAL MODEL
CHRIS A. SANDRIDGE and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 622-628. refs
(Contract NAG1-603)
(AIAA PAPER 87-0905)

The sensitivity of control system performance to structural changes is calculated for a multi-span beam with direct-rate feedback vibration control. Reduced models based on the natural modes of the structure are formed and derivatives of the damping ratios of the closed-loop eigenvalues are calculated. The convergence of the derivatives of the damping ratios with increasing number of modes is shown to be slower than the convergence of the damping ratios themselves. In particular, in some cases the convergence of finite-element approximations to the derivatives is much faster than the convergence of the modal approximations. The results indicate that the use of reduced models based on natural vibration modes may be ill-advised for calculating the sensitivity of control system performance to changes in the controlled structure. Author

A87-33727#
MODAL ANALYSES OF DYNAMICS OF A DEFORMABLE MULTIBODY SPACECRAFT - THE SPACE STATION: A CONTINUUM APPROACH
HARI B. HABLANI (Rockwell International Corp., Satellite Systems Div., Seal Beach, CA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 753-768. refs
(AIAA PAPER 87-0925)

Two classes of modes for multibody deformable spacecraft which are completely free in space are formulated: (1) internal rigid body degrees of freedom (IRB) unconstrained modes, referring to free hinges; and (2) IRB-constrained modes, referring to locked hinges. A continuum formulation of the dynamics of the Space Station with a mobile manipulator is presented, and discretized equations of motion of the Space Station are obtained using both modes. Modal moment coefficients of both modes represent the linear and angular momentum of the vehicle and the angular momentum of the hinged bodies. The analysis is general, with elastic deformation being three-dimensional, and structures being of arbitrary geometry and obeying Hooke's law of elasticity. R.R.

A87-33728*# Colorado Univ., Boulder.
EVALUATION OF CONSTRAINT STABILIZATION PROCEDURES FOR MULTIBODY DYNAMICAL SYSTEMS
K. C. PARK and J. C. CHIOU (Colorado, University, Boulder) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 769-773. refs
(Contract NAS1-17660)
(AIAA PAPER 87-0927)

Comparative numerical studies of four constraint treatment techniques for the simulation of general multibody dynamic systems are presented, and results are presented for the example of a classical crank mechanism and for a simplified version of the seven-link manipulator deployment problem. The staggered stabilization technique (Park, 1986) is found to yield improved accuracy and robustness over Baumgarte's (1972) technique, the singular decomposition technique (Walton and Steeves, 1969), and the penalty technique (Lotstedt, 1979). Furthermore, the staggered stabilization technique offers software modularity, and the only data each solution module needs to exchange with the other is a set of vectors plus a common module to generate the gradient matrix of the constraints, B. R.R.

A87-33730#
HIGH SPEED SIMULATION OF MULTI-FLEXIBLE-BODY SYSTEMS WITH LARGE ROTATIONS
R. E. JONES, T. W. MORSE, and W. C. RUSSELL (Boeing Aerospace Co., Seattle, WA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 781-789. refs
(AIAA PAPER 87-0930)

The paper describes a fast multi-flexible-body dynamics code that combines nonlinear rigid and linearized flexible mode formulations and is applicable to systems with moderate rotation rates and flexibilities. Large angular motions are handled by updating the flexible modes and restarting the integration of the equations of motion. Comparisons of numerical results and computation times with those of the DISCOS code are given. Author

A87-33731*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DYNAMIC AND ATTITUDE CONTROL CHARACTERISTICS OF AN INTERNATIONAL SPACE STATION
THOMAS R. SUTTER, PAUL A. COOPER, JOHN W. YOUNG (NASA, Langley Research Center, Hampton, VA), and DON K. MCCUTCHEN (NASA, Johnson Space Center, Houston, TX) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 790-799.
(AIAA PAPER 87-0931)

The structural dynamic characteristics of the International Space Station (ISS), the interim reference configuration established for NASA's Space Station developmental program, are discussed, and a finite element model is described. Modes and frequencies of the station below 2.0 Hz are derived, and the dynamic response of the station is simulated for an external impulse load corresponding to a failed shuttle-docking maneuver. A three-axis attitude control system regulates the ISS orientation, with control moment gyros responding to attitude and attitude rate signals. No instabilities were found in the attitude control system. R.R.

A87-33737#
STRUCTURAL AND CONTROL OPTIMIZATION OF SPACE STRUCTURES
N. S. KHOT, V. B. VENKAYYA (USAF, Flight Dynamics Laboratory, Wright-Patterson, AFB, OH), and R. V. GRANDHI (Wright State University, Dayton, OH) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 850-860. USAF-supported research. refs
(AIAA PAPER 87-0939)

Results are obtained by three optimization algorithms to design the structure and control system with weight as the objective function and constraints on the closed-loop eigenvalue distribution and the damping parameters. The nonunique nature of the optimizations is discussed, and the minimization of the Frobenious norm is investigated. A two bar truss and an ACOSS-four structure were designed, and from numerical comparisons it is found that when the structure is completely constrained, minimization of the weight and the Frobenious norm both give identical results. Qualitative aspects of the optimum solutions are considered with the transient response and control effort simulations. R.R.

A87-33738#
ADAPTIVE TRACKING OF DYNAMICAL MODEL BY UNCERTAIN NONLINEARIZABLE SPACECRAFT
J. M. SKOWRONSKI (Queensland, University, Brisbane, Australia) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 861-867. refs
(AIAA PAPER 87-0940)

Model reference adaptive control (MRAC) extended to cover the nonlinearizable systems with several equilibria, is used to control a mechanical space structure. The structure is modelled in general terms as a hybrid system, i.e., assembly of rigid bodies and flexible appendages, with only estimated data on its own configuration. The structure should track in real, possibly stipulated time and with stipulated accuracy a rigid body model with a desired state space behavior. Closed form algorithms for the signal adaptive feedback controllers and adaptive laws are designed together with state predictors which provide the feedback information without having to solve the motion equations. All the above makes the on-board computer to work as a calculator. The technique used bases on Liapunov Design, but the Liapunov functions are well defined and used as intermediate steps only, without appearing in the result. Author

A87-33739*# PRC Kentron, Inc., Hampton, Va.
EFFECTS OF LOCAL VIBRATIONS ON THE DYNAMICS OF SPACE TRUSS STRUCTURES
DIRK B. WARNAAR (PRC Kentron, Inc., Hampton, VA) and PAUL E. MCGOWAN (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 868-875.
(AIAA PAPER 87-0941)

The paper discusses the influence of local member vibrations on the dynamics of repetitive space truss structures. Several focus problems wherein local member vibration modes are in the frequency range of the global truss modes are discussed. Special attention is given to defining methods that can be used to identify the global modes of a truss structure amidst many local modes. Significant interactions between the motions of local member vibrations and the global behavior are shown to occur in truss structures when: (1) the natural frequencies of the individual members for clamped-clamped boundary conditions are in the vicinity of the global truss frequency; and (2) the total mass of the individual members represents a large portion of the mass of the whole structure. The analysis is carried out with a structural analysis code which uses exact member theory. The modeling detail required using conventional finite element codes to adequately represent such a class of problems is examined. The paper concludes with some practical considerations for the design and dynamic testing of structures which might exhibit such behavior. Author

A87-33740#
IMPLEMENTATION OF ACTIVE SUPPRESSION OF TRAVELING WAVES IN STRUCTURES
JEFFREY K. RENNIGHOFT and LEONARD MEIROVITCH (Virginia Polytechnic Institute and State University, Blacksburg) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 876-887. refs
(Contract AF-AFOSR-83-0017)
(AIAA PAPER 87-0942)

The performance of direct feedback control in suppressing wave motion in several structures is studied, and results are compared with those obtained by means of independent modal-space control (IMSC). IMSC is found to be attractive when there is a small amount of material damping in a structure, because the lower modes are targeted for control and higher modes are damped out more quickly on their own. For the case of the string, where modal frequencies are closely spaced, direct feedback control is more effective because the number of modes from which energy is to be dissipated is much greater than the number of actuators, which is the limit on the number of modes that can be controlled using IMSC. In IMSC, the actuator forces are shown to concentrate near a localized disturbance such as a traveling wave. R.R.

A87-33741#
AN EXPERIMENTAL STUDY OF TRANSIENT WAVES IN A PLANE GRID STRUCTURE
WILLIAM L. HALLAUER, JR. and DINESH J. TRIVEDI (Virginia Polytechnic Institute and State University, Blacksburg) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 888-899. refs
(Contract F49620-85-C-0024)
(AIAA PAPER 87-0943)

Flexural waves were generated and measured in a two-dimensional laboratory structure which is dynamically representative in many respects of flexible large spacecraft structures. The structure's first vibration mode is at 0.6 Hz, and

its average modal density for 0-100 Hz is 0.55 mode/Hz. The excitation used was suddenly applied sinusoidal forcing at a point on the structure, with frequencies of 30, 60, 120 and 240 Hz. Time series motion responses were measured at several points on the structure, permitting observation of the wavefront traveling outward from the point of excitation. Complementary theoretical transient responses were computed for a refined finite element model of the laboratory structure, and the theoretical predictions are compared with the experimental measurements. Author

A87-33742#
WAVE PROPAGATION IN PERIODIC TRUSS STRUCTURES
A. H. VON FLOTOW (MIT, Cambridge, MA) and JOEL SIGNORELLI IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 900-909. refs
(AIAA PAPER 87-0944)

Wave propagation in periodic truss-work structures is analytically investigated. Transfer matrix methods are applied to the analysis of a truss beam. The results, with members modeled as rods with pinned joints, agree well with results obtained from an equivalent continuum model of the same structure. Use of beam models for the members, including bending, shows that the pinned rod model loses fidelity above the first resonant frequency of lateral motion of the members. The truss, modeled with beam members exhibits complicated mechanical filtering properties. Fixed and free boundary conditions are converted to reflection matrices. The phase closure principle is invoked to predict natural frequencies of a fixed-free portion of the truss. It is found that closely spaced resonant frequencies are not identified by this method. Computed results show subtle erroneous characteristics which are attributed to numerical effects. Author

A87-33745#
LOCALIZATION OF VIBRATIONS IN LARGE SPACE REFLECTORS
ODDVAR O. BENDIKSEN (Princeton University, NJ) and PHILLIP J. CORNWELL IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 925-935. refs
(AIAA PAPER 87-0949)

A study is presented of the mode localization phenomenon in a generic class of large space reflectors. The study is based on a Rayleigh-Ritz formulation using the first five cantilevered beam bending modes and a finite element formulation using Bernoulli-Euler beam elements. Coupling between the structures is provided by massless axial members. Numerical results indicate that mode localization does in fact occur in engineering structures of this type. Localization is characterized by the amplitude of a global mode becoming confined to a local region of the structure. For the 18-rib reflector studied, the first rib bending mode did not localize but the second and third modes did. Localization is found to become more severe with increasing mode number. Increasing the number of ribs to 48 resulted in significant distortion in some of the first rib bending modes and severe localization of the second and third bending modes. The phenomenon of wave confinement in finite structures is also demonstrated using a single-degree-of-freedom per substructure model. Author

A87-33751#
OPTIMAL VIBRATION CONTROL BY THE USE OF PIEZOCERAMIC SENSORS AND ACTUATORS
S. HANAGUD, A. J. CALISE (Georgia Institute of Technology, Atlanta), and M. W. OBAL IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 987-997. refs
(AIAA PAPER 87-0959)

In this paper, a discrete degrees of freedom model has been formulated for a structural dynamic system consisting of a linear elastic structure, bonded piezoceramic sensors and actuators and a feedback signal conditioning system. The formulated analytical model has been used to develop a procedure for optimum control by minimizing a quadratic performance index of state and control vectors using limited state feedback. An example of a linear elastic beam with piezoceramic sensors and actuators occupying discrete subdomains of the beam upper and lower surfaces has been used to illustrate the developed optimal control procedure. A model for the linear elastic beam has been obtained by using test results and a structural dynamic system identification method based on an equation error approach. Author

A87-33752*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON SINE DWELL OR BROADBAND METHODS FOR MODAL TESTING
JAY-CHUNG CHEN and BEN K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 998-1004. refs
(Contract NAS7-918)
(AIAA PAPER 87-0961)

For large, complex spacecraft structural systems, the objectives of the modal test are outlined. Based on these objectives, the comparison criteria for the modal test methods, namely, the broadband excitation and the sine dwell methods are established. Using the Galileo spacecraft modal test and the Centaur G Prime upper stage vehicle modal test as examples, the relative advantages or disadvantages of each method are examined. The usefulness or shortcoming of the methods are given from a practicing engineer's view point. Author

A87-33754#
A MODERN APPROACH FOR MODAL TESTING USING MULTIPLE INPUT SINE EXCITATION
DAVID L. HUNT (SDRC, Inc., San Diego, CA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 1016-1023. refs
(AIAA PAPER 87-0964)

Sinusoidal excitation continues to be the method preferred by many companies for conducting modal tests of structures. Frequency-response-based modal analysis has been made popular and shown to be quite accurate through the use of multiple input random excitation. A multiple input sine excitation capability has been developed and implemented which retains the benefits associated with both normal mode testing and frequency response function measurement and analysis. A digitally based system has replaced analog/manual force appropriation and control with a multichannel system that automates both exciter control and data acquisition. Other important aspects of the system include determination of force appropriation, informative graphic displays, and system portability. Author

A87-33755*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
OPTIMAL PLACEMENT OF EXCITATIONS AND SENSORS FOR VERIFICATION OF LARGE DYNAMICAL SYSTEMS
M. SALAMA, T. ROSE, and J. GARBA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B . New York, American Institute of Aeronautics and Astronautics, 1987, p. 1024-1031. refs
(AIAA PAPER 87-0782)

The computationally difficult problem of the optimal placement of excitations and sensors to maximize the observed measurements is studied within the framework of combinatorial optimization, and is solved numerically using a variation of the simulated annealing heuristic algorithm. Results of numerical experiments including a square plate and a 960 degrees-of-freedom Control of Flexible Structure (COFS) truss structure, are presented. Though the algorithm produces suboptimal solutions, its generality and simplicity allow the treatment of complex dynamical systems which would otherwise be difficult to handle. R.R.

A87-34510#
COMPARISON OF THE CRAIG-BAMPTON AND RESIDUAL FLEXIBILITY METHODS OF SUBSTRUCTURE REPRESENTATION
DANIEL C. KAMMER and MARY BAKER (Structural Dynamics Research Corp., San Diego, CA) (Structures, Structural Dynamics and Materials Conference, 26th, Orlando, FL, Apr. 15-17, 1985, Technical Papers. Part 2, p. 699-706) Journal of Aircraft (ISSN 0021-8669), vol. 24, April 1987, p. 262-267. Previously cited in issue 13, p. 1900, Accession no. A85-30399. refs

A87-34701#
ON A BALANCED PASSIVE DAMPING AND ACTIVE VIBRATION SUPPRESSION OF LARGE SPACE STRUCTURES
S. S. SIMONIAN, M. S. LUKICH, and R. GLUCK (TRW, Inc., Engineering and Test Div., Redondo Beach, CA) AIAA, Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987. 33 p. refs
(AIAA PAPER 87-0901)

A methodology which blends passive damping and active vibration suppression of large space structures is described. The methodology involves the development of a finite element model of the spacecraft, analysis of the system requirements for the mission, identification of the spacecraft natural modes that require damping augmentation, and the incorporation of damping in the model. Weight cost functions for active and passive suppression systems are developed and compared. The methodology is evaluated by employing it in a laboratory demonstration of a space structure reflecting and/or transmitting electromagnetic radiation. The horizontal displacement and rotation of the simulated mirror are measured by a surface accuracy measurement system. The data from a single vertical column and a complete structure test are analyzed. The control problem is examined and the performance of the open- and closed-loop response characteristics are assessed. It is determined that the modal strain energy methodology is useful for the blending of active and passive damping systems. I.F.

A87-35077#
A STUDY ON SINGULARITY OF SINGLE GIMBAL CMG SYSTEMS
HARUHISA KUROKAWA and NOBUYUKI YAJIMA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 395, 1986, p. 661-666. In Japanese, with abstract in English. refs

A single gimbal CMG system is a promising candidate for an actuator of attitude control systems for large space structures. One of its problems is the existence of singular states. Various steering laws assume redundancy in the system and avoid singular states by maximizing a certain criterion function value by a gradient method. But it is not theoretically clear whether these steering laws can actually avoid all singular states. In this paper, a quadratic form is defined for each singular state, which enables to classify singular states into three types. In the vicinity of two types of singular states, escape from the vicinity is not guaranteed locally. Also it is difficult to guarantee that the system does not go into the vicinity of any two types of singular points by using the gradient method only. Examples of the three types of singular states are shown for three configurations. Author

A87-37135
STABILITY OF TIME VARYING LINEAR SYSTEMS
SHASHI K. SHRIVASTAVA and S. PRADEEP (Indian Institute of Science, Bangalore, India) IN: Space dynamics and celestial mechanics; Proceedings of the International Workshop, Delhi, India, Nov. 14-16, 1985 . Dordrecht, D. Reidel Publishing Co., 1986, p. 87-101. refs

The history and fundamental principles of stability theory are examined in an analytical review, and some recent results are presented. Topics addressed include the early history of stability theory, stability of linear and nonlinear constant-parameter systems, periodic systems, second-order equations, arbitrarily time-varying systems, the absolute stability problem, and the functional analytical approach. The authors' recent work on multidimensional linear time-varying systems such as large space structures is summarized, and the results for the damped Mathieu equation (Pradeep and Shrivastava, 1986) are shown to be superior (for some parameter ranges) to those obtained by Taylor and Narenda (1969) and Gunderson et al. (1974). T.K.

A87-38824#
APPLICATION OF REANALYSIS TECHNIQUES IN DYNAMIC ANALYSIS OF SPACECRAFT STRUCTURES
F. H. CHU and P. WALKER (RCA/Astro Electronics, Princeton, NJ) IN: Reanalysis of structural dynamic models; Proceedings of the Symposium, Anaheim, CA, Dec. 7-12, 1986 . New York, American Society of Mechanical Engineers, 1986, p. 95-104. refs

This paper demonstrates some useful applications of reanalysis techniques to spacecraft structure design. The applications include prediction of the dynamic effects of stiffness and mass changes, optimization of structures subjected to frequency constraints, and model refinement based on modal test data. Software has been developed to integrate the reanalysis formulation with the general purpose finite element software NASTRAN. The time savings and accuracy of the approach is illustrated using a spacecraft, a space truss, and a reflector finite element model as test cases. Author

A87-39543*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
CONTROL OF FLEXIBLE STRUCTURES BY APPLIED THERMAL GRADIENTS
DONALD L. EDBERG (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA Journal (ISSN 0001-1452), vol. 25, June 1987, p. 877-883. refs

Thermal, elastic, and feedback analyses are applied to the case of a beam with a distributed thermal actuator. The actuator is capable of producing a thermal gradient across the section of the beam. One candidate for such an actuator uses the Peltier effect, which appears in certain semiconductors. These devices act as heat pumps when a voltage is applied, causing a temperature gradient. It is shown that the thermal gradients can induce deflection in the beam. If the thermal gradients are applied in the proper sense to a vibrating beam, it is possible to increase the vibration damping exhibited by the structure. Experimental results are given for a cantilever beam, whose first vibrational mode damping ratio was increased from 0.81 to 7.4 percent with simple lead compensation. Author

A87-39644#
THE DESIGN AND ANALYSIS OF PASSIVE DAMPING FOR AEROSPACE SYSTEMS
DERRICK W. JOHNSON, ROY IKEGAMI (Boeing Aerospace Co., Seattle, WA), and ERIC M. AUSTIN (CSA Engineering, Inc., Palo Alto, CA) AIAA, ASME, ASCE, and AHS, Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987. 11 p.
(Contract F33615-82-C-3226)
(AIAA PAPER 87-0891)

A study has been performed to investigate the use of viscoelastic passive damping technology to decrease the vibroacoustic response of avionics equipment in typical satellite systems. The Boeing Inertial Upper Stage (IUS) was selected as a baseline satellite system to demonstrate these techniques on an established aerospace vehicle with the associated design requirements. To serve as a developmental test bed for evaluation of various damping concepts and validation of the analytical design tools, a smaller component test article, representative of the IUS equipment support section, was fabricated. Using the experience gained from the component test article, damping treatments were designed for the IUS dynamic test vehicle using finite element modeling and the modal strain energy method. These treatments were then installed on the dynamic test vehicle and evaluated through acoustic noise testing. The results of this testing are given compared to previous undamped test results and preestablished goals. Discussions are included about the basis of the goals on system reliability and the impact of the damping treatments on system requirements. Author

A87-39958*
VARIABLE STRUCTURE CONTROLLER DESIGN FOR SPACECRAFT NUTATION DAMPING
HEBERTT SIRA-RAMIREZ and THOMAS A. W. DWYER, III (Illinois, University, Urbana) IEEE Transactions on Automatic Control (ISSN 0018-9286), vol. AC-32, May 1987, p. 435-438. refs
(Contract NAG1-436; NSF ECS-85-16445; N00014-84-C-0149)

Variable structure systems theory is used to design an automatic controller for active nutation damping in momentum biased stabilized spacecraft. Robust feedback stabilization of roll and yaw angular dynamics is achieved with prescribed qualitative characteristics which are totally independent of the spacecraft defining parameters. Author

A87-40074#
DEPLOYMENT DYNAMICS OF SPACE STRUCTURES
V. J. MODI (British Columbia, University, Vancouver, Canada) IN: U.S. National Congress of Applied Mechanics, 10th, Austin, TX, June 16-20, 1986, Proceedings . New York, American Society of Mechanical Engineers, 1987, p. 403-413. refs
(Contract NSERC-67-1547)

Computational techniques for analyzing the deployment of complex flexible space structures are described and demonstrated. The general formulation of Modi and Ibrahim (1984) is extended to account for membrane, shell, and tether appendages with viscous/structural damping and momentum/reaction wheels. The basic principles of this approach are explained, and results for three sample problems (local-vertical deployment of a beam, arbitrary-orientation deployment of a beam from the Shuttle Orbiter, and Shuttle deployment of a subsatellite on a 100-km tether) are presented graphically. The importance of deployment-dynamics analysis tools and data bases for the Space Station is indicated. T.K.

A87-40075#
INCORPORATION OF THE EFFECTS OF MATERIAL DAMPING AND NONLINEARITIES ON THE DYNAMICS OF SPACE STRUCTURES
E. F. CRAWLEY and K. J. O'DONNELL (MIT, Cambridge, MA) IN: U.S. National Congress of Applied Mechanics, 10th, Austin, TX, June 16-20, 1986, Proceedings . New York, American Society of Mechanical Engineers, 1987, p. 415-420. refs

A procedure is presented for incorporating the distributed material damping effects and discrete nonlinear joint properties of truss structures into a linear analysis technique. A testing apparatus has been constructed which measures the transient response of a truss member in free-fall in a vacuum to obtain its material damping characteristics. The force-state mapping technique is presented for identifying localized nonlinearities in joints by presenting the force transmitted through the joint as a function of the full mechanical state of the joint. The nonlinear structural parameters are then linearized using an equivalent energy approach which finds the equivalent linear stiffness and linear viscous damping of each nonlinearity by equating the integrated average of the work done and energy dissipated by the nonlinearity to those of a spring and damper undergoing sinusoidal motion. Incorporation of both the distributed material damping and localized nonlinear effects is discussed in the context of forming a linearized damped finite element model. Author

A87-40866#
GRADIENT-BASED COMBINED STRUCTURAL AND CONTROL OPTIMIZATION
DAVID F. MILLER and JAEDONG SHIM (Wright State University, Dayton, OH) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, May-June 1987, p. 291-298. Previously cited in issue 07, p. 938, Accession no. A86-19736. refs
(Contract F33615-84-C-3217)

A87-40867#
DYNAMICS OF A MULTIBODY SYSTEM WITH RELATIVE TRANSLATION ON CURVED, FLEXIBLE TRACKS
DECHANG LI (East China Institute of Technology, Nanjing, People's Republic of China) and PETER W. LIKINS (Lehigh University, Bethlehem, PA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, May-June 1987, p. 299-306. refs

Previous generic formulations of equations of motion for multibody systems treat explicitly only special cases of interbody translation, such as unconstrained translation or translation constrained to a straight, rigid track or a rigid plane. But real, physical tracks are not always even nominally straight, and they are always somewhat flexible. In this paper, the previous formulations are extended to accommodate interbody translations that can be characterized nominally by a single scalar variable (such as distance traveled on a curved track or screw path) plus motions induced by small deformations of the track or guideway. Author

A87-40869#
NEW TIME-DOMAIN IDENTIFICATION TECHNIQUE
FANG-BO YEH and CIANN-DONG YANG (National Chen Kung University, Taiwan, Republic of China) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, May-June 1987, p. 313-316.

The novel methodology presented for the identification of vibrating structure model parameters obtains mass, stiffness, and damping matrices corresponding to a lumped equivalent model of the tested structure directly from the impulse response data. The scheme requires only a simple manipulation of the impulse response data. A spring mass-damper system shows the high accuracy of the identification procedure even under conditions in which the number of sampling points is limited. O.C.

A87-41052
MODELING, STABILIZATION AND CONTROL OF SERIALLY CONNECTED BEAMS
G. CHEN, A. M. KRALL (Pennsylvania State University, University Park), M. C. DELFOUR (Montreal, Universite, Canada), and G. PAYRES (Sherbrooke, Universite, Canada) SIAM Journal on Control and Optimization (ISSN 0363-0129), vol. 25, May 1987, p. 526-546. refs
(Contract NSERC-A-8730; NSF DMS-84-01297; AF-AFOSR-85-0253; CDC-24ST-36001-3-1898)

Many flexible structures consist of a large number of components coupled end to end in the form of a chain. In this paper, consideration is given to the simplest type of such structures which is formed by N serially connected Euler-Bernoulli beams, with N actuators and sensors co-located at nodal points. When these N beams are strongly connected at all intermediate nodes and their material coefficients satisfy certain properties, uniform exponential stabilization can be achieved by stabilizing at one end point of the composite beam. Finite elements are used to discretize the partial differential equation and compute the spectra of these boundary damped operators. Numerical results are also illustrated. Author

A87-41159*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
EXPERIENCES WITH THE LANCZOS METHOD ON A PARALLEL COMPUTER
SUSAN W. BOSTIC (NASA, Langley Research Center, Hampton, VA) and ROBERT E. FULTON (Georgia Institute of Technology, Atlanta) ASME, International Computers in Engineering Conference and Exhibition, New York, Aug. 9-13, 1987, Paper. 9 p. refs

A parallel computer implementation of the Lanczos method for the free-vibration analysis of structures is considered, and results for two example problems show substantial time-reduction over the sequential solutions. The major Lanczos calculation tasks are subdivided into subtasks, and parallelism is introduced at the subtask level. A speedup of 7.8 on eight processors was obtained for the decomposition step of the problem involving a 60-m three-longeron space mast, and a speedup of 14.6 on 16 processors was obtained for the decomposition step of the problem involving a blade-stiffened graphite-epoxy panel. R.R.

A87-41574
A FORMULATION FOR STUDYING DYNAMICS OF N CONNECTED FLEXIBLE DEPLOYABLE MEMBERS
A. M. IBRAHIM and V. J. MODI (British Columbia, University, Vancouver, Canada) (IAF, International Astronautical Congress on Space: New Opportunities for all People, 37th, Innsbruck, Austria, Oct. 4-11, 1986) Acta Astronautica (ISSN 0094-5765), vol. 16, 1987, p. 151-164.
(Contract NSERC-G-1547)

A relatively general formulation for studying dynamics of a system, consisting of N connected flexible deployable members (beams, plates, shells, membranes, strings) forming a topological tree or a closed configuration, is presented. The mathematical description of the system can be, in general, a combination of discrete and distributed coordinates. Joints, elastic and dissipative, permit relative rotation and translation between bodies. The elastic deformations (lateral, axial, and torsional) can be discretized using admissible functions, finite elements or lumped mass method. Rotations of the members, as well as of the entire system, can be described using a set of orientation angles, Euler parameters or Rodrigues vectors. The formulation accounts for: the presence of momentum or reaction wheels (gimballed or fixed); thrusters distributed over the flexible and rigid portions; and any prescribed forms of energy dissipation mechanisms. Of course, the generalized forces can simulate desired environmental effects. The formulation is valid for orbiting as well as ground based and marine systems. Application of the formulation is illustrated through several examples, in spacecraft dynamics, which are of contemporary interest. Author

A87-41611*# Hughes Aircraft Co., Los Angeles, Calif.
MODELING OF ENVIRONMENTALLY INDUCED TRANSIENTS WITHIN SATELLITES
N. JOHN STEVENS, GORDON J. BARBAY, MICHAEL R. JONES, and R. VISWANATHAN (Hughes Aircraft Co., Los Angeles, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, May-June 1987, p. 257-263. refs
(Contract NAS3-23869)
(AIAA PAPER 85-0387)

A technique is described that allows an estimation of possible spacecraft charging hazards. This technique, called SCREENS (spacecraft response to environments of space), utilizes the NASA charging analyzer program (NASCAP) to estimate the electrical stress locations and the charge stored in the dielectric coatings due to spacecraft encounter with a geomagnetic substorm environment. This information can then be used to determine the response of the spacecraft electrical system to a surface discharge by means of lumped element models. The coupling into the electronics is assumed to be due to magnetic linkage from the transient currents flowing as a result of the discharge transient. The behavior of a spinning spacecraft encountering a severe substorm is predicted using this technique. It is found that systems are potentially vulnerable to upset if transient signals enter through the ground lines. Author

A87-41617
ATTITUDE CONTROL OF A SPACECRAFT USING AN EXTENDED SELF-ORGANIZING FUZZY LOGIC CONTROLLER
S. DALEY (Brunel University, Uxbridge, England) and K. F. GILL (Leeds University, England) Institution of Mechanical Engineers, Proceedings, Part C - Mechanical Engineering Science (ISSN 0263-7154), vol. 201, no. C2, 1987, p. 97-106. refs

A simple method for extending the range of sensitivity of the self-organizing fuzzy logic controller (SOC) is proposed. The performance of the resulting controller is studied through its application to the attitude control of a flexible satellite. It is found that the extended SOC can provide excellent control and also possess a high degree of robustness. Author

A87-42266#
MODAL-SURVEY TESTING OF THE OLYMPUS SPACECRAFT
R. STEELS and D. BASTON (ESA, Communications Satellite Dept., Noordwijk, Netherlands) ESA Journal (ISSN 0379-2285), vol. 10, no. 4, 1986, p. 363-371.

This paper describes the background to the introduction of a spacecraft modal-survey test into the development program for ESA's Olympus telecommunications satellite. It details the objectives of such tests, how the test was actually performed, and the use to which the test results have been put. A concluding section assesses the benefits that have accrued to the Olympus satellite program from the tests performed. Author

A87-42505#
RESPONSE BOUNDS FOR LINEAR UNDERDAMPED SYSTEMS
K. H. YAE and D. J. INMAN (New York, State University, Buffalo) ASME, Transactions, Journal of Applied Mechanics (ISSN 0021-8936), vol. 54, June 1987, p. 419-423. refs
(Contract NSF MEA-83-51807; AF-AFOSR-82-0242; AF-AFOSR-85-0220)
(ASME PAPER 87-APM-34)

This paper examines simple bounds on the displacement response of linear oscillatory multiple degree of freedom systems. Both the free and steady state forced responses are considered. The effect of mode coupling due to viscous damping is examined. The bounds are derived and stated in terms of the physical parameters of the structure and its inputs. Simple examples are given to illustrate the bounds and to compare the bounds developed here with previously published results. Author

A87-42678*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
INTERDISCIPLINARY ANALYSIS PROCEDURES IN THE MODELING AND CONTROL OF LARGE SPACE-BASED STRUCTURES
PAUL A. COOPER (NASA, Langley Research Center, Hampton, VA), ALAN E. STOCKWELL, and ZEEN C. KIM (PRC Kentron, Inc., Hampton, VA) ASME, Symposium on Engineering Data Management: Critical Issues, New York, Aug. 10-14, 1987, Paper. 10 p.

The paper describes a computer software system called the Integrated Multidisciplinary Analysis Tool, IMAT, that has been developed at NASA Langley Research Center. IMAT provides researchers and analysts with an efficient capability to analyze satellite control systems influenced by structural dynamics. Using a menu-driven interactive executive program, IMAT links a relational database to commercial structural and controls analysis codes. The paper describes the procedures followed to analyze a complex satellite structure and control system. The codes used to accomplish the analysis are described, and an example is provided of an application of IMAT to the analysis of a reference space station subject to a rectangular pulse loading at its docking port.
Author

A87-42816* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
ACTUATORS FOR ACTIVELY CONTROLLED SPACE STRUCTURES
P. STUDER, R. SHARMA (NASA, Goddard Space Flight Center, Greenbelt, MD), and A. BAZ (Catholic University of America, Washington, DC) IN: Acquisition, tracking, and pointing; Proceedings of the Meeting, Orlando, FL, Apr. 3, 4, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 148-159. refs

A free-flying platform of about 4 x 17 m overall dimensions, carrying a variety of imaging and sounding payloads, calls for an intelligent structure with active dynamic control of structural resonances. The actuators for such a structure must be lightweight, require low power, and allow integration into the structure without degradation of its integrity; the dc-to-100 Hz dynamic range required may entail several types of actuators, as is presently emphasized. Broadband damping of higher-order modes requires modeling of the structure with a distributed array of sensors and actuators.
O.C.

A87-42817* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SOFT MOUNTED MOMENTUM COMPENSATED POINTING SYSTEM FOR THE SPACE SHUTTLE ORBITER
SAMUEL W. SIRLIN and CHARLES E. BELL (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Acquisition, tracking, and pointing; Proceedings of the Meeting, Orlando, FL, Apr. 3, 4, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 160-173. DOD-sponsored research.

This paper describes a potential pointing and tracking system for the Space Shuttle with possible future application to Space Station. In order to accomplish high precision pointing and tracking (at rates up to 2 deg/s) in the expected disturbance environment, a high bandwidth gimbaled pointing system is required. A soft-mounted, momentum-compensated gimbal system is suggested for this role. A momentum-compensated system is inertially reacting, decoupling the control system dynamics from the basebody structural dynamics. This allows a soft isolation stage to be added between the basebody and the articulation stage, which attenuates high frequency disturbances. In this paper, three configurations are examined: a hard-mounted system, a passive soft-mounted system, and an active soft-mounted system. Analysis demonstrates that the soft-mounted systems have superior disturbance-rejection properties. The active soft mount allows reduction of the isolation stiffness to zero, and so obtains the highest level of performance. Author

A87-46121
DETERMINATION OF THE NATURAL FREQUENCIES OF THE LONGITUDINAL AND TORSIONAL VIBRATIONS OF TRUSS STRUCTURES WITH ATTACHED RIGID BODIES [OB OPREDELENII SOBSTVENNYKH CHASTOT PRODOL'NYKH I KRUTIL'NYKH KOLEBANII FERMENNYKH KONSTRUKTSII S PRISOEDINENNYMI TVERDYMI TELAMI]
S. V. KOZLOV and N. I. VOITKOV (AN USSR, Institut Mekhaniki, Kiev, Ukrainian SSR) Prikladnaia Mekhanika (ISSN 0032-8243), vol. 23, May 1987, p. 95-102. In Russian. refs

A method is presented for determining the effective elastic and inertial characteristics of a continuum idealized model of large truss structures with allowance for rigid connections between the rod elements. The method is applied to the analysis of the longitudinal and torsional vibrations of a truss structure consisting of beam members with attached massive bodies at the ends. Changes in the natural vibration frequencies of the structure are determined as a function of the attached masses. V.L.

A87-46301* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
FLEXIBLE SYSTEM MODEL REDUCTION AND CONTROL SYSTEM DESIGN BASED UPON ACTUATOR AND SENSOR INFLUENCE FUNCTIONS
YEUNG YAM (California Institute of Technology, Jet Propulsion Laboratory, Pasadena), TIMOTHY L. JOHNSON (General Electric Co., Schenectady, NY), and JEFFREY H. LANG (MIT, Cambridge, MA) IEEE Transactions on Automatic Control (ISSN 0018-9286), vol. AC-32, July 1987, p. 573-582. Sponsorship: Research supported by the Lockheed Missiles—and Space Co. refs
(Contract DAAG29-78-C-0020; AF-AFOSR-83-0318)

A model reduction technique based on aggregation with respect to sensor and actuator influence functions rather than modes is presented for large systems of coupled second-order differential equations. Perturbation expressions which can predict the effects of spillover on both the reduced-order plant model and the neglected plant model are derived. For the special case of collocated actuators and sensors, these expressions lead to the derivation of constraints on the controller gains that are, given the validity of the perturbation technique, sufficient to guarantee the stability of the closed-loop system. A case study demonstrates the derivation of stabilizing controllers based on the present technique. The use of control and observation synthesis in modifying the dimension of the reduced-order plant model is also discussed. A numerical example is provided for illustration.
Author

A87-46793*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
AN APPROACH TO STRUCTURE/CONTROL SIMULTANEOUS OPTIMIZATION FOR LARGE FLEXIBLE SPACECRAFT
JUNJIRO ONODA and RAPHAEL T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) AIAA Journal (ISSN 0001-1452), vol. 25, Aug. 1987, p. 1133-1138. refs
(Contract NAG1-224)

This paper presents an approach to the simultaneous optimal design of a structure and control system for large flexible spacecrafts based on realistic objective function and constraints. The weight or total cost of structure and control system is minimized subject to constraints on the magnitude of response to a given disturbance involving both rigid-body and elastic modes. A nested optimization technique is developed to solve the combined problem. As an example, simple beam-like spacecraft under a steady-state white-noise disturbance force is investigated and some results of optimization are presented. In the numerical examples, the stiffness distribution, location of controller, and control gains are optimized. Direct feedback control and linear quadratic optimal controls laws are used with both inertial and noninertial disturbing force. It is shown that the total cost is sensitive to the overall structural stiffness, so that simultaneous optimization of the structure and control system is indeed useful. Author

A87-47809*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
EFFECTS OF ATMOSPHERE ON SLEWING CONTROL OF A FLEXIBLE STRUCTURE
JER-NAN JUANG and LUCAS G. HORTA (NASA, Langley Research Center, Hampton, VA) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 2, p. 613-620) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, July-Aug. 1987, p. 387-392. Previously cited in issue 18, p. 2618, Accession no. A86-38942. refs

A87-47810#
ROBUST MULTIVARIABLE CONTROL OF LARGE SPACE STRUCTURES USING POSITIVITY
G. L. SLATER (Cincinnati, University, OH) and M. D. MCLAREN Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, July-Aug. 1987, p. 393-400. Previously cited in issue 23, p. 3428, Accession no. A86-47925. refs

A87-47811#
DYNAMICS OF GYROELASTIC SPACECRAFT
G. M. T. D'ELEUTERIO and P. C. HUGHES (Toronto, University, Downsview, Canada) (Structures, Structural Dynamics, and Materials Conference, 26th, Orlando, FL, Technical Papers. Part 2, p. 384-390) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, July-Aug. 1987, p. 401-405. Previously cited in issue 13, p. 1941, Accession no. A85-30365. refs
(Contract NSERC-A-4183)

A87-47812*# California Univ., Los Angeles.
PERTURBATION ANALYSIS OF INTERNAL BALANCING FOR LIGHTLY DAMPED MECHANICAL SYSTEMS WITH GYROSCOPIC AND CIRCULATORY FORCES
P. A. BLELLOCH, D. L. MINGORI, and J. D. WEI (California, University, Los Angeles) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, July-Aug. 1987, p. 406-410. refs
(Contract NAS7-918)

Approximate expressions are developed for internally balanced singular values corresponding to the modes of mechanical systems with gyroscopic forces, light damping, and small circulatory forces. A brief overview is first given of the balanced realization model reduction method, including a discussion of recent work. The models considered are defined, and a perturbation analysis is used to show that the modal representation becomes asymptotically balanced as damping reduces to zero. The approximate balanced singular values are calculated, and a simple example of a flexible, dual-spin spacecraft is given as an illustration of the results.
C.D.

A87-48273* Nevada Univ., Las Vegas.
ROBUST NONLINEAR ATTITUDE CONTROL OF FLEXIBLE SPACECRAFT
SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. AES-23, May 1987, p. 380-387. refs
(Contract NAS1-17369)

This paper presents an approach to large-angle rotational maneuvers of a spacecraft-beam-tip body configuration based on nonlinear invertibility and linear feedback stabilization. A control law u sub d is derived for the decoupled control of attitude angles, lateral elastic deflections, slopes due to bending and angular deflection due to torsion at the tip of the beam using torquers and force actuators. For the stabilization of the elastic modes, a linear feedback control law u sub s is obtained based on a linearized model augmented with a servocompensator. Simulation results are presented to show that large slewing and elastic mode stabilization can be accomplished. Author

A87-48714#
FLEXIBILITY EFFECTS - ESTIMATION OF THE STIFFNESS MATRIX IN THE DYNAMICS OF A LARGE STRUCTURE
M. L. AMIROUCHE (Illinois, University, Chicago) ASME, Transactions, Journal of Vibration, Acoustics, Stress, and Reliability in Design (ISSN 0739-3717), vol. 109, July 1987, p. 283-288. refs

In this paper, an estimation of the stiffness matrix for a mechanical tree-like structure is presented. The coefficients of the stiffness matrix are evaluated based on Kane's equations together with the finite segment modeling technique and matrix structure analysis. The procedure developed is used to evaluate the stiffness coefficients in the case where the flexibility effects are modeled by uniform beam elements with springs and dampers at the connecting joints. The method presented in this paper is very useful in the study of the dynamics, vibration, and control of a large tree-like structuure undergoing large motions. An illustration of how the method is used in extracting the natural frequencies and their corresponding mode shapes is presented. The set of equations developed in this paper are the complement equations used to monitor the transient response of the structure undergoing a rigid-body motion. Author

A87-49615*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
SYNERGETIC PLANE-CHANGE CAPABILITY OF A CONCEPTUAL AEROMANEUVERING-ORBITAL-TRANSFER VEHICLE
GENE P. MENEES (NASA, Ames Research Center, Moffett Field, CA), JOHN F. WILSON (Sterling Software, Palo Alto, CA), and HENRY G. ADELMAN (Eloret Institute, Sunnyvale, CA) IN: AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers . New York, American Institute of Aeronautics and Astronautics, 1987, p. 388-397. refs
(AIAA PAPER 87-2565)

The flight strategy for a general low-earth orbit plane-change is analyzed for a conceptual, high-lift, aeromaneuvering-orbital-transfer vehicle, and applied to the important case of the 45 deg plane-inclination change. The study focuses on two principal methods: (1) the procedure to obtain a change in the inclination of the vehicle's orbital plane, and (2) the full rendezvous procedure. Optimal trajectories for minimal propellant use during the synergetic aerotransit are developed, which incorporate best estimates of constraints imposed by reusable thermal-protection requirements and human tolerance to g-load levels. The performance capability for one-way payload delivery to the target orbit is analyzed in detail and the capability for return to the base orbit demonstrated.
Author

A87-49797* Massachusetts Inst. of Tech., Cambridge.
MATERIAL DAMPING IN ALUMINUM AND METAL MATRIX COMPOSITES
EDWARD F. CRAWLEY and MARTHINUS C. VAN SCHOOR (MIT, Cambridge, MA) Journal of Composite Materials (ISSN 0021-9983), vol. 21, June 1987, p. 553-568. Research supported by Textron, Inc. refs
(Contract NAGW-21)

The material damping in beam-like specimens of aluminum and metal matrix composites was measured. A unique apparatus to determine damping by free decay while the specimens are in free fall in a vacuum was used. The specimens tested include 2024-T3 and 6061-T4 aluminum, and unidirectional graphite/metal matrix specimens with P55 and P100 fibers and 6061 Aluminum and AZ91C Magnesium as matrix materials. Tests were conducted to determine the dependence of damping on frequency and stress level. For the aluminum specimens, the material damping followed the Zener model at very low stress levels. Below the Zener relaxation frequency, a strong dependence of damping on stress was found for even moderate stress levels. Damping for the aluminum matrix materials was slightly above that predicted by the Zener model for a homogeneous bar of the matrix aluminum. For the magnesium matrix specimens, damping significantly above

the Zener prediction for the homogeneous matrix material was observed. Author

A87-50033
MODELING AND CONTROL OF TORSIONAL VIBRATIONS IN A FLEXIBLE STRUCTURE
TOSHIO FUKUDA, HIDEMI HOSOGAI (Tokyo, Science University, Japan), FUMIHITO ARAI, and NOBUYUKI YAJIMA (Ministry of International Trade and Industry, Mechanical Engineering Laboratory, Sakura, Japan) JSME International Journal (ISSN 0913-185X), vol. 30, June 1987, p. 976-981. refs

This paper describes a modeling method of torsional vibrations of flexible large space structures, such as solar battery arrays, and a control method based on this model. The torsional vibrations are modeled by taking into account the flexibility of the solar array and the inertial moments of the supporting rigid body, based on the unconstrained mode method. Employing this model of the flexible structure, the system and the observation equations of the dynamics can be derived in the form of a state representation after an n mode decomposition. The torsional vibrations can be measured by using a newly developed differential-type sensor, which consists of a pair of neighboring solar cells. A vibration control method is shown by the state feedback based on the dynamics. Some of the experimental results employing the proposed control method are also shown. Author

A87-50232
ACTIVE VIBRATION CONTROL OF A SIMPLY SUPPORTED BEAM USING A SPATIALLY DISTRIBUTED ACTUATOR
SHAWN E. BURKE and JAMES E. HUBBARD, JR. (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IEEE Control Systems Magazine (ISSN 0272-1708), vol. 7, Aug. 1987, p. 25-30. Research supported by the Charles Stark Draper Laboratory, Inc. refs

The application of a spatially shaped distributed actuator to the vibration control of a simply supported beam is studied analytically and experimentally with reference to component elements used in large space structures. The actuator consists of a layer of PVF2 bonded to one face of the beam; the requisite film controller has a linearly varying spatial distribution which facilitates the control of both even-order and odd-order vibrational modes, serving to increase the modal loss factors by up to a factor of 4.5. The experimental results are found to corroborate a simplified computer model of the controller. B.J.

A87-50404#
CONSTRUCTION OF POSITIVE REAL COMPENSATION FOR LSS CONTROL
G. L. SLATER (Cincinnati, University, OH) and M. D. MCLAREN IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronatuics and Astronautics, 1987, p. 19-24. USAF-supported research. refs
(AIAA PAPER 87-2238)

A novel technique for the determination of positive real transfer matrices with desired eigenvalues is presented. The algorithm employs a gradient technique in an iterative manner to approach a set of desired closed-loop eigenvalues in a minimum norm fashion. The method was found to be successful for both a simple second order problem and a more complicated fourth order model of the DRAPER I structure. K.K.

A87-50412*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON THE INADEQUACIES OF CURRENT MULTI-FLEXIBLE BODY SIMULATION CODES
FIDELIS O. EKE and ROBERT A. LASKIN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 79-89. refs
(AIAA PAPER 87-2248)

DISCOS was used to simulate the spin-up of a uniform flexible beam mounted on a rigid spinning disk. The system operated well for the first few seconds but then there was a drastic rise in deflection as the whole system became unstable. Attention is given to the reason for the breakdown of DISCOS and how this affects the simulation results from DISCOS and other multiflexible-body simulation programs. It is found that a formulation option already available in DISCOS will eliminate the dramatic divergence observed in high spin regimes and give good results in low spin regimes while requiring highly simplified input data. K.K.

A87-50413#
LOW-AUTHORITY CONTROL OF LARGE SPACE STRUCTURES BY USING TENDON CONTROL SYSTEM
Y. MUROTSU, H. OKUBO (Osaka, University, Sakai, Japan), and F. TERUI IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 90-98. refs
(AIAA PAPER 87-2249)

This paper deals with the problem of controlling the vibrations of large space structures by the use of a newly conceived torque actuation device, i.e., a tendon control system. It consists of a pair of tension cables transmitting as control torque to the structure at the moment arm position. The purpose of the study is twofold; first, to establish the analytical framework for low-authority control synthesis, and, second, to validate the proposed concept through a hardware experiment. A nonlinear optimization approach is proposed for the design of the control gains and the moment arm placement. This approach is useful when the total number of the control devices is smaller than that of the critical vibrational modes and exact pole placement is not possible. A hardware experiment has been done successfully, which shows the fundamental feasibility of the active tendon control for a highly flexible beam. However, for its practical application, further studies are needed especially on the interactions between the dynamics of the tension cables and the flexible structure. Author

A87-50414#
CONTROL OF DISTRIBUTED STRUCTURES WITH SMALL NONPROPORTIONAL DAMPING
L. MEIROVITCHT and M. A. NORRIS (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 99-105. refs
(Contract F33615-86-C-3233)
(AIAA PAPER 87-2250)

Undamped distributed structures represent self-adjoint systems, admitting real eigenvalues and real orthogonal eigenfunctions. Control of self-adjoint systems can be carried out conveniently by modal control. Distributed structures with proportional damping possess the same eigenfunctions as the corresponding undamped structures, so that the same modal approach can be used in this case as well. Nonproportional damping tends to destroy the self-adjointness of the system, so that modal control is not as convenient as for undamped structures. If damping is relatively small, however, it is possible to base the control design on the self-adjoint system and still obtain satisfactory control performance. Author

A87-50415#
THE CONTROL OF LINEAR DAMPERS FOR LARGE SPACE STRUCTURES
J. K. HAVILAND, T. W. LIM, W. D. PILKEY (Virginia, University, Charlottesville), and H. POLITANSKY IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 106-116. USAF-supported research. refs
(AIAA PAPER 87-2251)

This paper addresses the problem of designing a control system for a small laboratory model of a linear proof-mass damper for large space structures. Initially a linear control law was developed, however, it was shown that, although adequate damping could be

achieved at high frequencies, very little damping could be obtained at frequencies of one Herz or less with the linear law, because the system had to be constrained to operate within the physical limits set by the stops which limit the motion of the proof-mass. Because of this, recent efforts have been concentrated on a limiting performance control law. In a preliminary study, the optimal response was calculated for a single degree-of-freedom model of a cantilever beam controlled by a proof-mass damper using the limiting-performance/minimum-time formulations. It was found that considerable damping could be achieved at low frequencies. Parameter identification was used to find a suboptimal feedback control law based on the limiting performance characteristics, this could be considered for a practical application of a limiting performance control. Author

A87-50416*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ROBUST EIGENSYSTEM ASSIGNMENT FOR FLEXIBLE STRUCTURES
JER-NAN JUANG, KYONG B. LIM (NASA, Langley Research Center, Hampton, VA), and JOHN L. JUNKINS (Texas A&M University, College Station) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 117-123. refs
(AIAA PAPER 87-2252)

An improved method is developed for eigenvalues and eigenvectors placement of a closed-loop control system using either state or output feedback. The method basically consists of three steps. First, the singular value of QR decomposition is used to generate an orthonormal basis that spans admissible eigenvector space corresponding to each assigned eigenvalue. Secondly, given a unitary matrix, the eigenvector set which best approximates the given matrix in the least-square sense and still satisfy eigenvalue cosntraints is determined. Thirdly, a unitary matrix is sought to minimize the error between the unitary matrix and the assignable eigenvector matrix. For use as the desired eigenvector set, two matrices, namely, the open-loop eigenvector matrix and its closest unitary matrix are proposed. The latter matrix generally encourages both minimum conditioning and control gains. In addition, the algorithm is formulated in real arithmetic for efficient implementation. To illustrate the basic concepts, numerical examples are included. Author

A87-50442#
ACTIVE DAMPING CONTROL DESIGN FOR THE COFS MAST FLIGHT SYSTEM
FREDRIC M. HAM, BEN L. HENNIGES, and SCOTT W. GREELEY (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 354-360.
(AIAA PAPER 87-2321)

Design and development of the Mast Flight System for the COFS (Control of Flexible Structures) program for NASA is currently underway. An active damping controller is required to provide five percent damping for the first ten structural modes of a sixty meter truss beam structure. The baseline control system to provide the required damping is a Positive-Real Decentralized Velocity Feedback (PRDVF) type. Continuous and discrete time designs are presented. The system modeling details are also presented which includes the models for the truss beam and the colocated actuators and sensors. Author

A87-50443#
ACTIVE VIBRATION CONTROL SYNTHESIS FOR THE COFS-I - A CLASSICAL APPROACH
BONG WIE (Texas, University, Austin) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 361-369. refs
(AIAA PAPER 87-2322)

The major findings of a Guest Investigator study of the active vibration control for the NASA Control of Flexible Structures experiment I (COFS-I) are reported. The COFS-I flight structure is briefly characterized; the classical transfer-function approach employed is explained; and consideration is given to pole-zero modeling, proof-mass actuator dynamics, the effect of microprocessor computational delay, a generalized nonminimum-phase structural filtering concept, control using the tip-mounted actuator/sensor, and control using the noncolocated actuator/sensor. Diagrams and graphs are provided. T.K.

A87-50444#
SUBOPTIMAL FEEDBACK VIBRATION CONTROL OF A BEAM WITH A PROOF-MASS ACTUATOR
W. D. PILKEY (Virginia, University, Charlottesville) and H. POLITANSKY IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 370-378. USAF-supported research. refs
(AIAA PAPER 87-2323)

A clamped-free beam, damped by a proof-mass actuator, is selected for small scale model research of flexible structures in space. The dynamic behavior of this system is strongly influenced by the constraints on the motion of the proof-mass and by the maximum control forces available. An optimal solution is presented, using a linear programming algorithm. Then, a simplified feedback control is utilized, based on modern control theory, to obtain optimal low-frequency performance, and classical control theory to bound the high-frequency modes. By special consideration of the constraints, satisfactory control is achieved, even in the nonlinear region when the proof-mass approaches its stops. Author

A87-50446#
A LABORATORY SIMULATION OF FLEXIBLE SPACECRAFT CONTROL
J. A. BOSSI (Boeing Aerospace Co., Seattle, WA) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 389-394.
(AIAA PAPER 87-2325)

A low-cost test structure, including low-frequency lightly-damped modes, some of which have nearly identical frequencies, has been constructed for simulation of some of the control problems expected to arise with large flexible spacecraft. The test structure, floating freely on a flat air-bearing table, combines translational and rotational rigid-body modes with flexible modes. Closed-loop control of the test structure is made possible using discrete displacement measurements, digital control, and pulsed actuation. Preliminary results on flexible mode control are presented, and the spacecraft control simulator is found to be useful in gaining laboratory experience with multivariable control design methods. R.R.

A87-50471*# Old Dominion Univ., Norfolk, Va.
SINGLE-MODE PROJECTION FILTERS FOR IDENTIFICATION AND STATE ESTIMATION OF FLEXIBLE STRUCTURES
JEN-KUANG HUANG, CHUNG-WEN CHEN (Old Dominion University, Norfolk, VA), and JER-NAN JUANG (NASA, Langley Research Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 595-604. refs
(Contract NAG1-655)
(AIAA PAPER 87-2387)

Single-mode projection filters are developed for eigensystem parameter identification and state estimation from both analytical results and test data. Explicit formulations of these projection filters are derived using the pseudoinverse matrices of the controllabilty and observability matrices in the general sense. A global minimum optimization algorithm is developed to update the filter parameters by using the interval analysis method. Modal parameters can be identified and updated in the global sense within a specified region of parameters by passing the experimental data through the projection filters. For illustration of this new approach, a numerical example is shown by using a one-dimensional global optimization algorithm to estimate modal frequencies and damping. Author

A87-50472#
REDUCED-ORDER COMPENSATION - LQG REDUCTION VERSUS OPTIMAL PROJECTION
S. W. GREELEY and D. C. HYLAND (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 605-616. refs
(Contract F49620-84-C-0038)
(AIAA PAPER 87-2388)

Six methods for design of reduced-order compensation, five LQG reduction techniques and the Optimal Projection theory as implemented with a simple homotropy solution algorithm, are compared using the problem posed by Enns (1984). Design results are obtained by the methods for 42 different design cases, and comparison is made with respect to closed-loop stability and transient response characteristics. Although two of the LQG-reduction methods are shown to offer distinctly superior performance, only the Optimal Projection method provided stable performance in all the cases considered. R.R.

A87-50474*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
AN ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF OUTPUT FEEDBACK VS. LINEAR QUADRATIC REGULATOR
ZORAN N. MARTINOVIC, GEORGE C. SCHAMEL, II, RAPHAEL T. HAFTKA, and WILLIAM L. HALLAUER, JR. (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 628-638. refs
(Contract NAG1-224)
(AIAA PAPER 87-2390)

This paper presents analytical and experimental comparison of three control laws for a laboratory structure designed to simulate large space structures. The first control law is the standard time invariant linear quadratic regulator with state estimation, which requires model reduction for practical implementation. This model reduction is associated with the so-called spillover instability. Two new simple direct output feedback control laws guaranteeing stability are proposed. One minimizes the maximum control force, and the other minimizes the same quadratic performance index as the linear quadratic regulator. The three control laws are found to give comparable performance for the modes retained in the reduced model. However, the standard linear quadratic regulator with state estimation provides almost no margin of stability for the unmodeled modes, while the simpler direct feedback laws provide significant stability margins to all modes. The analytical results were verified experimentally using a digital implementation of the control laws. Good agreement between the analytical predictions and experimental measurements was observed. Author

A87-50475#
COMPARISON OF DIFFERENT ATTITUDE CONTROL SCHEMES FOR LARGE COMMUNICATIONS SATELLITES
S. K. SINGH, B. N. AGRAWAL (INTELSAT, Washington, DC), and R. GRAN (Grumman Aerospace Corp., Bethpage, NY) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 639-646. refs
(AIAA PAPER 87-2391)

A comparative study of the robustness of various spacecraft body attitude control systems with structural flexibility is presented in this paper. The control systems examined are: (1) 3-Reaction Wheels (2) Body-fixed momentum wheel with offset thrusters (3) Skewed body-fixed momentum wheels with two reaction wheels. For the size of large spacecraft considered in this paper, all these systems are shown to result in satisfactory performance. In order to exhibit their relative merits, the presence of severe structural interaction had to be introduced. Comparison was then made in terms of stability, which is affected by non-colocation of actuators and sensors. Performance borne out of the nonlinear simulation with both the large flexible spacecraft and dummy unstable interacting low structural mode is illustrated. This latter study shows that a system with single body-fixed momentum wheel along pitch axis and two reaction wheels oriented along roll and yaw axes, is the most robust. Author

A87-50486#
CONTROL/DYNAMICS SIMULATION FOR PRELIMINARY SPACE STATION DESIGN
PAUL BLELLOCH (SDRC, Inc., San Diego, CA) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 766-772. refs
(AIAA PAPER 87-2641)

A method for integrating linear control systems into a structural dynamic software module is presented. The method is in contrast to integrating a separte control software package and represents a structural analogy to control systems. The structural dynamnics software module is part of an integrated package used for preliminary design analysis of the Space Station. Examaples of PID attitude control and interaction with the control of a flexible manipulator arm are presented. Author

A87-50502#
A NEW CONCEPT OF GENERALIZED STRUCTURAL FILTERING FOR ACTIVE VIBRATION CONTROL SYNTHESIS
BONG WIE and KUK WHAN BYUN (Texas, University, Austin) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 919-929. refs
(AIAA PAPER 87-2456)

A new concept of generalized structural filtering and its application to active vibration control synthesis are presented. The concept is a natural extension of the classical notch and phase lead/lag filtering, and emphasizes the use of a nonminimum-phase filter which has zeros in the right-half s-plane. Application of this concept to single-input/single-output systems with many oscillatory modes results in a robust feedback compensator with much physical insight. The concept also enables the control designer to understand the inherent nature of an 'optimal' compensator, and to modify the optimal design to be more robust and meaningful. This paper shows that for certain cases, nonminimum-phase structural filtering provides the proper phase-lag to increase the closed-loop damping of the flexible modes, while maintaining good performance and robustness to parameter variations. Author

A87-50503#
AN AI-BASED MODEL-ADAPTIVE APPROACH TO FLEXIBLE STRUCTURE CONTROL
S. HANAGUD, B. J. GLASS, and A. J. CALISE (Georgia Institute of Technology, Atlanta) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 930-940. refs
(Contract DAAG29-82-K-0094)
(AIAA PAPER 87-2457)

An adaptive control technique for discontinuously time-varying structures is developed using model identification and parameter identification to replace controllers when large-scale discontinuous model changes occur. The controller model replacement (CMR) method, utilizing the AI techniques of heuristic search and object-oriented programming, is demonstrated for the test problem of controlling a beam for which boundary conditions change suddenly in time. A linear optimal output feedback approach is employed to design the controller, once a new model is identified. For SISO and MIMO test problems, the CMR method was found to follow the actual model more closely than a comparable explicit self-tuning regulator, yielding better stability and performance.
R.R.

A87-50504#
ADAPTIVE IDENTIFICATION OF FLEXIBLE STRUCTURES BY LATTICE FILTERS
FARYAR JABBARI (California, University, Irvine) and J. S. GIBSON (California, University, Los Angeles) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 941-949. refs
(Contract AF-AFOSR-84-0309)
(AIAA PAPER 87-2458)

Recent investigations on lattice filters, and their applications to adaptive identification of flexible structures, are presented. Since the order of the systems cannot be known -or the effective order may change- the order recursiveness of the lattices is of particular interest. Implementation of lattices would permit on-line order determination and would allow the order of the filter to be changed without the need to reprocess the previous data. Experimental data from the flexible grid structure at NASA-Langley are used to obtain results showing the feasibility of lattices and the advantages that result from their order recursive property. One-step-ahead prediction and estimates for natural frequencies are among the results shown. Of particular interest are the frequency estimates which agree closely with the frequency estimates obtained from off-line identification techniques. The one step-ahead prediction results also show the advantages that lattices provide with their order-determination capability, which would be significant for adaptive control purposes. Author

A87-50505*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ON-LINE IDENTIFICATION AND ATTITUDE CONTROL FOR SCOLE
R. C. MONTGOMERY, J. SHENHAR, and J. P. WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 950-958. refs
(AIAA PAPER 87-2459)

This paper documents on-line linear least-square identification and attitude control of SCOLE, a laboratory apparatus representing an offset-feed antenna attached to the Space Shuttle. Identification is done autonomously by starting a slew maneuver in pitch or roll with reaction jets and observing the time history data of associated Euler angles when the jets are quiescent. Linear least-square analysis is used to select the parameters that best fit the output of an Autoregressive (AR) model to the data. The control effectiveness of the jets is determined in a subsequent test, again using linear least squares. The parameters so derived are used to design switching lines for time-optimal attitude control. This report describes the identification and control algorithms and the experimental apparatus and procedures used. Also, experimental data are presented that reflect the performance of the identification algorithms and the attitude control system. Author

A87-50506*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DISTRIBUTED PARAMETER MODELING OF THE STRUCTURAL DYNAMICS OF THE SOLAR ARRAY FLIGHT EXPERIMENT
L. W. TAYLOR, JR. and J. L. WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 959-974. refs
(AIAA PAPER 87-2460)

A distributed-parameter model of the structural dynamics of the space-shuttle-deployed Solar Array Flight Experiment is developed and used to produce estimates of the modal frequencies and mode shapes. A lumped parameter version of the distributed model is used to estimate model characteristics by analyzing the measured responses of 32 targets. To make the modeling more tenable, a distributed parameter system is used to reduce the number of unknown parameters, a modified Newton-Raphson technique is used for rapid convergence, and a parallel processing supercomputer is used for more efficient computation. The performances of computers with a high-speed serial processor and with a high-speed parallel processor are compared. The best results are obtained with the modeling approach in which maximum likelihood estimation is applied to distributed parameter models.
R.R.

A87-50507#
PRACTICAL ISSUES IN COMPUTATION OF OPTIMAL, DISTRIBUTED CONTROL OF FLEXIBLE STRUCTURES
W. H. BENNETT (Systems Engineering, Inc., Greenbelt, MD) and H. G. KWATNY (Drexel University, Philadelphia, PA) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 975-987. refs
(Contract F49620-84-C-0115)
(AIAA PAPER 87-2461)

The computation of optimal, distributed state feedback control laws for continuum models arising in flexible space structures is considered. Practical issues are discussed relating to a computational procedure which does not necessarily employ modal or finite element methods for reduced-order modeling as an essential part of the computations. Instead, the frequency response of the distributed parameter system is sampled. The method for computing optimal control laws is based on a Wiener-Hopf problem whose solution involves the solution of an irrational spectral factorization problem. Effective numerical algorithms are discussed and a simple example is given which serves to illustrate the method and some numerical sensitivities associated with the evaluation of certain transcendental terms arising in the frequency response computations. Author

A87-50533#
LINEAR QUADRATIC CONTROL SYSTEM DESIGN FOR SPACE STATION POINTED PAYLOADS
ROBERT O. HUGHES (General Electric Co., Astro-Space Div., Philadelphia, PA) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 1247-1254. refs
(AIAA PAPER 87-2530)

A pointing control design using Linear Quadratic techniques and a newly-derived flexible model for the Payload Pointing System (PPS) is developed. Sensitivity of control loop stability to PPS stiffness and damping for a previous PID control design is analyzed. Performance and stability comparisons for three models/controllers are made using both time domain and frequency domain techniques. Author

A87-50561*# Illinois Univ., Urbana.
TRACKING AND POINTING MANEUVERS WITH SLEW-EXCITED DEFORMATION SHAPING
THOMAS A. W. DWYER, III (Illinois, University, Urbana) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 1503-1511. refs
(Contract NSF ECS-85-16445; NAG1-436; NAG1-613)
(AIAA PAPER 87-2599)

It is shown in this paper how it is possible to shape the slew-excited structural response of a deformable vehicle undergoing agile attitude maneuvers, so that the required fully corrected slew torque profiles can be computed on-line in closed form, and with the same bandwidth as required for the rigid body case. This is accomplished by simultaneously applying maneuver-dependent structural force controls of progressively smaller amplitudes, at the cost of progressively higher signal processing complexity of slew torque and structural force command generation. Author

A87-50562*# McDonnell-Douglas Astronautics Co., Houston, Tex.
THE DYNAMICS AND CONTROL OF THE SPACE STATION POLAR PLATFORM
M. M. WAHBAH (McDonnell Douglas Astronautics Co., Houston, TX) and G. C. ANDERSEN (NASA, Goddard Space Flight Center; Lockheed Missiles and Space Co., Inc., Greenbelt, MD) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 2 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 1512-1527. refs
(AIAA PAPER 87-2600)

The Space Station polar platform will carry a variety of earth observation instruments for NASA and the National Oceanic and Atmospheric Administration. In this paper, the asymmetrical platform is modeled as three connected rigid bodies. A generalized angular momentum equation is employed to derive the rotational equations of motion. These equations are linearized and used for preliminary sizing of control devices using a classical control approach. Two control systems are considered to stabilize the platform and satisfy the pointing requirements. The first system is composed of a single variable-speed, double-gimbaled momentum wheel and the second consists of three-reaction wheels. The performance of each system is assessed using a linear optimal control approach. Author

A87-51610
GLOBAL TREATMENT OF ENERGY DISSIPATION EFFECTS FOR MULTIBODY SATELLITES
F. P. J. RIMROTT (Toronto, University, Canada) IN: IUTAM/IFToMM Symposium on Dynamics of Multibody Systems, Udine, Italy, Sept. 16-20, 1985, Proceedings . Berlin and New York, Springer-Verlag, 1986, p. 213-225.

The attitude drift of a two-body gyrostat with viscous internal energy dissipation is investigated analytically, applying a global approach. The formulations for the platform and rotor of a dual spinner are given; the energy dissipation, spin-change allotment, and kinetics are explored in detail; and expressions for the attitude drift rate and attitude stability are obtained. It is recommended that, in the practical design of satellites for attitude stability, the rotor/platform energy-dissipation ratio be made less than 1 but greater than 0. T.K.

A87-52965*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
EQUATIONS OF MOTION FOR MANEUVERING FLEXIBLE SPACECRAFT
L. MEIROVITCH and R. D. QUINN (Virginia Polytechnic Institute and State University, Blacksburg) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Sept.-Oct. 1987, p. 453-465. refs
(Contract NAG1-225)

This paper is concerned with the derivation of the equations of motion for maneuvering flexible spacecraft both in orbit and in an earth-based laboratory. The structure is assumed to undergo large rigid-body maneuvers and small elastic deformations. A perturbation approach is presented in which the quantities defining the rigid-body maneuver are regarded as the unperturbed motion and the elastic motions and deviations from the rigid-body motions are regarded as the perturbed motion. The perturbation equations are linear, non-self-adjoint, and with time-dependent coefficients. A maneuver force distribution exciting the least amount of elastic deformation of the spacecraft is developed. Numerical results highlight the vibration caused by rotational maneuvers. Author

A87-52968#
MASS PROPERTY ESTIMATION FOR CONTROL OF ASYMMETRICAL SATELLITES
E. V. BERGMANN (Charles Stark Draper Laboratory, Inc., Cambridge, MA), B. K. WALKER (Cincinnati, University, OH), and D. R. LEVY (USAF, Space Div., Los Angeles, CA) (Guidance, Navigation and Control Conference, Snowmass, CO, Aug. 19-21, 1985, Technical Papers, p. 83-93) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Sept.-Oct. 1987, p. 483-491. Previously cited in issue 22, p. 3238, Accession no. A85-45886. refs

A87-52973#
MODEL REFERENCE ADAPTIVE CONTROL FOR LARGE STRUCTURAL SYSTEMS
I. H. MUFTI (National Research Council of Canada, Ottawa) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 10, Sept.-Oct. 1987, p. 507-509.

The implicit model reference adaptive control technique is here applied to the case of collocated actuators. By constructing a suitable Liapunov function, it is shown that the ratio of position-to-rate output is limited by twice the product of the damping ratio and the lowest structural frequency. The control law is proposed in the form of integral, proportional, and relay adaptations along with the integral of the output error. C.D.

N87-20347 Massachusetts Univ., Amherst.
DYNAMIC AND THERMAL EFFECTS IN VERY LARGE SPACE STRUCTURES Ph.D. Thesis
RAMESH-BABU MALLA 1986 326 p
Avail: Univ. Microfilms Order No. DA8701196

A mathematical formulation was developed for an axially flexible structure executing a planar motion in a general orbit in space in order to determine dynamic and thermal effects in the structure due to various disturbances in a space environment. The characteristic dimension of the structure is very large (of the order of a few kilometers). The influences of the differential gravitational forces, the radiation heating, and the radiation pressure forces were studied. Effects of these factors were studied on the structure's axial deformation, its attitude motion and its orbit simultaneously. Results are obtained for various initial conditions and physical parameter values. It is observed that the differential gravitational forces do not have any appreciable effects on the structure's axial length and its attitude motion. Thermal effects are significant in producing appreciable structural deformation, and they also affect the attitude motion of the structure considerably. The radiation pressure forces are very significant in changing attitude motion of the space structure, but it causes negligible effects in producing longitudinal deformation of the structure. All of the above factors have insignificant effects on the orbit of the structure chosen in this study. Of all the three external disturbances,

the radiation pressure forces are found to be strongest in affecting the orbit of the structure. Dissert. Abstr.

N87-20348 Georgia Inst. of Tech., Atlanta.
STUDIES IN NONLINEAR STRUCTURAL DYNAMICS: CHAOTIC BEHAVIOR AND POYNTING EFFECT Ph.D. Thesis
NANDAKISHOR SADASHIV ABHYANKAR 1986 237 p
Avail: Univ. Microfilms Order No. DA8628350

Nonlinear structural dynamics is one of the interdisciplinary fields used to predict and control the vibration of large space structures and flexible bodies. Transient response and steady state vibration constitute two integral parts of the field of structural dynamics. Specific problems consisting of the dynamic coupling of torsional and extensional deformations of a circular cylindrical bar and the chaotic forced vibration of buckled beams are addressed. Equations governing torsional and extensional coupling of waves for a finite hyperelastic cylindrical bar were formulated. Solutions are compared with available exact solutions. The period doubling and chaotic motion were studied for a simply supported buckled beam excited with periodic forcing function. The partial differential equations were solved directly by an explicit, stable finite difference scheme. Dissert. Abstr.

N87-20357# Messerschmitt-Boelkow-Blohm/Entwicklungspring Nord, Bremen (West Germany).
RECENT DEVELOPMENTS AND FUTURE TRENDS IN STRUCTURAL DYNAMIC DESIGN VERIFICATION AND QUALIFICATION OF LARGE FLEXIBLE SPACECRAFT
E. HORNUNG, E. BREITBACH (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany.), and H. OERY (Technische Univ., Aachen, West Germany.) *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 43 p Jul. 1986
Avail: NTIS HC A12/MF A01

A comprehensive dynamic verification concept is proposed, focusing on a multi-axis transient qualification test to be performed on the primary structure or on modular segments of it, respectively. First, practical experiences and development areas identified are addressed. Former existing barriers preventing the practical performance of this verification concepts are no longer relevant because of the extended analytical capabilities due to the positive developments in computer techniques and software and because of the availability of large multi-axis vibration simulators. A vital prerequisite for the applicability of this verification concept is the ability for analytical flightload identification and identification of the true dynamic characteristics on a high quality and reliability level. For this a comparative discussion is presented about the suitability of analytical methods for flightload predictions (shock spectra versus transient methods). The state of the art of design identification tests and of updating methods on mathematical models is summarized and discussed with respect to necessary development areas and the implementation into the proposed structure verification concept. First experience with this new verification cycle was made on a real satellite structure. The results and open development areas identified are discussed. Author

N87-20358# Societe Nationale Industrielle Aerospatiale, Cannes (France).
DYNAMIC MODELING AND OPTIMAL CONTROL DESIGN FOR LARGE FLEXIBLE SPACE STRUCTURES
L. PASSERON, CH. GARNIER, and B. SEVENNEC *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 14 p Jul. 1986
Avail: NTIS HC A12/MF A01

Some advanced results in dynamic modeling and control areas are unifyingly reviewed. Dynamic modeling for complex assemblies of interconnected, rigid or flexible bodies subject to wide relative motions is achieved through a Lagrangian formulation using quasi-coordinates. Lagrange multipliers are explicitly eliminated by way of singular value decomposition resulting in a minimized set of equations. An original software program using element shape functions interfaces the dynamic model with NASTRAN-performed individual substructure analyses. Section 3 summarizes the now classical results in optimal control, while section 4 gives a comprehensive coverage of robustness aspects. Last section is devoted to model order reduction. The Internal Balancing Approach is generalized to systems with rigid body modes. Moreover, an error bound between full order and reduced order transfer function is evidenced, which bridges truncation and robustness. Author

N87-20362# Rome Univ. (Italy). Dipt. Aerospaziale.
EFFECT OF MODAL DAMPING IN MODAL SYNTHESIS OF SPACECRAFT STRUCTURES
LUIGI BALIS CREMA and ANTONIO CASTELLANI *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 11 p Jul. 1986
Avail: NTIS HC A12/MF A01

In the modal synthesis of a large space structure, by a substructuring approach, a focal point is in the evaluation of the modal characteristics of the single components. As a matter of fact it is required to get the non-diagonal terms of the damping substructure matrix to acquire an efficient estimate of the damping characteristics of the whole structure. In this work it has been considered important to understand and to predict the physical causes of complex modes also in an elementary substructure as a sandwich carbon fiber plate. The results of the experimental work indicate that the modal analysis has to be gained in a very tight frequency range, with many averaged data, and the possibility of complex modes is increasing with the increase of the mode order. Author

N87-20363# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. of Aeroelasticity.
DYNAMIC QUALIFICATION OF SPACECRAFT BY MEANS OF MODAL SYNTHESIS
A. BERTRAM and P. CONRAD (Messerschmitt-Boelkow-Blohm/Entwicklungspring Nord, Bremen, West Germany.) *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 11 p Jul. 1986 Sponsored in part by ESA/ESTEC
Avail: NTIS HC A12/MF A01

The dynamic qualification process is essentially based on tests: verification tests and qualification tests. In order to render ground testing feasible, the structure has to be subdivided into modules. After performing tests on the module level, the dynamic behavior of the entire structure is obtained by modal synthesis. The experience gained in applying modal synthesis concepts to simple models and spacecraft-type structures is discussed. It is shown that the success of a modal synthesis approach is considerably dependent on the input data, i.e., the results of the modal survey tests. Accordingly, test data requirements are outlined. Finally, the discussion includes the way in which the coupling analyses can be improved by precise consideration of the coupling conditions in substructure tests and calculations. Author

N87-20364# Centre National d'Etudes Spatiales, Toulouse (France).
LOW FREQUENCY VIBRATION TESTING ON SATELLITES
A. GIRARD, A. MAMODE, and F. MERCIER *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 9 p Jul. 1986 In FRENCH; ENGLISH summary and title
Avail: NTIS HC A12/MF A01

Except the well known POGO phenomenon, the low frequency dynamic flight environment for a satellite consists of transient vibrations, mainly thrust transients. The qualification is generally achieved by a sine sweep on a shaker according to contractual specifications. Far from the POGO frequencies and near the main resonant frequencies of the satellite, notchings based on quasi static load criteria or launch vehicle/satellite coupled analysis results are applied to avoid overtesting. However this approach becomes unsatisfactory for complex structures with large appendages, where the initial specifications are widely modified, disturbing the qualification of secondary structures. In order to improve the representativity of these tests, transient vibration testing has been recently investigated. The feasability of such

tests on electrodynamic shakers using digital control techniques was demonstrated several years ago and the main problem remaining prior to their operational use has been the definition of an adequate specification for satellite qualification purposes. Several approaches are presented, including shock synthesis, production of a specified transient, and simulation of the launch vehicle impedance. Author

N87-20365# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. of Aeroelasticity.

MODAL-SURVEY TESTING FOR SYSTEM IDENTIFICATION AND DYNAMIC QUALIFICATION OF SPACECRAFT STRUCTURES

N. NIEDBAL and H. HUENERS *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 13 p Jul. 1986

Avail: NTIS HC A12/MF A01

Modal-survey testing is an increasingly common part of the qualification procedure for spacecraft structures, since it offers an experimental verification of normal mode parameters determined by dynamic finite-element anlaysis. Moreover, it permits identification of structural damping, knowledge of which is essential for reliable flight-load calculations. A state of the art survey of modern modal-survey testing is given here, covering the phase-resonance method and various phase-separation methods. The use of modal-survey results in the dynamic qualification of spacecraft structures is discussed, emphasizing the correlation of analytical and experimental modal data. This aspect has attracted growing interest in recent years, due to the obvious need for convenient tools that allow finite-element models to be updated with measured modal data. Author

N87-20366# Spar Aerospace Ltd., Weston (Ontario).

MODAL TESTING OF THE OLYMPUS DEVELOPMENT MODEL STOWED SOLAR ARRAY

S. DRAISEY, M. ELZEKI, A. S. JONES, and G. MARKS *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 14 p Jul. 1986

Avail: NTIS HC A12/MF A01

The modal testing portion of the structural verification of the stowed solar array configuration of the Olympus S/C, a high powered communication satellite is discussed. The Olympus S/C was designed for both Ariane and Shuttle launches. This versatility of launch configurations requires an emphasis on the ability to accurately predict loads and structural performance. The stowed array is comprised of: release mechanisms, a tip tensioning mechanism, a stowed astromast and a folded flexible blanket to which solar cells have been mounted. The blanket is held in place between a pallet and pressure plate. The prediction of accurate structural response for such a complicated arrangement from analytical data only would be difficult. Over the past few years Spar has undertaken several development studies in the area of modal analysis. Within these studies a technique, using base excitation of the structure has been established. The use of base input as the excitation for a modal test has provided an economical means of incorporating a modal test into a structural acceptance test procedure. Author

N87-20367# Politecnico di Milano (Italy). Dipt. di Ingegneria Aerospaziale.

ACTIVE STRUCTURAL CONTROLLERS EMULATING STRUCTURAL ELEMENTS BY ICUS

AMALIA ERCOLI FINZI, MASSIMILIANO LANZ, and PAOLO MANTEGAZZA *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 13 p Jul. 1986

Avail: NTIS HC A12/MF A01

An approach is presented to the active control design of Large Space Structures that is based on the adoption of decentralized control units. These control units use colocated sensors and actuators and adopt a control law that generates forces proportional to local motions in order to emulate real structural elements, discrete tuning masses and grounding spring-damper combinations. Some numerical examples are used to demonstrate the application of the Independent Control Unit (ICU) concept to a beam and a plate for which the active structure controls are obtained by using a suboptimal design procedure. It is shown how the use of this type of control unit allows the development of an intrinsic fail-safe design. The results obtained with the application of the concepts developed here are demonstrated by their application to an experiment in which a thin beam, suspended from the ceiling, is controlled by different combinations of the independent analog control units making use of a velocity trasducer, an integrator and an electrodynamic actuator. Author

N87-20368# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany). Modal Testing Sect.

SPACECRAFT QUALIFICATION USING ADVANCED VIBRATION AND MODAL TESTING TECHNIQUES

K. MUEHLBAUER and U. SCHILDT *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 9 p Jul. 1986

Avail: NTIS HC A12/MF A01

The classical single-shaker vibration test has played a dominant role in the mechanical qualification of flexible spacecraft. Due to the substantially increased payload capacity of modern carrier vehicles the existing test facilities have reached their limits in terms of test article mass and size. These limits are being extended by implementing multi-shaker systems for uni-axial testing. At the same time digital data acquisition and analysis techniques are employed to get a better understanding of the test results and of the test article itself. An alternative approach which overcomes the limitations imposed by the test article size is the analytical qualification. Besides static testing this is in particular supported by modal testing accomplished on system or on sub-system level. For modal testing a broad spectrum of computerized or computer-based techniques is now available which are capable of meeting manifold requirements. The dynamic testing techniques mentioned here are outlined and illustrated using actual examples of installations and applications. Author

N87-20369# British Aerospace Public Ltd. Co., Stevenage (England). Space and Communications Div.

INFLUENCE CO-EFFICIENT TESTING AS A SUBSTITUTE FOR MODAL SURVEY TESTING OF LARGE SPACE STRUCTURES

T. F. KEATES *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 9 p Jul. 1986

Avail: NTIS HC A12/MF A01

The American Space Transportation System is capable of placing large payload into low earth orbit. Since the presence of the payload has a significant effect on the behavior of the Shuttle under the low frequency and transient loading during launch and return, a flight loads analysis is performed using a mathematical model of the payload coupled to that of the Shuttle. The process of clearing a payload for launch involves performing this coupled analysis with a validated mathematical model of the payload. This validation usually includes modal survey testing on a structurally representative model which may also be used for static load testing. The advantages and disadvantages of modal survey testing (either fixed base or free/free) and of Static Influence Co-efficient (Flexibility) Testing are discussed. It is concluded that for parts of certain types of payload the latter is a cheaper and sufficient alternative to modal survey testing. Author

N87-20370# National Aeronautical Establishment, Ottawa (Ontario).

USE OF A VIDEO-PHOTOGRAMMETRY SYSTEM FOR THE MEASUREMENT OF THE DYNAMIC RESPONSE OF THE SHUTTLE REMOTE MANIPULATOR ARM

G. L. BASSO and R. B. KULCHYSKI *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 12 p Jul. 1986

Avail: NTIS HC A12/MF A01

A video-photogrammetry system was used to obtain the dynamic response of the Canadian developed, space transportation system remote manipulator arm from video tape recordings of two space based test events - specifically, an auto-trajectory and a backup

mode test sequence. The application of this system to this task represented a non-generic use in that no pre-launch preparations were made for implementing this technique. The procedures used to extract the response information from the video tapes are outlined. The stated resolution of the video-photogrammetry system is 1 part in 5000 (1 sigma) - typically, 0.03mm for a 12.5mm image plane size. Within this capability, the amplitude of the response for the auto-trajectory sequence was obtained with an estimated resolution of 1mm with a camera-to-object spacing of 2.18m; and for the backup mode, 3mm at a spacing of 13.78m. In both instances, dynamic parameters such as frequency and damping were readily derived from the response measurements. Author

N87-20371# Martin Marietta Aerospace, Denver, Colo.
BENEFITS OF PASSIVE DAMPING AS APPLIED TO ACTIVE CONTROL OF LARGE SPACE STRUCTURES
R. N. GEHLING, H. W. HARCROW, and G. MOROSOW *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 8 p Jul. 1986
Avail: NTIS HC A12/MF A01

Active vibration and shape control of large space structures (LSS) has received a great deal of attention recently, while passive damping measures have been somewhat neglected. However, benefits may be derived from simultaneously considering both passive and active control measures to achieve certain performance requirements. Presented are results of a preliminary study of the role passive damping plays in the design and performance of active vibration control strategies. Passive dampers were incorporated into a representative LSS and their effect on candidate active control laws was investigated. Viscous dampers were implemented in time simulations with direct velocity feedback and optimal quadratic regulator control laws. The impact of passive damping on overall closed-loop performance, control system spill-over and robustness, and active control requirements was evaluated. Numerical results are presented for a representative model. The merit of designing a LSS to incorporate discrete passive dampers in the overall approach to vibration suppression is demonstrated through a reduction in demands placed upon an active control system.

N87-20372# Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost. Space Div.
ACOUSTIC EFFECTS ON THE DYNAMIC OF LIGHTWEIGHT STRUCTURES
J. J. WIJKER *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 15 p Jul. 1986
Avail: NTIS HC A12/MF A01

The influence of the acoustic effects (surrounding air) on the dynamic behavior of lightweight structures is discussed. Emphasis is given to: the unexpected dynamic characteristics as shown during test; simulation of the acoustic loading within the finite element representation (linear domain); and comparison of the measured dynamic characteristics (modal survey) with the adapted finite element results.

N87-20373# Industrieanlagen-Betriebsgesellschaft m.b.H., Ottobrunn (West Germany). Abteilung Maschinenbau und Fahrzeuge.
MULTI-AXIS VIBRATION TESTS ON SPACECRAFT USING HYDRAULIC EXCITERS
H. HAHN and W. RAASCH *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 23 p Jul. 1986
Avail: NTIS HC A12/MF A01

Based on performance data that are specified for a spacecraft multi-axis hydraulic vibration test facility by ESA the feasibility of such a test facility is investigated. Technical problems and possible solutions concerning test table stiffness, elasticity of actuator oil column, actuator joints and oil consumption are discussed. More sophisticated problems may arise concerning the control and safety systems. The designed solutions include controllers for each individual actuator, controllers for a coordinated control of the multiple actuator system and a safety and monitoring system. The control system has to be based on a control strategy using a combination of analog fixed algorithm controllers and a digital variable algorithm controller both together performimg individual degree of freedom control including suitable decoupling procedures. The safety system has to be based on a triple redundancy concept for critical system components. It is recommended to built it by a digital multi-processor system. The investigations lead to the statement that multi-axis vibration tests of spacecrafts are realizable with respect to the necessary test equipment. Author

N87-20564 Virginia Polytechnic Inst. and State Univ., Blacksburg.
MODELING AND CONTROL OF FLEXIBLE STRUCTURES Ph.D. Thesis
JEFFREY KENT BENNIGHOF 1986 137 p
Avail: Univ. Microfilms Order No. DA8625796

Topics in the modeling and control of large flexible structures are examined. In the finite element convergence toward the natural modes and frequencies of a structure, it was found that two mechanisms limiting the accuracy of higher modes, are, first, a decrease in the number of active degrees of freedom for higher mode approximations due to orthogonality constraints, and, second, the fact that lower computed, rather than actual, eigenfunctions appear in the orthogonality constraints, so that inaccuracy in lower modes inhibits convergence to higher modes. Refining the elements using the hierarchial p-version proves to be far superior to refining the mesh, as demonstrated by numerical examples. A method is presented for solving the algebraic eigenvalue problem for a structure, which combines attractive features of the subspace iteration method and the component-mode synthesis methods. The effectiveness of modal control (IMSC) and direct feedback control are investigated for suppressing traveling waves on a string and on a beam, both with slight material damping. Dissert. Abstr.

N87-20567*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
MODELING OF JOINTS FOR THE DYNAMIC ANALYSIS OF TRUSS STRUCTURES
W. KEITH BELVIN May 1987 43 p
(NASA-TP-2661; L-16163; NAS 1.60:2661) Avail: NTIS HC A03/MF A01 CSCL 20K

An experimentally-based method for determining the stiffness and damping of truss joints is described. The analytical models use springs and both viscous and friction dampers to simulate joint load-deflection behavior. A least-squares algorithm is developed to identify the stiffness and damping coefficients of the analytical joint models from test data. The effects of nonlinear joint stiffness such as joint dead band are also studied. Equations for predicting the sensitivity of beam deformations to changes in joint stiffness are derived and used to show the level of joint stiffness required for nearly rigid joint behavior. Finally, the global frequency sensitivity of a truss structure to random perturbations in joint stiffness is discussed. Author

N87-20568*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
SPACE STATION STRUCTURES AND DYNAMICS TEST PROGRAM
CARLETON J. MOORE, JOHN S. TOWNSEND, and EDWARD W. IVEY Mar. 1987 47 p
(NASA-TP-2710; NAS 1.60:2710) Avail: NTIS HC A03/MF A01 CSCL 20K

The design, construction, and operation of a low-Earth orbit space station poses unique challenges for development and implementation of new technology. The technology arises from the special requirement that the station be built and constructed to function in a weightless environment, where static loads are minimal and secondary to system dynamics and control problems. One specific challenge confronting NASA is the development of a dynamics test program for: (1) defining space station design requirements, and (2) identifying the characterizing phenomena affecting the station's design and development. A general definition of the space station dynamic test program, as proposed by MSFC,

forms the subject of this report. The test proposal is a comprehensive structural dynamics program to be launched in support of the space station. The test program will help to define the key issues and/or problems inherent to large space structure analysis, design, and testing. Development of a parametric data base and verification of the math models and analytical analysis tools necessary for engineering support of the station's design, construction, and operation provide the impetus for the dynamics test program. The philosophy is to integrate dynamics into the design phase through extensive ground testing and analytical ground simulations of generic systems, prototype elements, and subassemblies. On-orbit testing of the station will also be used to define its capability. Author

N87-20569*# Auburn Univ., Ala. Dept. of Aerospace Engineering.

INITIAL INVESTIGATIONS INTO THE DAMPING CHARACTERISTICS OF WIRE ROPE VIBRATION ISOLATORS ***Final Technical Report***

M. A. CUTCHINS, J. E. COCHRAN, JR., K. KUMAR, N. G. FITZ-COY, and M. L. TINKER 29 Apr. 1987 89 p

(Contract NAG8-532)

(NASA-CR-180698; NAS 1.26:180698) Avail: NTIS HC A05/MF A01 CSCL 20K

Passive dampers composed of coils of multi-strand wire rope are investigated. Analytical results range from those produced by complex NASTRAN models to those of a Coulomb damping model with variable friction force. The latter agrees well with experiment. The Coulomb model is also utilized to generate hysteresis loops. Various other models related to early experimental investigations are described. Significant closed-form static solutions for physical properties of single-and multi-strand wire ropes are developed for certain specific geometries and loading conditions. NASTRAN models concentrate on model generation and mode shapes of 2-strand and 7-strand straight wire ropes with interfacial forces. Author

N87-20577# Air Force Office of Scientific Research, Bolling AFB, Washington, D.C. Aerospace Sciences.

AIR FORCE BASIC RESEARCH IN DYNAMICS AND CONTROL OF LARGE SPACE STRUCTURES

ANTHONY K. AMOS *In* Shock and Vibration Information Center The Shock and Vibration Bulletin. Part 1: Welcome, Invited Papers, Shipboard Shock, Blast and Ground Shock, Shock Testing and Analysis p 39-58 Aug. 1986

Avail: NTIS HC A13/MF A01

The Air Force Basic Research in dynamics and control of large space structures addresses several of the many scientific and technological issues relating to the development and operation of very large and sophisticated high performance systems in the relatively unfamiliar space environment. The design challenge has motivated most of the ongoing research to date. It is perceived that these have evolved modeling concepts, computational algorithms, and performance/stability criteria capable of supporting the design process. However, analytical and experimental methods and the experience data base needed to support the validation of designs prior to commitment to launch are still sparse or nonexistent. The program is therefore in the process of shifting emphasis from the synthesis to the simulation objectives of the technologies. It is entended to embark on the development of modeling and computational capabilities needed to perform high fidelity simulation of orbital dynamics including operational maneuvers and developmental functions of deployment and assembly. B.G.

N87-20581*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

MODAL TEST AND ANALYSIS: MULTIPLE TESTS CONCEPT FOR IMPROVED VALIDATION OF LARGE SPACE STRUCTURE MATHEMATICAL MODELS

B. K. WADA, C-P. KUO, and R. J. GLASER *In* Shock and Vibration Information Center The Shock and Vibration Bulletin. Part 2: Modal Test and Analysis, Testing Techniques, Machinery Dynamics, Isolation and Damping, Structural Dynamics p 1-8 Aug. 1986

Avail: NTIS HC A10/MF A01 CSCL 22B

For the structural dynamic analysis of large space structures, the technology in structural synthesis and the development of structural analysis software have increased the capability to predict the dynamic characteristics of the structural system. The various subsystems which comprise the system are represented by various displacement functions; the displacement functions are then combined to represent the total structure. Experience has indicated that even when subsystem mathematical models are verified by test, the mathematical representations of the total system are often in error because the mathematical model of the structural elements which are significant when loads are applied at the interconnection points are not adequately verified by test. A multiple test concept, based upon the Multiple Boundary Condition Test (MBCT), is presented which will increase the accuracy of the system mathematical model by improving the subsystem test and test/analysis correlation procedure. Author

N87-20584*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

SAFE/DAE: MODAL TEST IN SPACE

T. E. NESMAN and D. K. REED *In* Shock and Vibration Information Center The Shock and Vibration Bulletin. Part 2: Modal Test and Analysis, Testing Techniques, Machinery Dynamics, Isolation and Damping, Structural Dynamics p 29-36 Aug. 1986

Avail: NTIS HC A10/MF A01 CSCL 22B

In September of 1984, NASA performed a series of experiments on orbit with a large solar wing attached to the Space Shuttle orbiter. These experiments, the Solar Array Flight Experiment (SAFE), mark the first tests of a large space structure in space. Extension, retraction, and dynamic tests had to be performed in space due to the fragility of the solar array. Due to the extendable and retractable design of the solar array, accelerometers and associated wires could not be used; therefore, remote sensing, the Dynamics Augmentation Experiment (DAE), was added to the SAFE program. The DAE uses a remote sensor based on star tracker technology to measure the dynamic response of the solar array. The DAE sensor tracked 18 targets on the solar array during free-decay response to a transient excitation. An overview of the SAFE/DAE is presented, highlighting analysis results from the remotely sensed data. Modal parameter estimates from the remotely sensed data were computed using the complex exponential and polyreference techniques. Author

N87-20599# Spar Aerospace Ltd., Ste-Anne-de-Bellevue (Quebec).

OPTIMIZATION OF AEROSPACE STRUCTURES SUBJECTED TO RANDOM VIBRATION AND FATIGUE CONSTRAINTS

V. K. JHA, T. S. SANKAR (Concordia Univ., Montreal, Quebec.), and R. B. BHAT *In* Shock and Vibration Information Center The Shock and Vibration Bulletin. Part 2: Modal Test and Analysis, Testing Techniques, Machinery Dynamics, Isolation and Damping, Structural Dynamics p 193-200 Aug. 1986

Avail: NTIS HC A10/MF A01 CSCL 20K

Aerospace structures have to be designed with very strict reliability requirements, at the same time these structures should be as light as possible in weight to minimize the cost of launching into space. These structures are often subjected to random excitations with power spectral density varying in an arbitrary manner in the frequency domain. With the advent of the space shuttle, it is likely that these structures may have to be designed to withstand many launches, and hence fatigue will be an important factor along with other considerations while optimizing the design.

An approach for handling and incorporating fatigue design constraints in optimizing aerospace structures is presented. Miner's criterion of cumulative fatigue damage was used to formulate the fatigue constraint to ensure that the total expected fatigue damage over the required period of fatigue life does not exceed unity. The fatigue constaint is used in conjunction with other probabilistic constraints such as those on displacements, stresses and on component sizes, when subjected to random vibration loads, to arrive at an optimum design. An optimum design of a typical satellite antenna structure was realized using the proposed approach.
Author

N87-21025# Harris Corp., Melbourne, Fla. Government Aerospace Systems Div.
OPUS: OPTIMAL PROJECTION FOR UNCERTAIN SYSTEMS Annual Report, 1 Oct. 1985 - 1 Oct. 1986
DENNIS S. BERNSTEIN Oct. 1986 354 p
(Contract F49620-86-C-0002)
(AD-A176820; AFOSR-87-0161TR) Avail: NTIS HC A16/MF A01 CSCL 22B

Increased interest in deploying large flexible spacecraft has focused attention on active structural control techniques to achieve crucial advances in vibration suppression, pointing accuracy and shape control. The extreme complexity of such systems and the lack of accurate finite-element structural models present severe control design challenges which were extensively accumulated by previous government research programs. OPUS is a rigorous new approach to this class of problems, which embodies a fundamental generalization of classical steady state linear quadratic Gaussian (LQG) optimal control theory. The present scope of the theory includes robust, reduced order modelling, estimation and control for continuous-time, discrete-time and sample data systems.
GRA

N87-21030# WEA, Cambridge, Mass.
WAVE-MODE COORDINATES AND SCATTERING MATRICES FOR WAVE PROPAGATION Technical Report, 1 Sep. 1985 - 1 Oct. 1986
JAMES H. WILLIAMS, JR., RAYMOND J. NAGEM, and HUBERT K. YEUNG 1 Oct. 1986 50 p
(Contract F49620-85-C-0148)
(AD-A176998; AFOSR-87-0021TR) Avail: NTIS HC A03/MF A01 CSCL 22B

Wave-mode coordinates and scattering matrices are discussed in conjunction with the dynamic and wave propagation analyses of large space structures. Simple one-dimensional examples are given to illustrate how wave-mode coordinates and scattering matrices may be used to describe dynamics and wave propagation in such structures.
GRA

N87-21335 California Univ., Berkeley.
DYNAMICS OF FLEXIBLE STRUCTURES PERFORMING LARGE OVERALL MOTIONS: A GEOMETRICALLY-NONLINEAR APPROACH Ph.D. Thesis
LOC QUOC VU 1986 231 p
Avail: Univ. Microfilms Order No. DA8624976

The modeling of flexible structures subjected to large overall motions is discussed. Applications span diverse disciplines: from robotics and machine design to aircraft and spacecraft dynamics. Traditional approaches to this class of problems are based on the assumption of small deformations, thus relying crucially on the use of a floating reference frame. The resulting set of equations of motion is nonlinear and highly coupled in the inertia terms. By contrast, an alternative approach is proposed in which fully nonlinear structural theories, which are properly invariant with respect to superposed rigid body motions, are employed. Owing to this property, the dynamics of motion can be referred directly to the inertial frame, leading to a drastic simplification of the inertia operator (with a structure identical to that found in rigid body mechanics). Even though the methodology applies to a general class of structural elements, only a one-dimensional type (flexible rod) is considered. The dynamics of Earth-orbiting flexible satellites are completely described by the same system of equations of motion as for the fully nonlinear rod model. Applications of the proposed methodology to the dynamics of flexible multibody systems (rigid bodies with flexible appendages, all flexible chain systems, flexible closed-loop chains) are also considered.
Dissert. Abstr.

N87-21388# Systems Engineering Labs., Inc., Greenbelt, Md.
MODELING AND CONTROL OF FLEXIBLE STRUCTURES Annual Report, Oct. 1984 - Oct. 1985
W. H. BENNETT, G. L. BLANKENSHIP, and H. G. KWATNY 16 Dec. 1986 79 p
(Contract F49620-84-C-0115)
(AD-A177106; SEI-TR-86-13; AFOSR-87-0013TR) Avail: NTIS HC A05/MF A01 CSCL 20K

This report focuses on the roles of models of flexible structures in the design and evaluation of control laws for the damping of vibrational motions in those structures. The first section discusses a generic class of continuum models for flexible structures describing the abstract mathematical formulation of the models as a framework for the design of control laws. The second section shows how direct frequency domain designs for control laws may be achieved for this class of models based on a spectral factorization procedure which replaces the usual computation of Riccati equations. The third section examines the problem of deriving transfer function representations of the structural models as required in the frequency domain design procedure. Section four describes an analytical procedure for the derivation of continuum models for large scale structures with a regular infrastucture.
GRA

N87-21989 Ohio State Univ., Columbus.
VARIABLE STRUCTURE CONTROL SYSTEM MANEUVERING OF SPACECRAFT Ph.D. Thesis
OSAMA ABDERRHMAN MOSTAFA 1986 152 p
Avail: Univ. Microfilms Order No. DA8625264

Variable structure control systems (VSCS) are a class of nonlinear systems which change the structure of the controls when a set of prescribed hypersurfaces are reached in the phase space. The theory represents a real-time implementable approach to control in contrast to algorithmic approaches, and therefore eliminates the computational burden. This dissertation applies the VSCS theory to maneuvering of a rigid spacecraft with four momentum exchange wheels and maneuvering of a flexible spacecraft. General nonlinear equations of motion are presented for the three-axes maneuver of the rigid spacecraft and for a single axis maneuver of the flexible spacecraft. Three methods are presented for designing variable structure control logics. The theory is demonstrated for set point regulation, tracking, disturbance accommodation, spin-up and robust maneuvers of specific spacecraft configurations. A practical problem in the implementation of VSCS theory is the possibility of chatter about hypersurfaces known as sliding regimes. Three methods of chatter alleviation are introduced. Specifically, the methods are: a boundary layer approach, asymptotic reaching of sliding regimes, and digital input prefiltering.
Dissert. Abstr.

N87-21992# WEA, Cambridge, Mass.
COMPARISON OF WAVE-MODE COORDINATE AND PULSE SUMMATION METHODS Interim Report, 1 Sep. 1985 - 1 Dec. 1986
JAMES H. WILLIAMS, JR., RAYMOND J. NAGEM, and HUBERT K. YEUNG 1 Dec. 1986 18 p
(Contract F49620-85-C-0148)
(AD-A177795; AFOSR-87-0280TR) Avail: NTIS HC A02/MF A01 CSCL 20K

Nondispersive pulse propagation in a simple one-dimensional lattice structure is analyzed using the pulse summation method and the wave-mode coordinate method. The results of the two methods are shown to be identical, and both methods account for the existence of equivalent paths in the lattice. Some recommendations for future research are given.
GRA

N87-21993*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
EQUATIONS OF MOTION OF A SPACE STATION WITH EMPHASIS ON THE EFFECTS OF THE GRAVITY GRADIENT
L. P. TUELL Mar. 1987 127 p
(NASA-TM-86588; NAS 1.15:86588) Avail: NTIS HC A07/MF A01 CSCL 22B

The derivation of the equations of motion is based upon the principle of virtual work. As developed, these equations apply only to a space vehicle whose physical model consists of a rigid central carrier supporting several flexible appendages (not interconnected), smaller rigid bodies, and point masses. Clearly evident in the equations is the respect paid to the influence of the Earth's gravity field, considerably more than has been the custom in simulating vehicle motion. The effect of unpredictable crew motion is ignored. Author

N87-22060 California Univ., Los Angeles.
INTEGRATED CONTROL/STRUCTURE DESIGN AND ROBUSTNESS Ph.D. Thesis
ARMEN ADAMIAN 1986 198 p
Avail: Univ. Microfilms Order No. DA8702603

When a flexible structure is to be controlled actively, optimum performance is obtained by integrated, or simultaneous, design of the structure and the controller, as opposed to the common practice of designing the structure independently of control considerations and then designing a controller for a fixed structure. The primary design objective from the structural point of view usually is to minimize weight, while the control design objectives depend on the application. An important requirement for a practical control system is robustness with respect to uncertain plant parameters. Robust compensator design for fixed structures, and simultaneous control/structure design where the overall design objective combines the weight of the structure and the robustness of the closed-loop control system are discussed. For numerical optimization, robustness is represented by the sensitivity of the closed-loop eigenvalues with respect to uncertain parameters. An example illustrates the closed-loop control system with robust compensator, and two examples illustrate the optimal designs of a flexible structure along with robust compensators. Different finite element models are compared to determine models most efficient for compensator design. Dissert. Abstr.

N87-22252# Maryland Univ., College Park. Dept. of Aerospace Engineering.
DYNAMIC FINITE ELEMENT MODELING OF FLEXIBLE STRUCTURES Final Report, 1 Sep. 1985 - 23 Feb. 1986
C. S. CHOI, E. R. CHRISTENSEN, and S. W. LEE 20 Nov. 1986 39 p
(Contract AF-AFOSR-0352-85)
(AD-A177168; AFOSR-87-0165TR) Avail: NTIS HC A03/MF A01 CSCL 13M

In Part 1, reduced basis techniques are applied to the problem of the nonlinear analysis of the dynamics of unrestrained flexible structures. The reduced bases used consisted of mode shapes of the structure as well as some modal derivatives. The technique was tested on a simple spacecraft structure. The numerical results indicated that the technique did not appear very promising for this type of problem. In Part 2, a finite element technique is used for analysis of very flexible structures undergoing deployment maneuvers. The structure is assumed to consist of flexible bars attached to a rigid mass. The description of elastic deformation is based on the total Lagrangian formulation which allows finite rotation. Numerical tests demonstrates the validity of the present approach. GRA

N87-22256# WEA, Cambridge, Mass.
WAVE PROPAGATION IN TRANSVERSELY ISOTROPIC CONTINUUM MODELS OF LSS (LARGE SPACE STRUCTURES) Interim Report, 1 Sep. 1985 - 1 Jan. 1987
JAMES H. WILLIAMS, JR., RAYMOND J. NAGEM, and KARIM G. SALAME 1 Jan. 1987 35 p
(Contract F49620-85-C-0148)
(AD-A177271; AFOSR-87-0279TR) Avail: NTIS HC A03/MF A01 CSCL 20K

Continuum models of large repetitive lattice structures are often used to provide computationally efficient analyses of static, dynamic and thermomechanical properties. In this report, a continuum model is used to study wave propagation in lattice structures. Attention is focused on a tetrahedral lattice structure which may be modeled as an equivalent homogeneous transversely isotropic continuum. Numerical results for phase velocities, deviation angles, and wave front surfaces in the equivalent continuum show that wave propagation in lattice structures may be remarkably different from the more familiar wave propagation in isotropic continua. The results given here, which ignore all effects of boundaries of the lattice and which are valid for wavelengths that are long compared with the basic cell size of the lattice, are intended to give insight into how waves may propagate in large repetitive lattice structures. GRA

N87-22707*# Tennessee Univ. Space Inst., Tullahoma.
A GENERAL METHOD FOR DYNAMIC ANALYSIS OF STRUCTURES OVERVIEW
REMI C. ENGELS *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 119-132 Apr. 1987
(Contract F29601-85-K-0054)
Avail: NTIS HC A99/MF E03 CSCL 20K

The presented research deals with the development of a dynamic analysis method for structural systems. The modeling approach is essentially a finite element method in the sense that the structure is divided into n elements. An element is defined as any structural unit whose degree of freedom (dofs) can be categorized as either interface or non-interface dofs. An element could be a fundamental unit such as a rod, a beam, a plate etc., or it could be an entire structural component. Furthermore, the parameters for the element could be distributed or lumped. The choice of elements is totally arbitrary and is a matter of user convenience. In particular, issues of accuracy and convergence do not enter on the level of example that bookkeeping is reduced to a minimum. Each element is modeled using a set of interface constraint modes (ICM) combined with a set of interface restrained normal models (IRNM). The next step is the solution of the system eigenvalue problem. The procedure calls for the sequential solution of a number of small eigenvalue problems based on a truncation principle for IRNM. In addition, the form of these eigenvalue problems is very simple such that an escalator type of eigenvalue problem solver can be used which is extremely cost-effective and fast. Author

N87-22710*# Engineering Mechanics Association, Inc., Torrance, Calif.
A COMPUTER PROGRAM FOR MODEL VERIFICATION OF DYNAMIC SYSTEMS
J. D. CHROSTOWSKI and T. K. HASSELMAN *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 199-214 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 09B

Dynamic model verification is the process whereby an analytical model of a dynamic system is compared with experimental data, and then qualified for future use in predicting system response in a different dynamic environment. There are various ways to conduct model verification. The approach adopted in MOVER II employs Bayesian statistical parameter estimation. Unlike curve fitting whose objective is to minimize the difference between some analytical function and a given quantity of test data (or curve), Bayesian estimation attempts also to minimize the difference between the parameter values of that function (the model) and their initial

estimates, in a least squares sense. The objectives of dynamic model verification, therefore, are to produce a model which: (1) is in agreement with test data, (2) will assist in the interpretation of test data, (3) can be used to help verify a design, (4) will reliably predict performance, and (5) in the case of space structures, facilitate dynamic control. Author

N87-22714*# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
OPTIMUM MIX OF PASSIVE AND ACTIVE CONTROL OF SPACE STRUCTURES
LYNN ROGERS and KEN RICHARDS (Martin Marietta Aerospace, Denver, Colo.) *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 275-292 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

The objective of this research was to test vibration suppression (settling time and jitter) of a large space structure (LSS) characterized by low frequency high global vibration modes. Five percent passive damping in a large truss was analyzed, tested and correlated. A representative system article re-target analysis shows that modest levels of passive damping dramatically reduce the control energy required. LSS must incorporate passive damping from the outset. The LSS system performance will not be met by either active or passive damping alone. E.R.

N87-22715*# Control Dynamics Co., Huntsville, Ala.
ONE CONTROLLER AT A TIME (1-CAT): A MIMO DESIGN METHODOLOGY
J. R. MITCHELL and J. C. LUCAS *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 293-334 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

The One Controller at a Time (1-CAT) methodology for designing digital controllers for Large Space Structures (LSS's) is introduced and illustrated. The flexible mode problem is first discussed. Next, desirable features of a LSS control system design methodology are delineated. The 1-CAT approach is presented, along with an analytical technique for carrying out the 1-CAT process. Next, 1-CAT is used to design digital controllers for the proposed Space Based Laser (SBL). Finally, the SBL design is evaluated for dynamical performance, noise rejection, and robustness. Author

N87-22716*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
COMMIT YOUR WORKS TO THE LORD, AND YOUR THOUGHTS SHALL BE ESTABLISHED (PROV. 16:3). INTER-STABLE CONTROL SYSTEMS
GEORGE L. VONPRAGENAU *In its* Structural Dynamics and Control Interaction of Flexible Structures p 335-358 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Algebraic structures are discussed for control systems that maintain stability in the presence of resonance uncertainties. Dual algebraic operations serve as elementary connections that propagate the stability of inter-stable subsystems. Frequency responses within complex half-planes define different types of inter-stability. Dominance between incompatible types is discussed. Inter-stability produces sufficient but unnecessary stability conditions, except for conservative systems where the conditions become also necessary. Multivariable systems, colocation of actuator and sensor, and virtual colocation are treated. Instead of passivity, inter-stability relates stability to the mapping of poles and zeros by transfer functions and transfer matrices. Inter-stability determines stability on the subsystem level, is less complex even for multivariable systems, adds design flexibility, and relaxes the dynamic data problem of large systems such as space stations. Author

N87-22719*# Auburn Univ., Ala. Dept. of Electrical Engineering.
IMPROVING STABILITY MARGINS IN DISCRETE-TIME LQG CONTROLLERS
B. TARIK ORANC and CHARLES L. PHILLIPS *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 417-434 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 12A

Some of the problems are discussed which are encountered in the design of discrete-time stochastic controllers for problems that may adequately be described by the Linear Quadratic Gaussian (LQG) assumptions; namely, the problems of obtaining acceptable relative stability, robustness, and disturbance rejection properties. A dynamic compensator is proposed to replace the optimal full state feedback regulator gains at steady state, provided that all states are measurable. The compensator increases the stability margins at the plant input, which may possibly be inadequate in practical applications. Though the optimal regulator has desirable properties the observer based controller as implemented with a Kalman filter, in a noisy environment, has inadequate stability margins. The proposed compensator is designed to match the return difference matrix at the plant input to that of the optimal regulator while maintaining the optimality of the state estimates as directed by the measurement noise characteristics. Author

N87-22720*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
AN OVERVIEW OF CONTROLS RESEARCH ON THE NASA LANGLEY RESEARCH CENTER GRID
RAYMOND C. MONTGOMERY *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 435-456 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

The NASA Langley Research Center has assembled a flexible grid on which control systems research can be accomplished on a two-dimensional structure that has many physically distributed sensors and actuators. The grid is a rectangular planar structure that is suspended by two cables attached to one edge so that out of plane vibrations are normal to gravity. There are six torque wheel actuators mounted to it so that torque is produced in the grid plane. Also, there are six rate gyros mounted to sense angular motion in the grid plane and eight accelerometers that measure linear acceleration normal to the grid plane. All components can be relocated to meet specific control system test requirements. Digital, analog, and hybrid control systems capability is provided in the apparatus. To date, research on this grid has been conducted in the areas of system and parameter identification, model estimation, distributed modal control, hierarchical adaptive control, and advanced redundancy management algorithms. The presentation overviews each technique and presents the most significant results generated for each area. Author

N87-22721*# Rockwell International Corp., Downey, Calif. Space Station Systems Div.
STRUCTURAL/CONTROL INTERACTION (PAYLOAD POINTING AND MICRO-G)
C. R. LARSON *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 457-484 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

A 203rd order simulation model was developed to evaluate the space station customer accommodation payload pointing and micro-g requirements. The simulation shows the pointing errors on the telescope are significantly smaller than at the base of the telescope. The pointing results could change when the parametric studies are performed. The results show the micro-g requirement is met with an active isolation system. Author

N87-22724*# Boeing Aerospace Co., Seattle, Wash.
DYNAMICS OF TRUSSES HAVING NONLINEAR JOINTS
J. M. CHAPMAN, F. H. SHAW, and W. C. RUSSELL *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 539-566 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

The transient analysis of trusses having nonlinear joints can be accomplished using the residual force technique. The technique was applied a two degree of freedom spring mass system, a four bay planar truss, and an actual ten bay deployable truss. Joints chosen for analysis were the nonlinear gap joints and the linear Voigt joints. Results from the nonlinear gap analyses generally indicate that coupling between the modes can display some interesting effects during free vibration. One particularly interesting effect was that the damping of the structure appeared to be higher than could be accounted for from modal damping alone. Energy transferral from the lower to the higher modes was found to exist as a result of the modal coupling. The apparently increased damping was due to the fact that the energy transferred to the higher modes is inherently dissipated more quickly. Another interesting phenomenon was that the lower modes could drive the higher modes even during free vibration and that these modes could display a rather large quasi-steady state behavior even when modal damping was present. Gaps were also found to increase the amplitude and period of the free vibration response as expected. Author

N87-22726*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
DYNAMIC CHARACTERISTICS OF A VIBRATING BEAM WITH PERIODIC VARIATION IN BENDING STIFFNESS
JOHN S. TOWNSEND *In its* Structural Dynamics and Control Interaction of Flexible Structures p 595-624 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

A detailed dynamic analysis is performed of a vibrating beam with bending stiffness periodic in the spatial coordinate. Using a perturbation expansion technique the free vibration solution is obtained in a closed-form, and the effects of system parameters on beam response are explored. It is found that periodic stiffness acts to modulate the modal displacements from the characteristic shape of a simple sine wave. The results are verified by a finite element solution and through experimental testing. Author

N87-22727*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
STRUCTURAL DYNAMICS SYSTEM MODEL REDUCTION
J. C. CHEN, T. L. ROSE, and B. K. WADA *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 625-668 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

Loads analysis for structural dynamic systems is usually performed by finite element models. Because of the complexity of the structural system, the model contains large number of degree-of-freedom. The large model is necessary since details of the stress, loads and responses due to mission environments are computed. However, a simplified model is needed for other tasks such as pre-test analysis for modal testing, and control-structural interaction studies. A systematic method of model reduction for modal test analysis is presented. Perhaps it will be of some help in developing a simplified model for the control studies. Author

N87-22728*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
WORKSHOP ON STRUCTURAL DYNAMICS AND CONTROL INTERACTION OF FLEXIBLE STRUCTURES
L. P. DAVIS, J. F. WILSON (Sperry Corp., Phoenix, Ariz.), and R. E. JEWELL *In its* Structural Dynamics and Control Interaction of Flexible Structures p 669-690 Apr. 1987 Reprinted from Vibration Damping Workshop, 6 Mar. 1986
Avail: NTIS HC A99/MF E03 CSCL 20K

The Hubble Space Telescope features the most exacting line of sight jitter requirement thus far imposed on a spacecraft pointing system. Consideration of the fine pointing requirements prompted an attempt to isolate the telescope from the low level vibration disturbances generated by the attitude control system reaction wheels. The primary goal was to provide isolation from axial component of wheel disturbance without compromising the control system bandwidth. A passive isolation system employing metal springs in parallel with viscous fluid dampers was designed, fabricated, and space qualified. Stiffness and damping characteristics are deterministic, controlled independently, and were demonstrated to remain constant over at least five orders of input disturbance magnitude. The damping remained purely viscous even at the data collection threshold of .16 x .000001 in input displacement, a level much lower than the anticipated Hubble Space Telescope disturbance amplitude. Vibration attenuation goals were obtained and ground test of the vehicle has demonstrated the isolators are transparent to the attitude control system. Author

N87-22729*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
STRUCTURAL DYNAMICS AND CONTROL INTERACTION OF FLEXIBLE STRUCTURES
ROBERT S. RYAN, ed. and HAROLD N. SCOFIELD, ed. Apr. 1987 729 p Workshop held in Huntsville, Ala., 22-24 Apr. 1986
(NASA-CP-2467-PT-2; M-554-PT-2; NAS 1.55:2467-PT-2) Avail: NTIS HC A99/MF E03 CSCL 22B

A Workshop was held to promote technical exchange between the structural dynamic and control disciplines, foster joint technology, and provide a forum for discussing and focusing critical issues in the separate and combined areas. The workshop was closed by a panel meeting. Panel members' viewpoints and their responses to questions are included.

N87-22730*# California Inst. of Tech., Pasadena.
VIBRATION SUPPRESSION BY STIFFNESS CONTROL
JAMES FANSON, THOMAS CAUGHEY, and JAY CHEN *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 693-758 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 20K

The feasibility of using piezoelectric ceramics as both sensors and actuators for vibration suppression in a lightweight, flimsy structure was demonstrated. Multimode control was achieved using one sensor and actuator pair. The Positive Position Feedback control strategy requires only knowledge of the natural frequencies of the structure. Implementation of the Positive Position Feedback used only strain measurements to achieve damping, no velocities, or acceleration are needed. All spillover is stabilizing for sufficient small gains. B.G.

N87-22731*# Texas A&M Univ., College Station.
A QUASI-ANALYTICAL METHOD FOR NON-ITERATIVE COMPUTATION OF NONLINEAR CONTROLS
J. L. JUNKINS, R. C. THOMPSON, and J. D. TURNER (Cambridge Research Associates, Mass.) *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 759-774 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

An optimal control solution process was developed for a general class of nonlinear dynamical systems. The method combines control theory, perturbation methods, and Van Loan's recent matrix exponential results. A variety of applications support the practical utility of this method. Nonlinear rigid body optimal maneuvers are routinely solved. Flexible body dynamical systems of an order greater than 40 were solved. The method fails occasionally due to poor convergence of the perturbation expansion or numerical difficulties associated with computing the matrix exponential. The method is attractive because it appears to be a good candidate for semi-automation; no initial guess is required, and it usually converges at 2nd or 3rd order in minutes of machine time. B.G.

N87-22732*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
CONTROL OF FLEXIBLE STRUCTURES AND THE RESEARCH COMMUNITY
CLAUDE R. KECKLER and JON S. PYLE *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 789-840 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

The Control of Flexible Structures II (CPFS) program is a complex and ambitious undertaking which addresses several critical technology areas. Among them are modeling, structural dynamics, control, and ground testing issues, which are also applicable to other large space structure programs being contemplated. This effort requires early integration of controls and structural dynamic considerations. Several technological advances must be achieved in the areas of system modeling, control synthesis and methodology, sensor/actuator development, and ground testing techniques for system evaluation and on-orbit performance prediction and verification. This program offers an opportunity for the integration of several disciplines to produce technology advances which will benefit many future programs. B.G.

N87-22733*# General Electric Co., Philadelphia, Pa. Space Div.
IMPACT OF SPACE STATION APPENDAGE VIBRATIONS ON THE POINTING PERFORMANCE OF GIMBALLED PAYLOADS
ROBERT O. HUGHES *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures 841-866 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

A study of the interface problems between the Space Station Structure (vibrations) and the Payload Pointing Control System was undertaken. A major goal of the study was to identify any bounding factors that might limit the achievement of required pointing accuracies. A major result is that the space station will have a disturbance-rich environment and the background levels will be large enough to impact the pointing of some of the payloads. The need for an interface vibration specification between the structure and the payloads was identified. Author

N87-22734*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
MANEUVERING AND VIBRATION CONTROL OF FLEXIBLE SPACECRAFT
L. MEIROVITCH and R. D. QUINN *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 867-880 Apr. 1987
(Contract NAG1-225)
Avail: NTIS HC A99/MF E03 CSCL 22B

Equations of motion, control strategy, perturbation, rigid-body maneuvers, quasi-modal equations, and vibration control are discussed for flexible spacecraft. B.G.

N87-22737*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
DUAL KEEL SPACE STATION CONTROL/STRUCTURES INTERACTION STUDY
JOHN W. YOUNG, FREDERICK J. LALLMAN, and PAUL A. COOPER *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 945-978 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

A study was made to determine the influence of truss bay size on the performance of the space station control system. The objective was to determine if any control problems existed during reboost and to assess the level of potential control/structures interaction during operation of the control moment gyros used for vertical stabilization. The models analyzed were detailed finite-element representations of the 5 meter and 9 foot growth versions of the 300 kW dual keel station. Results are presented comparing the performance of the reboost control system for both versions of the space station. Standards for comparison include flexible effects at the attitude control sensor locations and flexible contributions to pointing error at the solar collectors. Bode analysis results are presented for the attitude control system and control, structural, and damping sensitivities are examined. Author

N87-22738*# *Boeing Aerospace Co., Seattle, Wash.*
HIGH SPEED SIMULATION OF FLEXIBLE MULTIBODY DYNAMICS
A. D. JACOT, R. E. JONES, and C. D. JUENGST *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 979-998 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 09B

A multiflexible body dynamics code intended for fast turnaround control design trades is described. Nonlinear rigid body dynamics and linearized flexible dynamics combine to provide efficient solution of the equations of motion. Comparison with results from the DISCOS code provide verification of accuracy. Author

N87-22739*# Texas Univ., Austin. Dept. of ASE-EM.
LANCZOS MODES FOR REDUCED-ORDER CONTROL OF FLEXIBLE STRUCTURES
ROY R. CRAIG, JR. and RUSSELL M. TURNER *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 999-1012 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Lanczos mode models represent low-frequency forced response better than do normal mode models and can be developed for both continuous and finite element structural representations. It was recommended that Lanczos mode models for systems with multiple input and/or rigid body modes should be developed; numerical stability of the Lanczos algorithm should be assessed; and control system designs employing the Lanczos mode models should be attempted. B.G.

N87-22740*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SLEWING CONTROL EXPERIMENT FOR A FLEXIBLE PANEL
JER-NAN JUANG *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1013-1032 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Technology areas are identified in which better analytical and/or experimental methods are needed to adequately and accurately control the dynamic responses of multibody space platforms such as the space station. A generic space station solar panel is used to experimentally evaluate current control technologies. Active suppression of solar panel vibrations induced by large angle maneuvers is studied with a torque actuator at the root of the solar panel. These active suppression tests will identify the hardware requirements and adequacy of various controller designs. Author

N87-22741*# Harris Corp., Melbourne, Fla. Government Aerospace Systems Div.
MAXIMUM ENTROPY/OPTIMAL PROJECTION (MEOP) CONTROL DESIGN SYNTHESIS: OPTIMAL QUANTIFICATION OF THE MAJOR DESIGN TRADEOFFS
D. C. HYLAND and D. S. BERNSTEIN *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1033-1070 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

The underlying philosophy and motivation of the optimal projection/maximum entropy (OP/ME) stochastic modeling and reduced control design methodology for high order systems with parameter uncertainties are discussed. The OP/ME design equations for reduced-order dynamic compensation including the effect of parameter uncertainties are reviewed. The application of the methodology to several Large Space Structures (LSS) problems of representative complexity is illustrated. B.G.

N87-22742*# Lockheed Missiles and Space Co., Sunnyvale, *Calif. Space Systems Div.*

VIBRATION ISOLATION FOR LINE OF SIGHT PERFORMANCE IMPROVEMENT

J. J. RODDEN, H. J. DOUGHERTY, and W. B. HAILE *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1071-1078 Apr. 1987

Avail: NTIS HC A99/MF E03 CSCL 20K

Diagrams of the Reaction Wheel Assembly (RWA) are presented along with charts and graphs illustrating jitter error model, induced vibration tests, radial displacement transfer function, and axial displacement power spectra density. The RWA isolator specification requirements are listed. B.G.

N87-22743*# Auburn Univ., Ala. Dept. of Aerospace *Engineering.*

A NEW APPROACH FOR VIBRATION CONTROL IN LARGE SPACE STRUCTURES

K. KUMAR and J. E. COCHRAN, JR. *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1079-1094 Apr. 1987

Avail: NTIS HC A99/MF E03 CSCL 20K

An approach for augmenting vibration damping characteristics in space structures with large panels is presented. It is based on generation of bending moments rather than forces. The moments are generated using bimetallic strips, suitably mounted at selected stations on both sides of the large panels, under the influence of differential solar heating, giving rise to thermal gradients and stresses. The collocated angular velocity sensors are utilized in conjunction with mini-servos to regulate the control moments by flipping the bimetallic strips. A simple computation of the rate of dissipation of vibrational energy is undertaken to assess the effectiveness of the proposed approach. Author

N87-22745*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

MODELING OF CONTROLLED FLEXIBLE STRUCTURES WITH IMPULSIVE LOADS

M. ZAK *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1161-1178 Apr. 1987

Avail: NTIS HC A99/MF E03 CSCL 22B

The characteristic wave approach is developed as an alternative to modal methods which may lead to significant errors in the presence of impulsive or concentrated loads. The method is applied to periodic structures. Some special phenomena like cumulation effects and transitions to ergodicity are analyzed. Author

N87-22746*# DYNACS Engineering Co., Inc., Clearwater, Fla.

NOTES ON IMPLEMENTATION OF COULOMB FRICTION IN COUPLED DYNAMICAL SIMULATIONS

R. J. VANDERVOORT and R. P. SINGH *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1197-1213 Apr. 1987

Avail: NTIS HC A99/MF E03 CSCL 20K

A coupled dynamical system is defined as an assembly of rigid/flexible bodies that may be coupled by kinematic connections. The interfaces between bodies are modeled using hinges having 0 to 6 degrees of freedom. The equations of motion are presented for a mechanical system of n flexible bodies in a topological tree configuration. The Lagrange form of the D'Alembert principle was employed to derive the equations. The equations of motion are augmented by the kinematic constraint equations. This augmentation is accomplished via the method of singular value decomposition. B.G.

N87-22747*# Jet Propulsion Lab., California Inst. of Tech., *Pasadena.*

ON THE CONTROL OF STRUCTURES BY APPLIED THERMAL GRADIENTS

DON EDBERG and JAY-C. CHEN *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1214-1250 Apr. 1987

Avail: NTIS HC A99/MF E03 CSCL 20K

Some preliminary results of research on control of flexible structures performed at the Jet Propulsion Laboratory are presented. It was shown that the thermoelectric device is a feasible actuator and may effectively be used to control structures, provided the structure has a relatively low thermal inertia. The control law only depends on the open-loop system natural frequency. B.G.

N87-22750*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

SYSTEM IDENTIFICATION FOR LARGE SPACE STRUCTURE DAMAGE ASSESSMENT

J. C. CHEN and J. A. GARBA *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1289-1318 Apr. 1987

Avail: NTIS HC A99/MF E03 CSCL 22B

The need for monitoring the dynamic characteristics of large structural systems for purposes of assessing the potential degradation of structural properties was established. A theory for assessing the occurrence, location, and extent of potential damage was developed utilizing on-orbit response measurements. Feasibility of the method is demonstrated using a simple structural system as an example. Author

N87-22751*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

SPACE STATION STRUCTURES AND DYNAMICS TEST PROGRAM

FRANK M. BUGG, E. W. IVEY, C. J. MOORE, and JOHN S. TOWNSEND *In its* Structural Dynamics and Control Interaction of Flexible Structures p 1319-1332 Apr. 1987

Avail: NTIS HC A99/MF E03 CSCL 22B

The design, construction, and operation of a low-Earth orbit space station poses challenges for development and implementation of technology. One specific challenge is the development of a dynamics test program for defining the space station design requirements, and identifying and characterizing phenomena affecting the space station's design and development. The test proposal, as outlined, is a comprehensive structural dynamics program to be launched in support of the space station (SS). Development of a parametric data base and verification of the mathematical models and analytical analysis tools necessary for engineering support of the station's design, construction, and operation provide the impetus for the dynamics test program. The four test phases planned are discussed: testing of SS applicable structural concepts; testing of SS prototypes; testing of actual SS structural hardware; and on-orbit testing of SS construction. B.G.

N87-22753*# Martin Marietta Aerospace, Denver, Colo. Analytical Mechanics.

SPACE STATION STRUCTURAL DYNAMICS/REACTION CONTROL SYSTEM INTERACTION STUDY

M. PINNAMANENI and J. MURRAY *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 1367-1394 Apr. 1987

Avail: NTIS HC A99/MF E03 CSCL 22B

The performance of the Reaction Control System is impacted by the extreme flexibility of the space station structure. The method used to analyze the periodic thrust profile of a simple form of phase plane logic is presented. The results illustrate the effect on flexible body response of the type of phase plane logic utilized and the choice of control parameters: cycle period and attitude deadband. Author

N87-22758*# Allied Bendix Aerospace, Teterboro, N.J. Guidance Systems Div.
ADAPTIVE MOMENTUM MANAGEMENT FOR LARGE SPACE STRUCTURES Final Report, 1 May 1986 - 31 Jan. 1987
E. HAHN 10 Feb. 1987 43 p
(Contract NAS8-36488)
(NASA-CR-179085; NAS 1.26:179085) Avail: NTIS HC A03/MF A01 CSCL 22B

Momentum management is discussed for a Large Space Structure (LSS) with the structure selected configuration being the Initial Orbital Configuration (IOC) of the dual keel space station. The external forces considered were gravity gradient and aerodynamic torques. The goal of the momentum management scheme developed is to remove the bias components of the external torques and center the cyclic components of the stored angular momentum. The scheme investigated is adaptive to uncertainties of the inertia tensor and requires only approximate knowledge of principle moments of inertia. Computational requirements are minimal and should present no implementation problem in a flight type computer and the method proposed is shown to be effective in the presence of attitude control bandwidths as low as .01 radian/sec. Author

N87-22761# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
MOVING-BANK MULTIPLE MODEL ADAPTIVE ESTIMATION APPLIED TO FLEXIBLE SPACESTRUCTURE CONTROL M.S. Thesis
DREW A. KARNICK Dec. 1986 213 p
(AD-A178870; AFIT/GE/ENG/86D-41) Avail: NTIS HC A10/MF A01 CSCL 22B

A significant problem in estimation and control is the uncertainty of parameters in the mathematical model used in the design of controllers and/or estimators. These parameters may be unknown, varying slowly, or changing abruptly due to a failure in the physical system. These changes in parameters often necessitate the identification of parameters within the mathematical model and changing the mathematical model during a real-time control problem. This is often referred to as adaptive control and/or estimation. This thesis investigates methods of adaptive control implementing a moving-bank multiple model adaptive estimator. GRA

N87-23980*# Catholic Univ. of America, Washington, D.C. Dept. of Mechanical Engineering.
MODIFIED INDEPENDENT MODAL SPACE CONTROL METHOD FOR ACTIVE CONTROL OF FLEXIBLE SYSTEMS
A. BAZ and S. POH Jul. 1987 32 p
(Contract NAG5-520; NAG5-749)
(NASA-CR-181065; NAS 1.26:181065) Avail: NTIS HC A03/MF A01 CSCL 13I

A modified independent modal space control (MIMSC) method is developed for designing active vibration control systems for large flexible structures. The method accounts for the interaction between the controlled and residual modes. It incorporates also optimal placement procedures for selecting the optimal locations of the actuators in the structure in order to minimize the structural vibrations as well as the actuation energy. The MIMSC method relies on an important feature which is based on time sharing of a small number of actuators, in the modal space, to control effectively a large number of modes. Numerical examples are presented to illustrate the application of the method to generic flexible systems. The results obtained suggest the potential of the devised method in designing efficient active control systems for large flexible structures. Author

N87-24497*# Air Force Weapons Lab., Kirtland AFB, N. Mex.
JOINT OPTICS STRUCTURES EXPERIMENT (JOSE)
DAVID FOUNDS *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 591-602 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 20F

The objectives of the JOSE program is to develop, demonstrate, and evaluate active vibration suppression techniques for Directed Energy Weapons (DEW). DEW system performance is highly influenced by the line-of-sight (LOS) stability and in some cases by the wave front quality. The missions envisioned for DEW systems by the Strategic Defense Initiative require LOS stability and wave front quality to be significantly improved over any current demonstrated capability. The Active Control of Space Structures (ACOSS) program led to the development of a number of promising structural control techniques. DEW structures are vastly more complex than any structures controlled to date. They will be subject to disturbances with significantly higher magnitudes and wider bandwidths, while holding higher tolerances on allowable motions and deformations. Meeting the performance requirements of the JOSE program requires upgrading the ACOSS techniques to meet new more stringent requirements, the development of requisite sensors and acturators, improved control processors, highly accurate system identification methods, and the integration of hardware and methodologies into a successful demonstration. Author

N87-24498*# General Dynamics Corp., Fort Worth, Tex.
LARGE SPACECRAFT POINTING AND SHAPE CONTROL
ARTHUR L. HALE *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 603-635 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The overall objective of this program was the development of control algorithms that allow the concurrent operation of slewing, pointing, vibration, and shape control subsystems. This objective is important for near-term space surveillance missions that require the rapid retargeting and precise pointing of large flexible satellites. The success of these missions requires the design and concurrent operation of the various interacting control subsystems. There were two phases conducted: phase 1 was mathematical model development, and phase 2 was control development. The program is detailed and major conclusions given. Author

N87-24499*# Honeywell Systems and Research Center, Minneapolis, Minn.
ROBUST CONTROL FOR LARGE SPACE ANTENNAS
M. F. BARRETT *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 637-664 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 13I

A brief description of program objectives and the space based radar application is given. General characteristics of the 100 m diameter reflector spacecraft are described along with the intended mission and associated requirements, and dynamic characteristics relevant to that mission. Preliminary control analyses are carried out for the critical rapid slew and settle maneuver to establish feedback control requirements and fundamental limitations in meeting those requirements with control hardware for a baseline reaction control system (RCS) jet placement assumed for the open loop bang-bang slew limitations. Control moment gyros (CMGs), angular position sensors, and linear translation sensors are placed for feedback control. Control laws are designed for the improved sensor and actuator placement and evaluated for performance and robustness to unstructured model uncertainty. The robustness of the control design is assessed with respect to modal parameter uncertainty. Results of the control designs analyses are summarized, conclusions are drawn, and recommendations made for future studies. Author

N87-24502*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
CONTROLS-STRUCTURES-ELECTROMAGNETICS ON PROGRAM
WILLIAM L. GRANTHAM, MARION C. BAILEY, WENDELL K. BELVIN, and JEFFREY P. WILLIAMS *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 701-715 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

A technology development program is described involving Controls Structures Electromagnetics Interaction (CSEI) for large space structures. The CSEI program was developed as part of the continuing effort following the successful kinematic deployment and RF tests of the 15 meter Hoop/Column antenna. One lesson learned was the importance of making reflector surface adjustment after fabrication and deployment. Given are program objectives, ground based test configuration, Intelsat adaptive feed, reflector shape prediction model, control experiment concepts, master schedule, and Control Of Flexible Structures-II (COFS-II) baseline configuration. Author

N87-24505*# TRW Space Technology Labs., Redondo Beach, Calif.
APPLICATION OF PHYSICAL PARAMETER IDENTIFICATION TO FINITE-ELEMENT MODELS
ALLEN J. BRONOWICKI, MICHAEL S. LUKICH, and STEVEN P. KURITZ *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 747-755 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The time domain parameter identification method described previously is applied to TRW's Large Space Structure Truss Experiment. Only control sensors and actuators are employed in the test procedure. The fit of the linear structural model to the test data is improved by more than an order of magnitude using a physically reasonable parameter set. The electro-magnetic control actuators are found to contribute significant damping due to a combination of eddy current and back electro-motive force (EMF) effects. Uncertainties in both estimated physical parameters and modal behavior variables are given. Author

N87-24507*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
CONTROL TECHNOLOGY OVERVIEW IN CSI
J. B. DAHLGREN and A. F. TOLIVAR *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 767-778 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

A brief control technology overview is given in Control Structures Interaction (CSI) by illustrating that many future NASA mission present significant challenges as represented by missions having a significantly increased number of important system states which may require control and by identifying key CSI technology needs. The JPL CSI related technology developments are discussed to illustrate that some of the identified control needs are being pursued. Since experimental confirmation of the assumptions inherent in the CSI technology is critically important to establishing its readiness for space program applications, the areas of ground and flight validation require high priority. Author

N87-24508*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ANTENNA TECHNOLOGY SHUTTLE EXPERIMENT (ATSE)
R. E. FREELAND, E. METTLER, L. J. MILLER, Y. RAHMET-SAMII, and W. J. WEBER, III *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 779-807 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 20N

Numerous space applications of the future will require mesh deployable antennas of 15 m in diameter or greater for frequencies up to 20 GHz. These applications include mobile communications satellites, orbiting very long baseline interferometry (VLBI) astrophysics missions, and Earth remote sensing missions. A Lockheed wrap rip antennas was used as the test article. The experiments covered a broad range of structural, control, and RF discipline objectives, which is fulfilled in total, would greatly reduce the risk of employing these antenna systems in future space applications. It was concluded that a flight experiment of a relatively large mesh deployable reflector is achievable with no major technological or cost drivers. The test articles and the instrumentation are all within the state of the art and in most cases rely on proven flight hardware. Every effort was made to design the experiments for low cost. Author

N87-24509*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
STRUCTURAL CONTROL BY THE USE OF PIEZOELECTRIC ACTIVE MEMBERS
J. L. FANSON and J.-C. CHEN *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 809-829 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

Large Space Structures (LSS) exhibit characteristics which make the LSS control problem different form other control problems. LSS will most likely exhibit low frequency, densely spaced and lightly damped modes. In theory, the number of these modes is infinite. Because these structures are flexible, Vibration Suppression (VS) is an important aspect of LSS operation. In terms of VS, the control actuators should be as low mass as possible, have infinite bandwidth, and be electrically powered. It is proposed that actuators be built into the structure as dual purpose structural elements. A piezoelectric active member is proposed for the control of LSS. Such a device would consist of a piezoelectric actuator and sensor for measuring strain, and screwjack actuator in series for use in quasi-static shape control. An experiment simulates an active member using piezoelectric ceramic thin sheet material on a thin, uniform cantilever beam. The feasibility of using the piezoelectric materials for VS on LSS was demonstrated. Positive positive feedback as a VS control strategy was implemented. Multi-mode VS was achieved with dramatic reduction in dynamic response. E.R.

N87-24511*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SLEW MANEUVERS ON THE SCOLE LABORATORY FACILITY
JEFFREY P. WILLIAMS *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 851-867 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The Spacecraft Control Laboratory Experiment (SCOLE) was conceived to provide a physical test bed for the investigation of control techniques for large flexible spacecraft. The control problems studied are slewing maneuvers and pointing operations. The slew is defined as a minimum time maneuver to bring the antenna line-of-sight (LOS) pointing to within an error limit of the pointing target. The second objective is to rotate about the LOS within the 0.02 degree error limit. The SCOLE problem is defined as two design challenges: control laws for a mathematical model of a large antenna attached to the Space Shuttle by a long flexible mast; and a control scheme on a laboratory representation of the structure modelled on the control laws. Control sensors and actuators are typical of those which the control designer would have to deal with on an actual spacecraft. Computational facilities consist of microcomputer based central processing units with appropriate analog interfaces for implementation of the primary control system, and the attitude estimation algorithm. Preliminary results of some slewing control experiments are given. Author

N87-24513*# University of Southern California, Los Angeles. Dept. of Civil Engineering.
EVALUATION OF ON-LINE PULSE CONTROL FOR VIBRATION SUPPRESSION IN FLEXIBLE SPACECRAFT Final Technical Report
SAMI F. MASRI 13 Jul. 1987 32 p
(Contract NAG1-636)
(NASA-CR-180391; NAS 1.26:180391; USC-53-4507-0031)
Avail: NTIS HC A03/MF A01 CSCL 22B

A numerical simulation was performed, by means of a large-scale finite element code capable of handling large deformations and/or nonlinear behavior, to investigate the suitability of the nonlinear pulse-control algorithm to suppress the vibrations induced in the Spacecraft Control Laboratory Experiment (SCOLE) components under realistic maneuvers. Among the topics investigated were the effects of various control parameters on the efficiency and robustness of the vibration control algorithm. Advanced nonlinear control techniques were applied to an idealized model of some of the SCOLE components to develop an efficient algorithm to determine the optimal locations of point actuators, considering the hardware on the SCOLE project as distributed in nature. The control was obtained from a quadratic optimization criterion, given in terms of the state variables of the distributed system. An experimental investigation was performed on a model flexible structure resembling the essential features of the SCOLE components, and electrodynamic and electrohydraulic actuators were used to investigate the applicability of the control algorithm with such devices in addition to mass-ejection pulse generators using compressed air. B.G.

N87-24514# Aeritalia S.p.A., Naples (Italy). Space Systems Group.
ATTITUDE AND ORIENTATION CONTROL SYSTEM (AOCS) TASKS ON RENDEZVOUS AND DOCKING (RVD) (DOCKING-UNDOCKING PHASES). DOCKING-UNDOCKING PHASE ANALYSIS Final Report
Paris, France ESA Feb. 1986 138 p
(Contract ESA-4750/81-NL-AK(SC))
(LP-RP-AI-204-VOL-1; ESA-CR(P)-2313-VOL-1; ETN-87-99868)
Avail: NTIS HC A07/MF A01

The docking and undocking phases that comprise all operations leading from the first physical contact to the integral configuration of assembled spacecraft, and operations necessary to separate the two satellites in case of malfunctioning of one of them were analyzed. Mathematical models are obtained from this analysis in order to simulate these phases using the DCAP-1 program and to obtain preliminary design evaluations and requirements for the relevant docking subsystems. A probe-drogue type mechanism, including mechanical damping; and the docking between rigid interfaces are considered. ESA

N87-24516# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany).
INVESTIGATION FOR DAMPING DESIGN AND RELATED NONLINEAR VIBRATIONS OF SPACECRAFT STRUCTURES Final Report
E. HILBRANDT, I. KOLSCH, and W. CHARON Paris, France ESA Dec. 1985 438 p
(Contract ESTEC-5326/83-NL-PB(SC))
(EMSB-64/85; ESA-CR(P)-2329; ETN-87-99881) Avail: NTIS HC A19/MF A01

The sources of damping in spacecraft structures and substructures, their representation, analytical methods, and test procedures are investigated. Design concepts are developed and are verified on hardware applications. The description of the single damping sources is one of the main problems for the damping prediction method for substructures. The efficiency of the different damping sources differs by orders of magnitude. Damping prediction of substructures by the loss factor analysis method is sensitive to damping source characterization. The damping prediction of the substructures program developed, is written as a data base oriented batch program. A finite element calculation delivers all modal data for the total description of the structure including eigenvalues, eigenmodes, modal stresses, modal strains, and energies on element level. ESA

N87-24517# Systems Engineering Labs., Inc., Greenbelt, Md.
SPECTRAL FACTORIZATION AND HOMOGENIZATION METHODS FOR MODELING AND CONTROL OF FLEXIBLE STRUCTURES Final Report, Sep. 1984 - Sep. 1986
WILLIAM H. BENNETT, G. L. BLANKENSHIP, and H. G. KWATNY 15 Dec. 1986 188 p
(Contract F49620-84-C-0115)
(AD-A179726; SEI-TR-86-14; AFOSR-87-0502TR) Avail: NTIS HC A09/MF A01 CSCL 22B

This report describes continuum modeling and vibration control of flexible structures with application to active control of vibrations in large space structures. A comprehensive methodology is discussed for the construction of effective (linear) models for large composite structures consisting of various flexible members(e.g. beams, trusses, etc.) and rigid body elements. It is convenient to concentrate on frequency domain modeling. A systematic procedure is shown for computing the irrational transfer functions. Then by standard transform methods a complete hybrid model is developed. The methods were coded in a computer algebra system (SMP was used) which automated the model building process and produced Fortran code for numerical evaluation of the frequency responses. Effective continuum models of lattice structures with regular infrastructure can be obtained by a systematic procedure based on an asymptotic analysis of multiple scales called homogenization. This method is applied to several examples and accurate computation made of the required parameters of such continuum models somewhat more subtle than merely averaging over lattice cells. For the computation of distributed parameter control an optimal frequency domain method is based on solving an associated Wiener Hopf problem. The method employs effective numerical algorithms (e.g. FFT, etc.) to compute a certain spectral factorization of a possibly matrix valued (in the multiple control case) Hermittian, positive definite transform by sampling the frequency response. The control laws take the form of distributed state feedback with respect to a naturally defined, distributed state-space of functions over the spatial domain of the structure. GRA

N87-24521*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
DISTRIBUTED CONTROL USING LINEAR MOMENTUM EXCHANGE DEVICES
J. P. SHARKEY, HENRY WAITES, and G. B. DOANE, III (Control Dynamics Co., Huntsville, Ala.) Jun. 1987 50 p
(NASA-TM-100308; NAS 1.15:100308) Avail: NTIS HC A03/MF A01 CSCL 22B

MSFC has successfully employed the use of the Vibrational Control of Space Structures (VCOSS) Linear Momentum Exchange Devices (LMEDs), which was an outgrowth of the Air Force Wright Aeronautical Laboratory (AFWAL) program, in a distributed control experiment. The control experiment was conducted in MSFC's Ground Facility for Large Space Structures Control Verification (GF/LSSCV). The GF/LSSCV's test article was well suited for this experiment in that the LMED could be judiciously placed on the ASTROMAST. The LMED placements were such that vibrational mode information could be extracted from the accelerometers on the LMED. The LMED accelerometer information was processed by the control algorithms so that the LMED masses could be accelerated to produce forces which would dampen the vibrational modes of interest. Experimental results are presented showing the LMED's capabilities. Author

N87-24709*# Edighoffer, Inc., Newport News, Va.
DYNAMIC AND THERMAL RESPONSE FINITE ELEMENT MODELS OF MULTI-BODY SPACE STRUCTURAL CONFIGURATIONS Final Report
HAROLD H. EDIGHOFFER Apr. 1987 156 p
(Contract NAS1-17210)
(NASA-CR-178289; NAS 1.26:178289) Avail: NTIS HC A08/MF A01 CSCL 20K

Presented is structural dynamics modeling of two multibody space structural configurations. The first configuration is a generic space station model of a cylindrical habitation module, two solar array panels, radiator panel, and central connecting tube. The second is a 15-m hoop-column antenna. Discussed is the special joint elimination sequence used for these large finite element models, so that eigenvalues could be extracted. The generic space station model aided test configuration design and analysis/test data correlation. The model consisted of six finite element models, one of each substructure and one of all substructures as a system. Static analysis and tests at the substructure level fine-tuned the finite element models. The 15-m hoop-column antenna is a truss column and structural ring interconnected with tension stabilizing cables. To the cables, pretensioned mesh membrane elements were attached to form four parabolic shaped antennae, one per quadrant. Imposing thermal preloads in the cables and mesh elements produced pretension in the finite element model. Thermal preload variation in the 96 control cables was adjusted to maintain antenna shape within the required tolerance and to give pointing accuracy. Author

N87-24723*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
CHARACTERIZATION AND HARDWARE MODIFICATION OF LINEAR MOMENTUM EXCHANGE DEVICES
GEORGE D. EDGEMON, SALLY CURTIS (Control Dynamics Co., Huntsville, Ala.), and HENRY B. WAITES Mar. 1987 44 p
(NASA-TM-86594; NAS 1.15:86594) Avail: NTIS HC A03/MF A01 CSCL 20K

A sequence of modifications were made on the TRW Linear Momentum Exchange Devices (LMEDs) which were supplied for a joint MSFC/Air Force Wright Aeronautical Laboratory (AFWAL) control venture called Vibrational Control of Space Structures (VCOSS)-II. The modifications were necessary to alleviate and assuage the LMED nonlinearities. Extensive discussion of the LMED modification are presented along with the test plan, test results and conclusions. In addition, a chronology of events, relative to the LMED changes, is given. Author

N87-25350# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
SOME PROBLEMS IN THE CONTROL OF LARGE SPACE STRUCTURES Final Report, 1 Jan. - 30 Jun. 1986
LEONARD MEIROVITCH 16 Dec. 1986 58 p
(Contract AF-AFOSR-0017-83)
(AD-A179989; AFOSR-87-0426TR) Avail: NTIS HC A04/MF A01 CSCL 22B

Work during this period has been concerned with control of traveling waves in structures and developments in the control of distributed structures. In modal control of traveling waves, the question can be raised whether actuator forces at points removed from a given disturbance can begin working before the arrival of the disturbance. This question is prompted by the fact that modal forces begin acting at t = O. However, the modal forces are not the actual forces, although the actual actuator forces are linear combinations of the modal forces. It is demonstrated that these combinations are such that the control forces tend to concentrate in the immediate vicinity of the disturbance and tend to vanish at points removed from the disturbance. One problem in the control of distributed structures is that control implementation must be carried out by discrete actuators. In using direct feedback, whereby the sensors and actuators are collocated and the actuator input depends only on the sensor output at the same location, asymptotic stability can be virtually guaranteed. Problems arise when one desires to place the closed-loop poles. It appears that there is some incompatibility between direct feedback and pole placement. In particular, in placing the poles for a number of controlled modes, the possibility of destabilizing uncontrolled modes exists. GRA

N87-25352# Army Military Personnel Center, Alexandria, Va.
SUBOPTIMAL CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES EXPERIENCING ROTATIONAL DYNAMICS NONLINEARITIES Final Report
GEORGE D. MITROKA 8 May 1987 102 p
(AD-A180606) Avail: NTIS HC A06/MF A01 CSCL 22B

Developed is a method to determine a suboptimal smooth trajectory for large flexible space structures during rotational slewing maneuvers. It consists of minimizing the quadratic integral of the corresponding second time derivative of the generalized coordinate subject to specified boundary conditions. A parametric study examined the consequences of varying the number of design parameters and the number of specified boundary conditions. Study results include: (1) Additional degrees of freedom reduce the curvature of the trajectory, reduce the peak maneuver angle rate and only slightly increase the peak rigid-body torques on the structure during slewing maneuvers; (2) Additional boundary conditions result in smoother transitions at the end points between targeting maneuvers and increase the peak maneuver angle rate and rigid-body torques by a larger percentage than do additional design parameters. Next, planar dynamics equations of motion for a uniform, inextensible, cantilevered beam capable of small transverse deformations and which retain the rotational (centrifugal) nonlinearities are derived via Newton's Laws, nondimensionalized and cast into a form suitable for numerical integration. GRA

N87-25355*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
DYNAMICS DURING THRUST MANEUVERS OF FLEXIBLE SPINNING SATELLITES WITH AXIAL AND RADIAL BOOMS
R. W. LONGMAN (Columbia Univ., New York.) and J. V. FEDOR *In* ESA *Proceedings of the Second International Symposium on* Spacecraft Flight Dynamics p 13-18 Dec. 1986
Avail: NTIS HC A22/MF A01 CSCL 22B

The dynamic response to operational maneuvers of spinning symmetric spacecraft with radial and axial booms was analyzed as part of the prelaunch dynamic analysis of the ISEE-3 spacecraft placed in a halo orbit around an Earth-Sun libration point, and later renamed ICE when it was directed to fly-by comet Giacobini-Zinner. The results presented use simple spacecraft models, and frequently give predictions that are good and easily obtained when the results from using a general purpose multibody dynamics program were very time consuming to obtain. Deployment of radial booms, spin-up after partial deployment, stationkeeping, and trajectory changes are analyzed. The latter two can involve both axial thrusting and pulsed radial thrusting once per revolution. ESA

N87-25356# Indian Inst. of Science, Bangalore.
DYNAMICS OF AN ACTIVELY CONTROLLED FLEXIBLE EARTH OBSERVATION SATELLITE
S. K. SHRIVASTAVA, P. S. GOEL (Indian Space Research Organization, Bangalore.), M. SEETHARAMABHAT, and A. G. SREENATHA *In* ESA Proceedings of the Second International Symposium on Spacecraft Flight Dynamics p 19-24 Dec. 1986
Sponsored by the Indian Space Research Organization
Avail: NTIS HC A22/MF A01

Attitude and flexural dynamics of an Earth-oriented satellite with a rigid main body and two large rectangular flexible Sun-tracking solar panels are presented. It is controlled using three reaction wheels operating on PWPFM logic with a modified Schmitt trigger and attitude sensors. The governing equations being highly nonlinear and coupled, numerical solution is resorted to. The system parameters corresponding to those of the Indian Remote Sensing satellite are used for the simulation. After studying the system performance, a modified controller with a 12th order Kalman filter and observer introduced to reduce the effects of the sensor noise and to improve the system characteristics is considered. The effects

of sampling and quantization of the sensor output are also studied. ESA

N87-25357# British Columbia Univ., Vancouver. Dept. of Mechanical Engineering.
A FORMULATION FOR STUDYING STEADY STATE/TRANSIENT DYNAMICS OF A LARGE CLASS OF SPACECRAFT AND ITS APPLICATION
A. M. IBRAHIM and V. J. MODI *In* ESA Proceedings of the Second International Symposium on Spacecraft Flight Dynamics p 25-30 Dec. 1986
(Contract NSERC-G-1547)
Avail: NTIS HC A22/MF A01

A formulation for studying dynamics of a system, consisting of n connected flexible deployable members forming a topological tree or a closed configuration, is presented. The mathematical description of the system can be a combination of discrete and distributed coordinates. Joints, elastic and dissipative, permit relative rotation and translation between bodies. The elastic deformations can be discretized using admissible functions, finite elements, or lumped mass method. Rotations of the members, as well as of the entire system, can be described using a set of orientation angles, Euler parameters or Rodrigues vectors. The formulation accounts for: the presence of momentum or reaction wheels; thrusters distributed over the flexible and rigid portions; and any prescribed forms of energy dissipation mechanisms. The formulation is valid for orbiting as well as ground based and marine systems. Application of the formulation is illustrated through an example in spacecraft dynamics. ESA

N87-25358# Rome Univ. (Italy). Dept. of Informatica e Sistemistica.
SAMPLED NONLINEAR CONTROL FOR LARGE ANGLE MANEUVERS OF FLEXIBLE SPACECRAFT
S. MONACO, D. N. CYROT, and S. STORNELLI (Telespazio, S.p.A., Rome, Italy) *In* ESA Proceedings of the Second International Symposium on Spacecraft Flight Dynamics p 31-38 Dec. 1986 Sponsored by Telespazio S.P.A.
Avail: NTIS HC A22/MF A01

A method for the design of attitude control systems for flexible spacecraft is presented. The design procedure employs input-output linearization and stabilization techniques; computation of the sampled-data control laws, and compensation techniques are applied to reduce the influence of the flexible part on the control system design. An idealized test vehicle subject to a variety of control laws was simulated. The improvements obtained by using a sampled-data scheme with an extended control are evident from the results of the simulations. ESA

N87-25359# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio.
THE EFFECTS OF STRUCTURAL PERTURBATIONS ON DECOUPLED CONTROL
R. A. CALICO and R. L. HINRICHSEN *In* ESA Proceedings of the Second International Symposium on Spacecraft Flight Dynamics p 39-45 Dec. 1986
Avail: NTIS HC A22/MF A01

The effects of structural perturbations on the decoupled control of a large space structure are considered. The structure is controlled through multiple subcontrollers, each of which controls a subset of the spacecraft modes. The stability of the entire system is assured by constraining the gain matrices for the individual subcontrollers such that the stability of the system is not affected by the coupling between the subcontrollers. Structural perturbations reintroduce coupling among the subcontrollers, which may lead to instability. This coupling is shown to be related to changes in the row and column spaces of the individual control and observation matrices, respectively. A simple test for the determination of the effects of these changes is presented. The use of the test is evaluated on the control of the CSDL I spacecraft using three subcontrollers. ESA

N87-25360# Technische Hochschule, Darmstadt (West Germany). Inst. fuer Mechanik II.
ACTIVE VIBRATION DAMPING OF FLEXIBLE STRUCTURES USING THE TRAVELING WAVE APPROACH
P. HAGEDORN and J. T. SCHMIDT *In* ESA Proceedings of the Second International Symposium on Spacecraft Flight Dynamics p 47-52 Dec. 1986 Sponsored by the Stiftung Volkswagenwerk
Avail: NTIS HC A22/MF A01

A traveling wave approach for the vibration control of networks of slender flexible structural components is presented. The performance of the resulting controller is evaluated and compared with a classical modal controller using a simple model of a prestressed string. Both controllers are tested in numerical simulations. The traveling wave approach is demonstrated to have significant advantages. In particular, it is insensitive to a change in system boundary conditions. ESA

N87-25605*# Catholic Univ. of America, Washington, D.C. Dept. of Mechanical Engineering.
A COMPARISON BETWEEN IMSC, PI AND MIMSC METHODS IN CONTROLLING THE VIBRATION OF FLEXIBLE SYSTEMS
A. BAZ and S. POH Aug. 1987 31 p
(Contract NAG5-520; NAG5-749)
(NASA-CR-181156; NAS 1.26:181156) Avail: NTIS HC A03/MF A01 CSCL 20K

A comparative study is presented between three active control algorithms which have proven to be successful in controlling the vibrations of large flexible systems. These algorithms are: the Independent Modal Space Control (IMSC), the Pseudo-inverse (PI), and the Modified Independent Modal Space Control (MIMSC). Emphasis is placed on demonstrating the effectiveness of the MIMSC method in controlling the vibration of large systems with small number of actuators by using an efficient time sharing strategy. Such a strategy favors the MIMSC over the IMSC method, which requires a large number of actuators to control equal number of modes, and also over the PI method which attempts to control large number of modes with smaller number of actuators through the use of an in-exact statistical realization of a modal controller. Numerical examples are presented to illustrate the main features of the three algorithms and the merits of the MIMSC method.
Author

N87-26038*# Howard Univ., Washington, D. C. Dept. of Mechanical Engineering.
MINIMUM TIME ATTITUDE SLEWING MANEUVERS OF A RIGID SPACECRAFT
FEIYUE LI and PETER M. BAINUM 1987 13 p Proposed for presentation at the AIAA 26th Aerospace Sciences Meeting, Reno, Nev., 11-14 Jan. 1988
(Contract NSG-1414)
(NASA-CR-181130; NAS 1.26:181130) Avail: NTIS HC A02/MF A01 CSCL 01C

The problems of large-angle attitude maneuvers of a spacecraft have gained much consideration in recent years. The configurations of the spacecraft considered are: completely rigid, a combination of rigid and flexible parts, or gyrostat-type systems. The performance indices usually include minimum torque integration, power criterion, and frequency-shaped cost functionals. The minimum time slewing problem of a rigid spacecraft was examined. Optimal control theory (Maximum Principal) was applied to the slewing motion of a general rigid spacecraft. Control torque about all three axes was computed. The equations for the system are composed of the Euler dynamical equations in the spacecraft body axes and the quaternion kinematical equation. By introducing the costates for the quaternion and the angular velocity, the Hamiltonian of the system can be formed and the optimal control obtained. Finally the methods are applied to the SCOLE slewing motion. The control variables include three control moments on the Shuttle and two control forces on the reflector. Numerical results are discussed. B.G.

N87-26071*# Carnegie-Mellon Univ., Pittsburgh, Pa.
RESPONSE OF JOINT DOMINATED SPACE STRUCTURES Semiannual Report
May 1987 73 p
(Contract NAG1-612)
(NASA-CR-180564; NAS 1.26:180564) Avail: NTIS HC A04/MF A01 CSCL 22B

An approximate method is developed for estimating the transient response of nonlinear systems in terms of linearized modes of response. Its advantages are that it is computationally more efficient than the time integration method and that it is possible to view the design problem in the more traditional physical terms of modal response. The major drawback of the approximate method is loss of accuracy. It seems that both approximate methods and time integration have their roles in design. Approximate methods provide efficient tools for performing parametric studies and they supply physical insights into how to optimize system performance that are not easily inferred from strictly numerical methods. Time integration provides a method for assessing the accuracy of the approximate solution for key simulations and for fine tuning the final design. In the procedure presented the nonlinear system is approximated by an equivalent linear system in which the system parameters are constant over the range of transient response.
Author

N87-26083*# Smithsonian Astrophysical Observatory, Cambridge, Mass.
ANALYTICAL INVESTIGATION OF THE DYNAMICS OF TETHERED CONSTELLATIONS IN EARTH ORBIT, PHASE 2 Quarterly Report No. 9, 1 Apr. - 30 Jun. 1987
ENRICO C. LORENZINI Jul. 1987 56 p
(Contract NAS8-36606)
(NASA-CR-179149; NAS 1.26:179149) Avail: NTIS HC A04/MF A01 CSCL 22B

A control law was developed to control the elevator during short-distance maneuvers along the tether of a 4-mass tethered system. This control law (called retarded exponential or RE) was analyzed parametrically in order to assess which control parameters provide a good dynamic response and a smooth time history of the acceleration on board the elevator. The short-distance maneuver under investigation consists of a slow crawling of the elevator over the distance of 10 m that represents a typical maneuver for fine tuning the acceleration level on board the elevator. The contribution of aerodynamic and thermal perturbations upon acceleration levels was also evaluated and acceleration levels obtained when such pertubations are taken into account were compared to those obtained by neglecting the thermal and aerodynamic forces. In addition, the preparation of a tether simulation questionnaire is illustrated. Analytic solutions to be compared to numerical cases and simulator test cases are also discussed.
Author

N87-26370*# Iowa Univ., Iowa City. Dept. of Mechanical Engineering.
SHAPE DESIGN SENSITIVITY ANALYSIS AND OPTIMAL DESIGN OF STRUCTURAL SYSTEMS
KYUNG K. CHOI 1987 54 p
(Contract NAG1-215)
(NASA-CR-181095; NAS 1.26:181095) Avail: NTIS HC A04/MF A01 CSCL 20K

The material derivative concept of continuum mechanics and an adjoint variable method of design sensitivity analysis are used to relate variations in structural shape to measures of structural performance. A domain method of shape design sensitivity analysis is used to best utilize the basic character of the finite element method that gives accurate information not on the boundary but in the domain. Implementation of shape design sensitivty analysis using finite element computer codes is discussed. Recent numerical results are used to demonstrate the accuracy obtainable using the method. Result of design sensitivity analysis is used to carry out design optimization of a built-up structure.
Author

N87-26387 Georgia Inst. of Tech., Atlanta.
VIBRATION CONTROL OF FLEXIBLE STRUCTURES USING PIEZOELECTRIC DEVICES AS SENSORS AND ACTUATORS Ph.D. Thesis
MICHAEL WALTER OBAL 1986 266 p
Avail: Univ. Microfilms Order No. DA8707860

The problem of the active control of linear elastic structures using piezoceramic transducers as sensors and actuators was investigated by a combined theoretical and experimental approach. The optimal rate feedback gain distribution of an active structure with multiple collocated sensors and actuators was obtained by using a limited state feedback approach which resulted in an increase in system damping. To model the active structure for the optimal control problem, a finite element model was developed. An active element consisting of a simple beam element with a bonded unimorphic piezoceramic sensors and actuators was obtained. The model incorporates the electromechanical coupling of the transducers, bonding effects and a mathematical model for the feedback signal conditioning circuitry. The resulting discrete degrees of freedom model is in the form of a set of coupled ordinary differential equations which describe the dynamic behavior of the active structure. To obtain the unknown dynamic coupling coefficients that represent the effects of bonding and other parameters of the model accurately, parameter identification methods were used. Modal control was also experimentally demonstrated.
Dissert. Abstr.

N87-26397*# Carnegie Inst. of Tech., Pittsburgh, Pa.
RESPONSE OF JOINT DOMINATED SPACE STRUCTURES Final Report
Aug. 1987 84 p
(Contract NAG1-612)
(NASA-CR-181202; NAS 1.26:181202) Avail: NTIS HC A05/MF A01 CSCL 20K

An efficient linearization method is presented for calculating the transient response of nonlinear systems due to initial disturbances. The method is an extension of the describing function approach in which the steady state response of the system is calculated by representing the nonlinear element, typically joints in the case of space structures, by impedances which are functions of the amplitude of response. Thus, the problem of solving the differential equation for the steady state response becomes one of solving a set of nonlinear algebraic equations involving the steady state amplitudes and phases of the system. It is shown that for the transient case the steady state impedances can be averaged over the range of responses in order to provide equivalent values of stiffness and damping that, for a given set of initial displacements, may be treated as being constant for purposes of calculating system response. Single degree of freedom system are used to demonstrate the method and to develop an approach for optimizing the joint's characteristics so as to minimize transient response times. The use of this method for response estimation and optimization in multiple degree of freedom systems is investigated.
Author

N87-26583*# Old Dominion Univ., Norfolk, Va. Dept. of Mechanical Engineering and Mechanics.
PROJECTION FILTERS FOR MODAL PARAMETER ESTIMATE FOR FLEXIBLE STRUCTURES Progress Report, period ending 31 Dec. 1986
JEN-KUANG HUANG and CHUNG-WEN CHEN Feb. 1987 30 p
(Contract NAG1-655)
(NASA-CR-180303; NAS 1.26:180303) Avail: NTIS HC A03/MF A01 CSCL 12A

Single-mode projection filters are developed for eigensystem parameter estimates from both analytical results and test data. Explicit formulations of these projection filters are derived using the pseudoinverse matrices of the controllability and observability matrices in general use. A global minimum optimization algorithm is developed to update the filter parameters by using interval analysis method. Modal parameters can be attracted and updated in the global sense within a specific region by passing the

experimental data through the projection filters. For illustration of this method, a numerical example is shown by using a one-dimensional global optimization algorithm to estimate model frequencies and dampings. Author

N87-26921 Virginia Polytechnic Inst. and State Univ., Blacksburg.
AN INVESTIGATION OF METHODOLOGY FOR THE CONTROL AND FAILURE IDENTIFICATION OF FLEXIBLE STRUCTURES Ph.D. Thesis
ZEEN CHUL KIM 1986 129 p
Avail: Univ. Microfilms Order No. DA8704683

The characteristics of four methods is examined for the control of flexible structures and the control performances of each method. Various control performance measures, such as control gain magnitude, settling time and overshoot in transient response, actuator phase and gain margins, and stability in the presence of actuator failure are emphasized. In conjunction with the system performance, a systematic approach to the choice of weighting matrices for optimal control is presented. The approach shows a relation between the weighting matrices and the closed loop eigenvalues. The robustness of Independent Modal Space Control (IMSC) is examined. In general, the parameters of the control system are usually approximated, so that the designed controller, based on a postulated model, will not perform on the actual system as expected. It is shown that when the IMSC method is used with collocated sensors and actuators, the modelling errors in the postulated system cannot lead to instability of the closed loop system containing control modes and residual modes. However, in the case of coupled control (MGPP), this property cannot be shown. This points to the robustness of the IMSC method with respect to the modelling errors. Author

N87-26960# Air Force Geophysics Lab., Hanscom AFB, Mass.
AUTOMATIC CHARGE CONTROL SYSTEM FOR GEOSYNCHRONOUS SATELLITES
B. M. SHUMAN, H. A. COHEN, J. HYMAN, R. R. ROBSON, J. SANTORU, and W. S. WILLIAMSON (Hughes Research Labs., Malibu, Calif.) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 17 p May 1987
Avail: NTIS HC A13/MF A01

An autonomous system to detect both absolute and differential spacecraft charging aboard high altitude satellites and to reduce those potentials before hazardous arcing levels are reached is being developed. The principle of safely reducing spacecraft charging levels by the emission of a low energy neutral plasma, effectively shorting the spacecraft and charged dielectric surfaces to the ambient space plasma, was demonstrated. The Charge Control System will utilize a xenon-based plasma source capable of igniting within one second, and capable of emmiting a quasi-neutral plasma containing more than 1 mA of ions. Author

N87-26966# Naval Postgraduate School, Monterey, Calif.
DYNAMIC ANALYSIS OF THE FLEXIBLE BOOM IN THE N-ROSS SATELLITE M.S. Thesis
CHOONG S. KANG Mar. 1987 149 p
(AD-A181488) Avail: NTIS HC A07/MF A01 CSCL 22A

Accurate ocean data is essential for successful fleet operation. The N-ROSS Satellite, which is being developed for this mission, will carry a Low Frequency Microwave Radiometer (LFMR). The LFMR consists of large flexible reflector and boom and spins at 15 r.p.m. The effects of the flexibility of the boom, the spin-up procedure and the structural damping on the pointing error of the LFMR are investigated by performing the dynamic simulation using the Dynamic Simulation Language. Two cases of boom material, aluminum alloy and the graphite/epoxy composite material, are analyzed and the results are compared. The simulation and analysis results are presented in graphical forms. Author (GRA)

N87-27259# Virginia Polytechnic Inst. and State Univ., Blacksburg.
THE EFFECT OF NONLINEARITIES ON FLEXIBLE STRUCTURES Annual Report, 30 Apr. 1986 - 30 Apr. 1987
A. H. NAYFEH and D. T. MOOK 30 Apr. 1987 9 p
(Contract AF-AFOSR-0090-86)
(AD-A181735; AFOSR-87-0712TR) Avail: NTIS HC A02/MF A01 CSCL 20K

Experimental-theoretical studies have been conducted on the influence of nonlinearities on flexible structures in the presence of either an external or a parametric excitation. A single-degree-of-freedom system with quadratic and cubic nonlinearities under the influence of a harmonic parametric excitation was studied using the method of multiple scales and digital-and analog-computer simulations. A global bifurcation diagram was obtained showing the different possible attractors (point, limit cycle, chaotic attractors). For small excitation amplitudes, the perturbation results are in excellent agreement with the digital- and analog-computer simulations. For moderate to large excitation amplitudes, the accuracy of the perturbation solution is questionable and only digital- and analog-computer simulations were used. The results are in full agreement. GRA

N87-27704*# Virginia Univ., Charlottesville. Dept. of Mechanical and Aerospace Engineering.
DIGITAL CONTROL SYSTEM FOR SPACE STRUCTURE DAMPERS Annual Report
J. K. HAVILAND Sep. 1985 96 p
(Contract NAG1-349)
(NASA-CR-181253; NAS 1.26:181253; UVA/528224-MAE86-105)
Avail: NTIS HC A02/MF A01 CSCL 22B

A digital controller was developed using an SKD-51 System Design Kit, which incorporates an 8031 microcontroller. The necessary interfaces were installed in the wire wrap area of the SKD-51 and a pulse width modulator was developed to drive the coil of the actuator. Also, control equations were developed, using floating-point arithmetic. The design of the digital control system is emphasized, and it is shown that, provided certain rules are followed, an adequate design can be achieved. It is recommended that the so-called w-plane design method be used, and that the time elapsed before output of the up-dated coil-force signal be kept as small as possible. However, the cycle time for the controller should be watched carefully, because very small values for this time can lead to digital noise. Author

N87-27705# Technische Hogeschool, Delft (Netherlands). Dept. of Aerospace Engineering.
MAXIMUM LIKELIHOOD PARAMETER IDENTIFICATION OF FLEXIBLE SPACECRAFT Ph.D. Thesis
QI PING CHU 1987 272 p Sponsored by the Chinese Academy of Sciences, and Technische Hogeschool, Delft, The Netherlands
(ETN-87-90235) Avail: NTIS HC A12/MF A01

The finite element method is applied to generate a linear mathematical model of a general flexible spacecraft in arbitrary orbits. Model order is reduced by a quasi-static approximation of the higher frequency characteristic modes. Stochastic models to approximate modeling errors are proposed. The models for parameter estimation are linear dynamical systems with unknown process noise. Algorithms for maximum likelihood parameter estimation which account for correlations between process and measurement noise are developed. Simulated measurements are used to verify the applicability of the maximum likelihood parameter estimation algorithms to the identification of flexible spacecraft. It is demonstrated that for the spacecraft used, all unknown parameters can be estimated from the simulated measurements simultaneously with the time histories of the system model states. ESA

N87-27706# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Space Flight Dynamics Section.
STUDY ON INVESTIGATION OF THE ATTITUDE CONTROL OF LARGE FLEXIBLE SPACECRAFT. PHASE 1, VOLUME 1: TECHNICAL REPORT Final Report
G. HEIMBOLD, comp., TH. LANGE, comp., B. SCHAEFER, R. STAPF, H. ROTH, comp., and G. THIEME, comp. (Dornier-Werke G.m.b.H., Friedrichshafen, West Germany) Paris, France ESA Feb. 1984 220 p
(Contract ESTEC-5310/82-NL-BI)
(ESA-CR(P)-2361-VOL-1; ETN-87-90462) Avail: NTIS HC A10/MF A01

Different techniques of attitude and vibration control were applied to structural dynamic models, representative of large flexible spacecraft. The high order systems are reduced to tractable design models using different order reduction methods. A two staged controller design was applied, including sensor/actuator positioning, low authority control for structural damping augmentation, and superimposed high authority control. Fundamental problems to be studied in a laboratory experiment were derived. A test structure represented by a rectangular flexible plate suspended by wires is proposed. The test procedure envisaged includes an ideal approach with respect to the peripheral hardware, and a realistic test where specific performance limitations can be included. ESA

N87-27707# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Space Flight Dynamics Section.
STUDY ON INVESTIGATION OF THE ATTITUDE CONTROL OF LARGE FLEXIBLE SPACECRAFT. PHASE 2, VOLUME 1: EXECUTIVE SUMMARY Final Report
G. HEIMBOLD, H. HOLZACH, TH. LANGE, comp., B. SCHAEFER, R. STAPF, G. THIEME, and N. DUSKE (Dornier-Werke G.m.b.H., Friedrichshafen, West Germany) Paris, France ESA Mar. 1985 55 p
(Contract ESTEC-5310/82-NL-BI)
(ESA-CR(P)-2361-VOL-1; ETN-87-90463) Avail: NTIS HC A04/MF A01

The hardware, experimental and theoretical modeling of the test element, and development and implementation of the controller software for large flexible spacecraft model simulation are described. Based on a finite element method structural model, confirmed by the experimental results, different sensor and actuator positions are derived. For selected configurations, active vibration and attitude controller design is performed. The feasibility of the approaches is proved by a computer performance simulation. The implementation of control laws is realized by an array processor real time routine. The experiments to be performed are summarized. ESA

N87-27708# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany).
STUDY ON THE INVESTIGATION OF THE ATTITUDE CONTROL OF LARGE FLEXIBLE SPACECRAFT. PHASE 2, VOLUME 2: TECHNICAL REPORT Final Report
Paris, France ESA 1986 267 p
(Contract ESTEC-5310/82-NL-BI)
(ESA-CR(P)-2361-VOL-2; ETN-87-90464) Avail: NTIS HC A12/MF A01

The hardware, experimental and theoretical modeling of the test element, and development and implementation of the controller software for large flexible spacecraft model simulation are described. Based on a finite element method structural model, confirmed by the experimental results, different sensor and actuator positions are derived. For selected configurations, active vibration and attitude controller design is performed. The feasibility of the approaches is proved by a computer performance simulation. The implementation of control laws is realized by an array processor real time routine. The experiments to be performed are summarized. ESA

N87-27709# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Space Flight Dynamics Section.
STUDY ON INVESTIGATION OF THE ATTITUDE CONTROL OF LARGE FLEXIBLE SPACECRAFT, PHASE 3 Final Report
G. HEIMBOLD, TH. LANGE, comp., N. DUSKE, and G. THIEME Paris, France ESA Oct. 1986 207 p
(Contract ESTEC-5310/82-NL-BI)
(ESA-CR(P)-2361-VOL-4; ETN-87-90465) Avail: NTIS HC A10/MF A01

A large flexible spacecraft (LFS) was simulated by a plate suspended from wires. Results revealed constraints, which were not predicted, so the controller was redesigned, to give reduced gain configurations, which the laboratory experience showed feasible. The first test results exhibit considerable discrepancies with respect to the theoretical predictions. A laboratory reference model was developed for theoretical performance prediction. Applying this to the tests using the updated controller design, satisfactory agreement with the test results is achieved. The modeling uncertainty has severe consequences with respect to LFS controller design, where usually the aspect is often considered not to play such an important role. It is concluded that the controller design approaches must be checked and possibly developed to end up at feasible designs for space applications. ESA

N87-27712*# Howard Univ., Washington, D. C. Dept. of Mechanical Engineering.
THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES X, PART 1 Final Report
PETER M. BAINUM, A. S. S. R. REDDY, FEIYUE LI, and CHEICK M. DIARRA Aug. 1987 72 p
(Contract NSG-1414)
(NASA-CR-181287; NAS 1.26:181287) Avail: NTIS HC A04/MF A01 CSCL 22B

The effect of delay in the control system input on the stability of a continuously acting controller which is designed without considering the delay is studied. The stability analysis of a second order plant is studied analytically and verified numerically. For this example it is found that the system becomes unstable for a delay which is equivalent to only 16 percent of its natural period of motion. It is also observed that even a small amount of natural damping in the system can increase the amount of delay that can be tolerated before the onset of instability. The delay problem is formulated in the discrete time domain and an analysis procedure suggested. The maximum principle from optimal control theory is applied to minimize the time required for the slewing of a general rigid spacecraft. The slewing motion need not be restricted to a single axis maneuver. The minimum slewing time is calculated based on a quasi-linearization algorithm for the resulting two point boundary value problem. Numerical examples based on the rigidized in-orbit model of the SCOLE also include the more general reflector line-of-sight slewing maneuvers. Author

N87-28937 California Inst. of Tech., Pasadena.
AN EXPERIMENTAL INVESTIGATION OF VIBRATION SUPPRESSION IN LARGE SPACE STRUCTURES USING POSITIVE POSITION FEEDBACK Ph.D. Thesis
JAMES L. FANSON 1987 204 p
Avail: Univ. Microfilms Order No. DA8710938

A new technique for vibration suppression in Large Space Structures is demonstrated in laboratory experiments on a thin cantilever beam, resulting in substantially reduced dynamic response. This technique, called Positive Position Feedback (PPF), makes use of generalized displacement measurements to accomplish vibration suppression. The concept of a piezoelectric active-member is developed in relation to controlling space-truss type structures. The active-member functions dually as a structural member and a control actuator. Piezoelectric ceramic material is adhered to a thin cantilever beam and simulates the use of an active-member. This space-realizable control scheme makes use of strain measurements, a preferred measurement quantity for vibration suppression, and internal control forces which completely decouple the rigid-body motion from the elastic motion. A simple

necessary and sufficient condition for stability with PPF is presented. This condition is nondynamic and is in general easily satisfied. As a result, PPF is demonstrated to have superior robust stability properties. It is also demonstrated that with PPF, all control and observation spillover is stabilizing. Five experiments are described. Dissert. Abstr.

N87-29004# Telespazio, S.p.A., Rome (Italy).
THERMAL-ELECTRICAL DYNAMICAL SIMULATION OF SPACECRAFT SOLAR ARRAY
M. RETICCIOLI *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 317-326 Nov. 1986
Avail: NTIS HC A21/MF A01

An approach to model, in an electrical analogy, a spacecraft solar array in the space environment during operating life is outlined. Thermal and electrical coupling effects are dynamically taken into account, so that the thermal and electrical behavior during spacecraft transient events can be simulated. The model takes into account other factors affecting the output power, such as illumination, environmental conditions, and seasonal and aging factors. Since the model is defined in terms of equivalent electrical circuits a general purpose circuit simulation program, such as SPICE, can be utilized. Results of simulations are reported. ESA

N87-29893# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Mathematics.
MODELING AND COMPUTATIONAL ALGORITHMS FOR PARAMETER ESTIMATION AND OPTIMAL CONTROL OF AEROELASTIC SYSTEMS AND LARGE FLEXIBLE STRUCTURES Final Report, 30 Sep. 1985 - 30 Sep. 1986
J. A. BURNS and E. M. CLIFF 1 Nov. 1986 5 p
(Contract AF-AFOSR-0287-85)
(AD-A183302; AFOSR-87-0956TR) Avail: NTIS HC A02/MF A01 CSCL 20K

The goal of this research is to develop computational algorithms for identifications and control, especially with application to aeroelastic and viscoelastic systems. The research has emphasized development of Chandresekhar algorithms for optimal control of distributed systems and state models and computational algorithms for aeroelastic control systems. During this period, the investigators developed fast algorithms for the general linear quadratic optimal control problems for functional differential equations using Chandresekhar factorization techniques. The resulting algorithms show improved rates of convergence over Ricatti techniques and for certain large problems is the only algorithms which was shown to converge in practice. Nine publications were produced during this period under this grant, including Factorization and Reduction Methods for Optimal Control of Hereditary Systems and Modeling and Approximation for a Viscoelastic Control Problem. GRA

N87-29898*# Catholic Univ. of America, Washington, D.C. Dept. of Mechanical Engineering.
OPTIMUM SHAPE CONTROL OF FLEXIBLE BEAMS BY PIEZO-ELECTRIC ACTUATORS
A. BAZ and S. POH 1987 35 p
(Contract NAG5-520; NAG5-749)
(NASA-CR-181413; NAS 1.26:181413) Avail: NTIS HC A03/MF A01 CSCL 20K

The utilization of piezoelectric actuators in controlling the static deformation and shape of flexible beams is examined. An optimum design procedure is presented to enable the selection of the optimal location, thickness and excitation voltage of the piezoelectric actuators in a way that would minimize the deflection of the beam to which these actuators are bonded. Numerical examples are presented to illustrate the application of the developed optimization procedure in minimizing structural deformation of beams using ceramic and polymeric piezoelectric actuators bonded to the beams with a typical bonding agent. The obtained results emphasize the importance of the devised rational produce in designing beam-actuator systems with minimal elastic distortions. Author

N87-29899*# George Washington Univ., Washington, D.C. Joint Inst. for Advancement of Flight Sciences.
COMPUTATIONAL PROCEDURES FOR EVALUATING THE SENSITIVITY DERIVATIVES OF VIBRATION FREQUENCIES AND EIGENMODES OF FRAMED STRUCTURES
TIMOTHY L. FETTERMAN and AHMED K. NOOR Washington NASA Oct. 1987 88 p
(Contract NAG1-728)
(NASA-CR-4099; NAS 1.26:4099) Avail: NTIS HC A05/MF A01 CSCL 20K

Computational procedures are presented for evaluating the sensitivity derivatives of the vibration frequencies and eigenmodes of framed structures. Both a displacement and a mixed formulation are used. The two key elements of the computational procedure are: (a) Use of dynamic reduction techniques to substantially reduce the number of degrees of freedom; and (b) Application of iterative techniques to improve the accuracy of the derivatives of the eigenmodes. The two reduction techniques considered are the static condensation and a generalized dynamic reduction technique. Error norms are introduced to assess the accuracy of the eigenvalue and eigenvector derivatives obtained by the reduction techniques. The effectiveness of the methods presented is demonstrated by three numerical examples. Author

06

ELECTRONICS

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

A87-32535
SOLAR CONCENTRATOR SYSTEM FOR EXPERIMENTS IN THE SPACE STATION
YOSHIHIRO NAKAMURA, HISAO AZUMA (National Aerospace Laboratory, Chofu, Japan), KUNIHIKO KAWAKAMI, and TATSUYA HAMAGUCHI (Mitsubishi Electric Corp., Communication Equipment Works, Amagasaki, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1945-1950. refs

The results of a preliminary study of the solar concentrator system (SCS), which will be used for experiments aboard the Space Station, are presented. The SCS, scheduled for launch in 1994 after the Space Station will have been positioned in LEO, is designed to make it possible to conduct experiments in the fields of material science, life science, space technology, and space energy. The features of these experiments are described along with a design study of the SCS elements which will make it possible to perform these experiments, such as the solar flux concentrating device, the primary and secondary reflectors, the shutters, the optical systems, and the solar energy transmitting device. A deployable truss beam and a pointing mechanism will make it possible to place the SCS in a location away from the pressurized module and to orient it toward the sun during one half of each orbit. Design diagrams are included. I.S.

A87-33611*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
INTEGRATED STRUCTURAL ELECTROMAGNETIC OPTIMIZATION OF LARGE SPACE ANTENNA REFLECTORS
S. L. PADULA, H. M. ADELMAN, and M. C. BAILEY (NASA, Langley Research Center, Hampton, VA) IN: Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 508-517. refs
(AIAA PAPER 87-0824)

The requirements for extremely precise and powerful large space antenna reflectors have motivated the development of a

procedure for shape control of the reflector surface. A mathematical optimization procedure has been developed which improves antenna performance while minimizing necessary shape correction effort. In contrast to previous work which proposed controlling the rms distortion error of the surface thereby indirectly improving antenna performance, the current work includes electromagnetic (EM) performance calculations as an integral part of the control procedure. The application of the procedure to a radiometer design with a tetrahedral truss backup structure demonstrates the potential for significant improvement. The results indicate the benefit of including EM performance calculations in procedures for shape control of large space antenna reflectors. Author

A87-34345
SHAPE CONTROL OF THE DIRECTIONAL PATTERN IN A MICROWAVE-BEAM POWER TRANSMISSION CHANNEL [UPRAVLENIE FORMOI DIAGRAMMY NAPRAVLENNOSTI V TRAKTE PEREDACHI ENERGII SVCH-PUCHKOM]
V. A. VANKE, S. K. LESOTA, and A. V. RACHNIKOV Radiotekhnika (ISSN 0033-8486), Jan. 1987, p. 70-73. In Russian.

It is demonstrated that it is possible to control the position of the field-intensity peak in the highly efficient microwave power transmission channel in a satellite solar power system. A channel having a directional pattern with an intensity dip on the beam axis is characterized by a high utilization coefficient (up to 0.58) of the receiving antenna and high levels of transmitted power. High values of channel efficiency (greater than 90 percent) are observed for values of the wave parameter tau greater than 3. B.J.

A87-34460*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
POTENTIAL MODULATION ON THE SCATHA SPACECRAFT
P. D. CRAVEN (NASA, Marshall Space Flight Center, Huntsville, AL), R. C. OLSEN (Alabama, University, Huntsville), J. FENNELL, D. CROLEY (Aerospace Corp., Los Angeles, CA), and T. AGGSON (NASA, Goddard Space Flight Center, Greenbelt, MD) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, Mar.-Apr. 1987, p. 150-157. refs
(Contract F04701-85-C-0086; NAS8-33982)

A small (1-V) modulation of the spacecraft potential is observed on the SCATHA satellite through its effects on the data from four instruments: two particle detectors and two field detectors. It is shown that there is a strong causal link between the modulation of the potential at this 1-V level and a nonuniform distribution of the photoemissive properties of the conducting material on the surface of the satellite. Author

A87-34797
COMMUNICATION MISSIONS FOR GEOSTATIONARY PLATFORMS
TAKASHI IIDA, MASAAKI SHIMADA, SHIGETOSHI YOSHIMOTO, YOSHIAKI SUZUKI, and KAZUHIKO HASHIMOTO (Ministry of Posts and Telecommunications, Radio Research Laboratory, Koganei, Japan) Space Communication and Broadcasting (ISSN 0167-9368), vol. 4, Dec. 1986, p. 425-433. refs

It is estimated that several thousand transponders will be needed in the 36 MHz slot by the year 2000 by the U.S. and Japan, while the GEO position above the U.S. will be congested and the slot above Japan is shared by the Soviets. Additional demands may arise from the development of mobile communications services in Japan and the U.S. A large GEO platform could benefit from the economies of scale by making servicing an economical prospect. The platform could carry 50/40 GHz antennas for personal radio communications, multibeam DBS antennas, a mobile telephone system functioning at 900/800 MHz, a relay station for earth-moon communications, and global data relay system. The limitations and necessary operational parameters of each system are examined. M.S.K.

A87-38643* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE ENVIRONMENTAL EFFECTS ON ADHESIVES FOR THE GALILEO SPACECRAFT
F. L. BOUQUET and T. HASEGAWA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 1101-1110. refs

Requirements for the adhesives used on the Galileo Jovian probe are discussed, and the results of mechanical and radiation experiments for their qualification are presented. The five types of adhesives used for the Wide Field Camera, SXA Antenna, temperature control louvers, and structural bonds all passed the proton and electron tests and the low temperature radiation tests. Possible bond improvements through techniques including gamma ray radiation exposure and ion implantation are also considered. R.R.

A87-43165* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
AN ADVANCED GEOSTATIONARY COMMUNICATIONS PLATFORM
THADDEUS A. HAWKES, WILLIAM CLOPP (RCA, Astro-Space Div., Princeton, NJ), and JACK LEKAN (NASA, Lewis Research Center, Cleveland, OH) IEEE Journal on Selected Areas in Communications (ISSN 0733-8716), vol. SAC-5, May 1987, p. 749-758. refs

A large geostationary communications platform can offer many attractive possibilities for providing lower cost communications. The platform payload concept described in this paper attempts to exploit these possibilities. The use of a combination of spot and wide-area coverage beams accommodates users in both high- and low-density population areas, and provides a good degree of frequency reuse. A standard channel bandwidth, used for most traffic, facilitates interconnectivity among C-, Ku-, and Ka-band users who may all access the platform. Adoption of a 36-MHz channel bandwidth leads to transmission rates that would be easily handled by low-cost terminals providing direct customer premises service. This also lends itself well to a solution using a large number of solid-state power amplifiers operating in all three frequency bands and sharing a common, redundant, conditioned power supply. Author

A87-46281
ON-BOARD K- AND S-BAND MULTI-BEAM ANTENNAS
TAKAO ITANAMI, MASAHIRO MINOMO, and KENJI UENO (Nippon Telegraph and Telephone Public Corp., Radio Communications Networks Laboratories, Musashino, Electrical Communications Laboratories, Review (ISSN 0029-067X), vol. 35, March 1987, p. 159-167. refs

This paper describes the configurations and performances of foldable 1.3 m K- and 3.5 m S-band offset Cassegrain multibeam antenna module on a three axes stabilized bus. This module is accommodated to a limited launch vehicle payload area of 2.2 m in inner diameter and 2.8 m in height. Electrical and structural tests results confirm that manufactured antenna characteristics agree well with the design values and that these antennas are well suited to on-board equipment. Author

A87-46773#
DIELECTRIC DISCHARGES AND ELECTROMAGNETIC DISTURBANCES ON GEOSTATIONARY SATELLITES [DECHARGES DIELECTRIQUES ET PERTURBATIONS ELECTROMAGNETIQUES SUR SATELLITES GEOSTATIONNAIRES]
J. P. MARQUE (ONERA, Chatillon-sous-Bagneux, France) (Colloque sur la Compatibilite Electromagnetique, 4th, Limoges, France, June 23-25, 1987) ONERA, TP, no. 1987-82, 1987, 7 p. In French. refs
(ONERA, TP NO. 1987-82)

Characteristics of the electrostatic discharges occurring on the surfaces of geostationary satellites during periods of magnetic storm activity are discussed, stressing the need for adequate

modeling in order to optimize satellite protective measures. The internal problem of flashover involves the cancelling out of the differential potentials appearing on the surface between the various materials, whereas the external problem of blowoff involves the cancelling out of the potential of the satellite relative to the plasma. The problem of electromagnetic coupling is separated into the external problem of radiation of the discharge and the internal problem of the interaction of this radiation with the wiring, either by direct coupling or across the structure. R.R.

A87-48240
THE STATISTICAL ELECTRON ENVIRONMENT FOR DEFENSE METEOROLOGICAL SATELLITE PROGRAM ECLIPSE CHARGING
H.-C. YEH (Boston College, Chestnut Hill, MA) and M. S. GUSSENHOVEN (USAF, Geophysics Laboratory, Hascom AFB, MA) Journal of Geophysical Research (ISSN 0148-0227), vol. 92, July 1, 1987, p. 7705-7715. refs
(Contract F19628-82-K-0011; F19628-86-C-0029)

The current balance equations and simplifying assumptions used in charging models for spacecraft operating in high-inclination, low-altitude polar orbits are identified. The statistical characteristics of the auroral electron precipitation associated with the 11 DMSP satellite charging events reported by Gussenhoven et al. (1985) are presented, and the observed spectra are classified into four types. The spectra are parametrized, and empirical values of the parameters which can be used for charge modeling are presented. The modeled electron distributions are used to calculate the critical energy and net electron current during the DMSP charging events. The charging current is calculated at the surface of various spacecraft materials. The significance of the results for magnetospheric source populations is considered. C.D.

A87-51713* Maxwell Labs., Inc., San Diego, Calif.
RAM ION SCATTERING CAUSED BY SPACE SHUTTLE V X B INDUCED DIFFERENTIAL CHARGING
I. KATZ and V. A. DAVIS (Maxwell Laboratories, Inc., S-Cubed Div., La Jolla, CA) Journal of Geophysical Research (ISSN 0148-0227), vol. 92, Aug. 1, 1987, p. 8787-8791. refs
(Contract NAS3-23881)

Observations of secondary, high-inclination ions streams have been reported in the literature. The authors of these previous papers attributed the source of the secondary ions to a disturbed region in the plasma about 10 m from the Space Shuttle Orbiter. A new theory has been developed which shows how v x B induced differential charging on the plasma diagnostics package (PDP) can scatter the ram ion flux. Some of these ions are reflected back to the PDP and may be the sorce of the observed ion distributions. The effect is unique to large spacecraft; it occurs only when the magnitude of the induced v x B potentials are much larger than the electron thermal energy and of the order of the ion ram energy. That the ion streams observed at large angles must have been reflected from the PDP surface is demonstrated with three-dimensional sheath and particle trajectory calculations using the low earth orbit version of the NASA Charging Analyzer Program (NASCAP/LEO). Author

A87-53560
POWER PLANTS IN SPACE [KOSMISCHE KRAFTWERKE]
SERGEI GRISHIN Astronautik (ISSN 0004-6221), vol. 24, Apr.-June 1987, p. 45, 46. In German.

Proposals for space conversion of solar energy to electric power for earth use are examined. The history of the basic concepts is traced, and the factors to be weighed when considering the construction and operation of such plants are indicated. For example, a system of 150 10-GW GEO power plants (required to meet global requirements for the year 2000) would require space installations of total mass 5-10 million tonnes (and hence orders of magnitude more propellants and semiconductors than the current or predicted world annual production, as well as significant pollution of the atmosphere by rocket launches). The possible use of lunar or asteroidal material to lower launch requirements is discussed, and it is pointed out that large-scale economic, social, political, and ecological problems must be solved before even the most modest proposals (for LEO power satellites) can be undertaken. T.K.

N87-20339*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
EFFECTS OF SPACE PLASMA DISCHARGE ON THE PERFORMANCE OF LARGE ANTENNA STRUCTURES IN LOW EARTH ORBIT
HANS-JUERGEN C. BLUME Feb. 1987 21 p
(NASA-TM-89118; NAS 1.15:89118) Avail: NTIS HC A02/MF A01 CSCL 20I

The anomalous plasma around spacecrafts in low Earth orbit represents the coma of an artificial comet. The plasma discharge is caused by an energetic disturbance of charged particles which were formerly in a state of equilibrium. The plasma can effect the passive and active radio frequency operation of large space antennas by inducing corona discharge or strong arcing in the antenna feeds. One such large space antenna is the 15-meter hoop column antenna which consists of a mesh membrane material (tricot knitted gold plated wire) reflector and carbon fiber tension cords. The atomic oxygen in the plasma discharge state can force the wire base metal particles through the gold lattice and oxydize the metal particles to build a Schottky-barrier contact at the point where the wires meet. This effect can cause strong deviations in the reflector performance in terms of antenna pattern and losses. Also, the carbon-fiber cords can experience a strength reduction of 30 percent over a 40-hour exposure time. Author

N87-21024# Aerospace Corp., El Segundo, Calif. Space Sciences Lab.
POTENTIAL MODULATIONS ON SCATHA (SPACECRAFT CHARGING AT HIGH ALTITUDE) SPACECRAFT
P. D. CRAVEN, R. C. OLSEN, T. AGGSON, J. F. FENNELL, and D. R. CROLEY, JR. 30 Sep. 1986 36 p
(Contract F04701-85-C-0086)
(AD-A176815; TR-0086(6940-05)-13; SD-TR-86-92) Avail: NTIS HC A03/MF A01 CSCL 04A

A small (1 volt) modulation of the spacecraft potential is observed on the SCATHA satellite through its effects on four instruments, two particle detectors and two field detectors. It is shown that there is a strong causal link between the modulation of the potential at this 1 volt level and a nonuniform distribution of the photoemissive properties of the conducting material on the surface of the satellite. GRA

N87-21661* National Aeronautics and Space Administration. Pasadena Office, Calif.
VARIABLE ENERGY, HIGH FLUX, GROUND-STATE ATOMIC OXYGEN SOURCE Patent
ARA CHUTJIAN, inventor (to NASA) (Jet Propulsion Lab., California Inst. of Tech., Pasadena) and OTTO J. ORIENT, inventor (to NASA) 10 Mar. 1987 12 p Filed 10 Apr. 1986 Supersedes N86-27055 (24 - 17, p 2809)
(NASA-CASE-NPO-16640-1-CU; US-PATENT-4,649,273; US-PATENT-APPL-SN-852468; US-PATENT-CLASS-250-251; US-PATENT-CLASS-250-396-R; US-PATENT-CLASS-250-423-P; US-PATENT-CLASS-376-127) Avail: US Patent and Trademark Office CSCL 20H

A variable energy, high flux atomic oxygen source is described which is comprised of a means for producing a high density beam of molecules which will emit O(-) ions when bombarded with electrons; a means of producing a high current stream of electrons at a low energy level passing through the high density beam of molecules to produce a combined stream of electrons and O(-) ions; means for accelerating the combined stream to a desired energy level; means for producing an intense magnetic field to confine the electrons and O(-) ions; means for directing a multiple pass laser beam through the combined stream to strip off the excess electrons from a plurality of the O(-) ions to produce ground-state O atoms within the combined stream; electrostatic deflection means for deflecting the path of the O(-) ions and the electrons in the combined stream; and, means for stopping the

O(-) ions and the electrons and for allowing only the ground-state O atoms to continue as the source of the atoms of interest. The method and apparatus are also adaptable for producing other ground-state atoms and/or molecules.
Official Gazette of the U.S. Patent and Trademark Office

N87-21987*# Martin Marietta Aerospace, Denver, Colo.
NEAR-FIELD TESTING OF THE 5-METER MODEL OF THE TETRAHEDRAL TRUSS ANTENNA
NEILL KEFAUVER, TOM CENCICH, JIM OSBORN, and J. T. OSMANSKI Aug. 1986 167 p
(Contract NAS1-18016)
(NASA-CR-178147; NAS 1.26:178147; MCR-85-640) Avail: NTIS HC A08/MF A01 CSCL 22B

This report documents the technical results from near-field testing of the General Dynamics 5-meter model of the tetrahedral truss antenna at the Martin Marietta Denver Aerospace facility. A 5-meter square side of the tetrahedral served as the perimeter of the antenna, and a mesh surface and extensive surface contouring cord network was used to create a parabolic aperture shape to within an rms accuracy of 30 mils or better. Pattern measurements were made with offset feed systems radiating at frequencies of 7.73, 11.60, 2.27, and 4.26 (all in GHz). This report discusses the method of collecting the data, system measurement accuracy, the test data compiled, and diagostics and isolation of causes of pattern results. The technique of using near-field phase for measuring surface mechanical tolerances is included. Detailed far field antenna patterns and their implications are provided for all tests conducted. Author

N87-24504*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
HOOP/COLUMN AND TETRAHEDRAL TRUSS ELECTRO-MAGNETIC TESTS
M. C. BAILEY *In its* NASA/DOD Control/Structures Interaction Technology, 1986 p 737-746 Jun. 1987
Avail: NTIS HC A14/MF A01 CSCL 22B

The distortion of antennas was measured with a metric camera system at discrete target locations on the surface. Given are surface distortion for hoop column reflector antennas, for tetrahedral truss reflector antennas, and distortion contours for the tetrahedral truss reflector. Radiation patterns at 2.27-GHz, 4.26-GHz, 7.73-GHz and 11.6-GHz are given for the hoop column antenna. Also given are radiation patterns at 4.26-GHz and 7.73-GHz for the tetrahedral truss antenna. E.R.

N87-25838*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
NUCLEAR REACTOR POWER FOR A SPACE-BASED RADAR. SP-100 PROJECT
HARVEY BLOOMFIELD, JACK HELLER, LEONARD JAFFE, RICHARD BEATTY, PRADEEP BHANDARI, EDWIN CHOW, WILLIAM DEININGER, RICHARD EWELL, TOSHIO FUJITA, MERLIN GROSSMAN et al. 31 Aug. 1986 176 p Prepared in cooperation with JPL, Pasadena, Calif. and Los Alamos National Lab., N. Mex.
(Contract NAS7-918; DE-AI03-86SF-16013)
(NASA-TM-89295; JPL-PUB-86-47; NAS 1.15:89295) Avail: NTIS HC A09/MF A01 CSCL 18I

A space-based radar mission and spacecraft, using a 300 kWe nuclear reactor power system, has been examined, with emphasis on aspects affecting the power system. The radar antenna is a horizontal planar array, 32 X 64 m. The orbit is at 61 deg, 1088 km. The mass of the antenna with support structure is 42,000 kg; of the nuclear reactor power system, 8,300 kg; of the whole spacecraft about 51,000 kg, necessitating multiple launches and orbital assembly. The assembly orbit is at 57 deg, 400 km, high enough to provide the orbital lifetime needed for orbital assembly. The selected scenario uses six Shuttle launches to bring the spacecraft and a Centaur G upper-stage vehicle to assembly orbit. After assembly, the Centaur places the spacecraft in operational orbit, where it is deployed on radio command, the power system started, and the spacecraft becomes operational. Electric propulsion is an alternative and allows deployment in assembly orbit, but introduces a question of nuclear safety. Author

N87-26177*# Alabama Univ., Huntsville. Dept. of Chemistry.
INTERACTION OF HYPERTHERMAL ATOMS ON SURFACES IN ORBIT: THE UNIVERSITY OF ALABAMA EXPERIMENT
J. C. GREGORY *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 29-36 1 Jun. 1987
(Contract NAGW-823; NAGW-812)
Avail: NTIS HC A09/MF A01 CSCL 07D

The University of Alabama experiment which flew on the STS-8 mission had several objectives which were mostly of a speculative nature since so little was known of the processes of interest. The experiment provided original data on: (1) oxidation of metal surfaces; (2) reaction rates of atomic oxygen with carbon and other surfaces and the dependence of these rates on temperature; and (3) the angular distribution of 5 eV atoms scattered off a solid surface. A review of the results is provided. Author

N87-26178*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
O-ATOM DEGRADATION MECHANISMS OF MATERIALS
DANIEL R. COULTER, RANTY H. LIANG, SHIRLEY Y. CHUNG, KERI ODA SMITH, and AMITAVA GUPTA *In its* Proceedings of the NASA Workshop on Atomic Oxygen Effects p 39-46 1 Jun. 1987
Avail: NTIS HC A09/MF A01 CSCL 07D

The low Earth orbit environment is described and the critical issues relating to oxygen atom degradation are discussed. Some analytic techniques for studying the problem and preliminary results on the underlying degradation mechanisms are presented. Author

N87-26179*# National Bureau of Standards, Gaithersburg, Md. Chemical Kinetics Div.
KINETICS AND MECHANISMS OF SOME ATOMIC OXYGEN REACTIONS
R. J. CVETANOVIC *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 47-54 1 Jun. 1987
Avail: NTIS HC A09/MF A01 CSCL 07D

Mechanisms and kinetics of some reactions of the ground state of oxygen atoms, O(3P), are briefly summarized. Attention is given to reactions of oxygen atoms with several different types of organic and inorganic compounds such as alkanes, alkenes, alkynes, aromatics, and some oxygen, nitrogen, halogen and sulfur derivatives of these compounds. References to some recent compilations and critical evaluations of reaction rate constants are given. Author

N87-26949# York Univ., Toronto (Ontario). Dept. of Physics.
SPACECRAFT CHARGING IN THE AURORAL PLASMA: PROGRESS TOWARD UNDERSTANDING THE PHYSICAL EFFECTS INVOLVED
J. G. LAFRAMBOISE and L. W. PARKER (Parker, Lee W., Inc., Concord, Mass) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 16 p May 1987
(Contract F19628-83-K-0028)
Avail: NTIS HC A13/MF A01

The main differences between the plasma environments in geostationary orbit and low polar orbit with respect to high-voltage charging situations are reviewed. Results are presented from a calculation of secondary electron escape currents from negatively charged spacecraft surfaces having various orientations relative to the local magnetic field direction. A simple rough estimate of the required conditions for high-voltage auroral-zone charging is developed. The results suggest that for any given spacecraft, surface potentials are likely to depend more strongly on the ratio of ambient flux of high-energy electrons to that of all ions, than any other environmental parameter. Preliminary results of simulation

work directed toward testing this hypothesis are presented.
Author

N87-26953# Centre d'Etudes et de Recherches, Toulouse (France). Dept. Technologie Spatiale.
ON THE POSSIBILITY OF A SEVERAL-KILOVOLT DIFFERENTIAL CHARGE IN THE DAY SECTOR OF A GEOSYNCHRONOUS ORBIT [SUR LA POSSIBILITE DE CHARGE DIFFERENTIELLE DE PLUSIEURS KILOVOLTS DANS LE SECTEUR JOUR DE L'ORBITE GEOSYNCHRONE]
L. LEVY, D. SARRAIL, J. P. PHILIPPON, J. P. CATANI, and J. M. FOURQUET (MATRA Service Aerodynamique, Toulouse, France) *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 12 p May 1987 In FRENCH
Avail: NTIS HC A13/MF A01

Day-sector charging events detected with the Telecom 1-A satellite were analyzed. The temporal distribution of the events, seasonal variations, and correlations with geomagnetic activity are discussed. In addition, several covering materials were subjected to quasi-monoenergetic electron bombardment in a simulation chamber. It was found that floating metallic surfaces, although small, produced enduring discharges with short rise times. M.G.

N87-26954# ERA Ltd., Leatherhead (England). Applied Physics Dept.
RADIATION CHARGING AND BREAKDOWN OF INSULATORS
D. K. DAVIES *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 7 p May 1987
Avail: NTIS HC A13/MF A01

An experimental investigation of the charge produced by photo-emission from insulators in vacuo is described. It is shown that the emission from materials commonly used in spacecraft construction, such as polyimide, as well described by solid state theory, but that externally applied fields modify both the emission dynamics as well as the eventual saturation charge density. The energetics of the electric breakdown of such charged surfaces is analyzed. Author

N87-26956# Societe Nationale Industrielle Aerospatiale, Cannes (France).
SPACECRAFT PROTECTION AGAINST ELECTROSTATIC DISCHARGE APPLICATION TO THE ARABSAT SPACECRAFT
LAURENT BROIHANNE *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 11 p May 1987
Avail: NTIS HC A13/MF A01

The protections against electrostatic discharge (ESD) phenomena effects which were implemented on the ARABSAT spacecraft are summarized. The origins of ESD phenomena on geostationary spacecraft are recalled. The basic design rules concerning ESD which were applied to ARABSAT are given.
Author

N87-26961# Aerospace Corp., Los Angeles, Calif. Space Sciences Lab.
THICK DIELECTRIC CHARGING ON HIGH ALTITUDE SPACECRAFT
A. L. VAMPOLA *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 7 p May 1987 Previously announced as N87-13480
(Contract F04701-82-C-83)
Avail: NTIS HC A13/MF A01

Thick dielectric charging, in which energetic electrons embed within bulk dielectrics and build up to potentials in excess of the breakdown potential of the dielectric, is shown to be a causitive factor in the anomalous operation of high altitude satellites. Results of laboratory studies are reviewed and a table of maximum expected electron fluxes orbits of various altitudes is presented. The combination of maximum expected electron fluxes and the small energy associated with a bulk dielectric breakdown permits the elimination of bulk charging as a spacecraft problem through the minimum shielding (400 mg/sq cm) of all cables and circuit boards otherwise exposed to the environment, and through the desensitizing of digital logic inputs that are serviced by cables.
Author

N87-28186# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
COMPUTER MODELING OF HIGH-VOLTAGE SOLAR ARRAY EXPERIMENT USING THE NASCAP/LEO (NASA CHARGING ANALYZER PROGRAM/LOW EARTH ORBIT) COMPUTER CODE M.S. Thesis
KARL O. REICHL, JR. Jun. 1987 211 p
(AD-A182589; AFIT/GE/ENG/87J-2) Avail: NTIS HC A10/MF A01 CSCL 10B

The relationship between the Interactions Measurement Payload for Shuttle (IMPS) flight experiment and the low Earth orbit plasma environment is discussed. Two interactions (parasitic current loss and electrostatic discharge on the array) may be detrimental to mission effectiveness. They result from the spacecraft's electrical potentials floating relative to plasma ground to achieve a charge flow equilibrium into the spacecraft. The floating potentials were driven by external biases applied to a solar array module of the Photovoltaic Array Space Power (PASP) experiment aboard the IMPS test pallet. The modeling was performed using the NASA Charging Analyzer Program/Low Earth Orbit (NASCAP/LEO) computer code which calculates the potentials and current collection of high-voltage objects in low Earth orbit. Models are developed by specifying the spacecraft, environment, and orbital parameters. Eight IMPS models were developed by varying the array's bias voltage and altering its orientation relative to its motion. The code modeled a typical low Earth equatorial orbit. NASCAP/LEO calculated a wide variety of possible floating potential and current collection scenarios. These varied directly with both the array bias voltage and with the vehicle's orbital orientation. GRA

N87-28972# 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) *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 95-103 Nov. 1986
Avail: NTIS HC A21/MF A01

A fold out solar array with carbon-frame panel structure and stirrup-fastening peripheral hold-down concept for communication satellites in multiple payload launches was developed. Over 35W/kg end of life is achieved by using BSR 180 micron classic solar cells. Computation shows that the 50W/kg line can be surpassed with 50 micron BSFR solar cells. Modularity and versatility as well as expected performances suggest an extension to domains such as low-orbit missions, space stations, and retractable solar arrays. ESA

N87-28984# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
STOPPING DIFFERENTIAL CHARGING OF SOLAR ARRAYS
H. G. LECHTE *In its* Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 189-193 Nov. 1986
Avail: NTIS HC A21/MF A01

Assuming that the build up of electrostatic charge on solar arrays of geostationary satellites is a contributing factor in reducing the lifetime of insulators, the mechanism of charging the elements of a rigid solar array was analyzed and means to reduce differential charging proposed. These include avoidance of charging the array rear, a better matching of secondary emission yields between both faces of the array, and the provision of an electrical leakage path between cover slips and solar cells to bleed off any charge. It is advised that the design of solar generators for geostationary missions takes seriously into account the build up of electrostatics

and provides for sufficient precautions against resulting stresses, including those from micrometeorites. ESA

07

ADVANCED MATERIALS

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

A87-32058* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
A SPACE DEBRIS SIMULATION FACILITY FOR SPACECRAFT MATERIALS EVALUATION
ROY A. TAYLOR (NASA, Marshall Space Flight Center, Huntsville, AL) SAMPE Quarterly (ISSN 0036-0821), vol. 18, Jan. 1987, p. 28-34. refs

A facility to simulate the effects of space debris striking an orbiting spacecraft is described. This facility was purchased in 1965 to be used as a micrometeoroid simulation facility. Conversion to a Space Debris Simulation Facility began in July 1984 and it was placed in operation in February 1985. The facility consists of a light gas gun with a 12.7-mm launch tube capable of launching 2.5-12.7 mm projectiles with a mass of 4-300 mg and velocities of 2-8 km/sec, and three target tanks of 0.067 m, 0.53 a m and 28.5 a m. Projectile velocity measurements are accomplished via pulsed X-ray, laser diode detectors, and a Hall photographic station. This facility is being used to test development structural configurations and candidate materials for long duration orbital spacecraft. A summary of test results are also described. Author

A87-32060
HIGH INTENSITY 5 EV CW LASER SUSTAINED 0-ATOM EXPOSURE FACILITY FOR MATERIAL DEGRADATION STUDIES
J. B. CROSS, L. H. SPANGLER, M. A. HOFFBAUER, and F. A. ARCHULETA (Los Alamos National Laboratory, NM) SAMPE Quarterly (ISSN 0036-0821), vol. 18, Jan. 1987, p. 41-47. refs

An atomic oxygen exposure facility has been 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 material for use in low earth orbit. The studies that are being undertaken using the facility will provide: (1) absolute reaction cross sections for use in engineering design problems, (2) formulations of reaction mechanisms for use in selection of suitable existing materials and design of new more resistant ones, and (3) calibration of flight hardware (mass spectrometers, etc.) in order to directly relate experiments performed in low earth orbit to ground based investigations. Author

A87-32061* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
SELECTED MATERIALS ISSUES ASSOCIATED WITH SPACE STATION
L. LEGER, J. VISENTINE, and B. SANTOS-MASON (NASA, Johnson Space Center, Houston, TX) SAMPE Quarterly (ISSN 0036-0821), vol. 18, Jan. 1987, p. 48-54. refs

Compatibility of Space Station hardware with the space environment is one of the major materials development issues. The projected long life of the Space Station elements (about 30 years for structural components and 20 years for power systems), the large number of day/night thermal cycles that have to be withstood during the life of the Station, and the effects of atomic oxygen and UV irradiation on exposed surfaces demand new considerations in selection of materials. Reaction efficiencies of materials for Space Station applications derived from LEO experiments are presented together with surface recession predictions for various Space Station components. Developments in the areas of protective coatings and of laboratory facilities for evaluating the effects of atomic oxygen are discussed. I.S.

A87-32342
DEVELOPMENT OF GRAPHITE EPOXY SPACE STRUCTURE
MASANOBU YAMAGUCHI, KATSUHIDE KITAMURA, YOSHIKAZU OJIMA (Ishikawajima-Harima Heavy Industries Co., Ltd., Space Development Div., Tokyo, Japan), and TASUKU YAMAGATA (Ishikawajima-Harima Heavy Industries Co., Ltd., Research Institute, Yokohama, Japan) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 509-514.

This paper describes application of graphite epoxy composites to truss type space structures. The design method of graphite epoxy tube is studied, and influences of the space environment on graphite epoxy composites are discussed. Fiber orientation of unidirectional laminae must be carefully selected in order to prevent transverse cracks from arising. A basic structure of truss type space structure which is 1.5 m long, 0.75 m wide, and 0.75 m high was manufactured. Author

A87-32346
ENHANCEMENT OF SOLAR ABSORPTANCE DEGRADATION DUE TO CONTAMINATION OF SOLAR RADIATOR PANELS IN GEOSYNCHRONOUS ORBIT - CORRELATION OF FLIGHT DATA AND LABORATORY MEASUREMENTS
FRANCOIS LEVADOU, KEITH DERBYSHIRE (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), and ALAIN PAILLOUS (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 1 . Tokyo, AGNE Publishing, Inc., 1986, p. 535-542. refs

The results of contamination/degradation tests and of a preliminary analysis of 2.5 years of operation of the Thermal Housekeeping Package (THP) aboard ECS-1, ESA's telecommunications satellite, are presented. Tests for UV and particle irradiation performed before the launch of ESA's Orbital Test Satellite (OTS), a forerunner of ECS-1, are briefly reviewed, and the irradiation and housekeeping tests undertaken after the OTS degradation analysis are discussed. The analysis of the degradation/contamination of the Optical Surface Reflector (OSR) and the ECS-1 is addressed. An enhancement of solar absorptance degradation due to contamination of OSR was clearly demonstrated by ground tests. C.D.

A87-33100*# Rome Air Development Center, Hanscom AFB, Mass.
SPACECRAFT DIELECTRIC MATERIAL PROPERTIES AND SPACECRAFT CHARGING
A. R. FREDERICKSON, J. A. WALL (USAF, Rome Air Development Center, Bedford, MA), D. B. COTTS (SRI International, Menlo Park, CA), and F. L. BOUQUET (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Research supported by USAF and NASA. New York, American Institute of Aeronautics and Astronautics, Inc. (Progress in Astronautics and Aeronautics. Volume 107), 1986, 89 p. refs

The physics of spacecraft charging is reviewed, and criteria for selecting and testing semiinsulating polymers (SIPs) to avoid charging are discussed and illustrated. Chapters are devoted to the required properties of dielectric materials, the charging process, discharge-pulse phenomena, design for minimum pulse size, design to prevent pulses, conduction in polymers, evaluation of SIPs that might prevent spacecraft charging, and the general response of dielectrics to space radiation. SIPs characterized include polyimides, fluorocarbons, thermoplastic polyesters, poly(alkanes), vinyl polymers and acrylates, polymers containing phthalocyanine, polyacene quinones, coordination polymers containing metal ions, conjugated-backbone polymers, and 'metallic' conducting polymers. Tables summarizing the results of SIP radiation tests (such as those performed for the NASA Galileo Project) are included. T.K.

A87-36279
COMPARISON OF SATELLITE SUPPORT STRUCTURE ALUMINUM VERSUS GRAPHITE EPOXY
JOSEPH G. LOTTA (Hughes Aircraft Co., Space and Communications Group, El Segundo, CA) SAWE, Annual Conference, 45th, Williamsburg, VA, May 12-14, 1986. 18 p.
(SAWE PAPER 1692)

A program is described aimed at achieving minimum-weight hardware for the GOES (Geostationary Operational Environmental Satellite) spacecraft while meeting requirements for load-carrying capability and adequate stiffness, with additional constraints of meeting or surpassing all existing structural and thermal requirements and introducing no redesign of remaining spacecraft elements. The program involved engineering tradeoff and manufacturing development to replace aluminum support structure with graphite/epoxy resin laminates. Manufacturing techniques were developed in-house to lay up a hybrid composite laminate of high-modulus GY-70 and high-strength Celion 3000 and to debulk the layups to eliminate air pockets in a light vacuum bag at room temperature, usually overnight. Proof load tests demonstrated that strength and stiffness requirements were met or improved upon, and a 60 percent weight saving was achieved at a cost of $27,500 per pound saved (slightly more than half the maximum cost allowed per pound saved). D.H.

A87-38587
STANDARDIZED SPACECRAFT MATERIALS OUTGASSING AND SURFACE EFFECTS MEASUREMENTS TESTS
PATRICK M. FALCO, JR. (USAF, Materials Laboratory, Wright-Patterson AFB, OH) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 254-261.

The Air Force Materials Laboratory has two on-going programs designed to provide data to aid in materials outgassing modeling. One program is being performed by Lockheed Missile and Space Company and is entitled 'Material Selection Criteria'. It is designed to provide outgassing kinetics data from a standardized test procedure and apparatus. The other program is co-sponsored by Arnold Engineering and Development Center and is entitled 'Surface Effects of Contamination'. It provides optical effects data of the deposited outgassed materials. These measurements include bi-directional reflectance distribution functions, transmission, change in solar reflectance, and change in a solar cell output measurements. Author

A87-38589* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ELECTRICALLY CONDUCTIVE, BLACK THERMAL CONTROL COATINGS FOR SPACE CRAFT APPLICATION. II - SILICONE MATRIX FORMULATION
V. F. HRIBAR, J. L. BAUER, and T. P. O'DONNELL (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, CA) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 272-286. refs

Five black electrically conductive thermal-control coatings have been formulated and tested for application on the Galileo spacecraft. The coatings consisted of organic and inorganic systems applied on titanium and aluminum surfaces. The coatings were tested under simulated space environment conditions. Coated specimens were subjected to thermal radiation and convective and conductive heating from -196 to 538 C. Mechanical, physical, thermal, electrical, and optical characteristics, formulation, mixing, application, surface preparation of substrates, and a method of determining electrical resistance are presented for the silicone matrix formulation designated as GF-580. Author

A87-38600
JOINT TECHNOLOGY FOR GRAPHITE EPOXY SPACE STRUCTURES
D. M. MAZENKO, G. A. JENSEN, and P. J. MCCORMICK (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 401-413.

Graphite epoxy tubes are commonly used to construct truss assemblies for spacecraft application. The joining of these tubes usually employs metallic end fittings attached to the ends of the tubes. This paper describes tube development, and methods for bonding tubes to aluminum, titanium and silicon carbide/aluminum fittings. Three tube/fitting attachment methods were evaluated: (1) adhesively bonded without fasteners, (2) adhesively bonded with fasteners and (3) attached with fasteners without adhesive. 76 mm (3 in.) diameter tubes constructed of 393 GPa (57 MSI) and 227 GPa (33 MSI) modulus fibers in epoxy prepreg (32 plies) were used to fabricate 305 mm (12 in.) gauge length tensile specimens utilizing the three different end-fitting attachment concepts. The specimens were tested for tensile strength and stiffness in both the as-fabricated condition and after thermal cycling. A combination of adhesive bonding with fasteners produced the highest joint strengths. Author

A87-38615* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THERMAL EXPANSION BEHAVIOR OF GRAPHITE/GLASS AND GRAPHITE/MAGNESIUM
STEPHEN S. TOMPKINS (NASA, Langley Research Center, Hampton, VA), K. E. ARD (Harris Corp., Aerospace Systems Div., Melbourne, FL), and G. RICHARD SHARP (NASA, Lewis Research Center, Cleveland, OH) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 623-637. refs

The thermal expansion behavior of n (+/- 8)s graphite fiber reinforced magnesium laminate and four graphite reinforced glass-matrix laminates (a unidirectional laminate, a quasi-isotropic laminate, a symmetric low angle-ply laminate, and a random chopped-fiber mat laminate) was determined, and was found, in all cases, to not be significantly affected by thermal cycling. Specimens were cycled up to 100 times between -200 F and 100 F, and the thermal expansion coefficients determined for each material as a function of temperature were found to be low. Some dimensional changes as a function of thermal cycling, and some thermal-strain hysteresis, were observed. R.R.

A87-38641* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
DEGRADATION STUDIES OF SMRM TEFLON
RANTY H. LIANG, KERI L. ODA, SHIRLEY Y. CHUNG, and AMITAVA GUPTA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 1050-1055.

Teflon samples returned from the Solar Max Satellite (SMS) suffered noticeable damage such as cracking and yellowing. This is in contrast to teflon exposed aboard STS-5 and STS-8 which showed no detectable changes. Selected teflon tape samples from SMS were studied to evaluate the extent and mechanism of degradation. ESCA studies revealed that these teflon samples contain hydrocarbon segments which were susceptible to oxygen atom degradation. Mechanical measurements also showed bulk property changes as a result of LEO exposure. A molecular model of material and energetic oxygen atom interaction was proposed. SMS data and the importance of developing correlation between accelerated exposure data from STS and ground-based testing and real time data will be presented. Author

A87-38642
STRUCTURE-PROPERTY RELATIONSHIPS IN POLYMER RESISTANCE TO ATOMIC OXYGEN
LARRY P. TORRE and H. GARY PIPPIN (Boeing Aerospace Co., Seattle, WA) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 1086-1100. refs

A theory based on the surface recombination of atomic oxygen is proposed to partially explain the degradation of materials in LEO, with application to the development of space-base materials. Such recombination processes can provide up to 5.07 eV to a chemical bond, and are shown to account for many of the observations of degradation. Previous results show the contribution of bond strengths (of greater than 4.2 eV), fluoridation, and bulky side groups to the resistance of certain polymers to attack by atomic oxygen. R.R.

A87-39426#
EFFECT OF LONG-TERM EXPOSURE TO LEO SPACE ENVIRONMENT ON SPACECRAFT MATERIALS
D. G. ZIMCIK (CDC, Communications Research Centre, Ottawa, Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821), vol. 33, March 1987, p. 4-10. refs

The resistance of some polymeric materials to the LEO environment is evaluated. Long-term exposure data obtained from components and materials from the SMM satellite are compared with data obtained from the Advanced Composite Material Exposure to Space Experiment flown Shuttle mission STS-41G. The Modular Attitude Control System for the SMM satellite, which contains Kapton, Teflon, and Chemglaze Z306, and specimens of Kapton and Chemglaze Z306 from the STS-41G mission are analyzed. It is observed that the reaction rate for surface degradation of Kapton in both experiments correlate well. The changes in the morphology of the silver-backed Teflon second surface mirrors of the SMM satelltie are examined. The absorptance/emittance ratio for Kapton, Teflon, and Chemglaze Z306 are calculated and studied. The data reveal that there are changes in the Kapton and Teflon ratios; however, for the Chemglaze no significant differences in the absorptance/emittance ratio are detected. I.F.

A87-41022
MICROCRACK RESISTANT STRUCTURAL COMPOSITE TUBES FOR SPACE APPLICATIONS
HENRY W. BABEL, TIMOTHY P. SHUMATE, and DANIEL F. THOMPSON (McDonnell Douglas Astronautics Co., Huntington Beach, CA) SAMPE Journal (ISSN 0091-1062), vol. 23, May-June 1987, p. 43-48. refs

A program was initiated and is continuing to evaluate and select carbon fiber/resin combinations which would not microcrack when exposed to the temperature variations encountered in space. Service temperatures were analytically predicted for anodized aluminum and Teflon coatings. Proven MY720/DDS type resins, new toughened resins with high residual compression strength after impact and resins which permit low cost processing were selected for evaluation. A 1000-cycle screening test program from room temperature to -157 C was initiated to evaluate the microcracking resistance of the candidate resins. Selected candidates will be identified for a long term verification test program in which cyclic temperatures expected in space will be used. Three of the material systems tested during 1986 exhibited test induced microcracking. Several of the test specimens that cracked had processing related defects present prior to testing. Additional testing will be conducted during 1987 to determine if the preexisting defects contributed to the observed cracking. Author

A87-41302#
CARBON FIBRE SLOTTED WAVEGUIDE ARRAYS
R. WAGNER (Dornier System GmbH, Friedrichshafen, West Germany) IN: Military microwaves '86; Proceedings of the Conference, Brighton, England, June 24-26, 1986 . Tunbridge Wells, England, Microwave Exhibitions and Publishers, Ltd., 1986, p. 231-236. Research sponsored by the Swedish Space Corp., DFVLR, BMFT, and ESA.

Spaceborne SARs call for antennas of large aperture and high structural performance; attention is accordingly given to the slotted waveguide antenna concept, which yields high aperture efficiency, good beam-shaping, and low losses in conjunction with great compactness and high stiffness. A distinctive technology for the manufacture of such waveguides from metallized carbon fiber-reinforced plastics, as well as for the construction of radiating arrays for such waveguides, is presented. O.C.

A87-43090#
SURFACE EFFECTS OF SATELLITE MATERIAL OUTGASSING PRODUCTS
B. E. WOOD, W. T. BERTRAND, R. J. BRYSON, B. L. SEIBER (Calspan Corp., Arnold Air Force Station, TN), PATRICK M. FALCO (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) et al. AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 11 p. USAF-sponsored research. refs
(AIAA PAPER 87-1583)

A program has been initiated for measuring optical and radiative effects of satellite material outgassing products on thermal-control and cryo-optic surfaces. Two systems were required for making the measurements: (1) an optical properties chamber for measuring the optical properties such as the complex refractive indices (n,k) and bidirectional distribution function (BRDF) of condensed contaminants on cryo-optic surfaces and (2) a solar absorptance chamber for making reflectance/absorptance measurements on contaminated thermal-control materials. This paper describes the operation of the cryogenic system and presents some of the condensed optical property data for condensed contaminants on cryogenic surfaces. Refractive and absorptive index data are presented. Author

A87-43103*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
THE DEFINITION OF THE LOW EARTH ORBITAL ENVIRONMENT AND ITS EFFECT ON THERMAL CONTROL MATERIALS
J. T. DURCANIN, D. R. CHALMERS (RCA Aerospace and Defense, RCA Astro-Space Div., Princeton, NJ), and J. T. VISENTINE (NASA, Johnson Space Center, Houston, TX) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 13 p. refs
(AIAA PAPER 87-1599)

The LEO environment and its effects on thermal-control materials (TCMs) being evaluated for use in long-term-mission space structures such as the Space Station are characterized, summarizing the results of recent space and laboratory experiments. Factors examined include atomic oxygen (a serious problem out to 600-700 km), ionizing radiation, solar UV radiation, solid particles (manmade debris and micrometeoroids, a significant hazard out to about 1000 km), and synergistic effects. Numerical data on the expected intensity of these effects for the different Space Station components, the resistance of specific TCMs to the effects, and the effectiveness of protective coatings are compiled in extensive tables and illustrated with diagrams, graphs, and micrographs. T.K.

A87-44588
PEEK (POLYETHER ETHER KETONE) WITH 30 PERCENT OF CARBON FIBRES FOR INJECTION MOLDING
PAUL HEBRARD and MICHEL PARCELIER (Aerospatiale, Division Systemes Balistiques et Spatiaux, Les Mureaux, France) IN: *High tech - The way into the nineties; Proceedings of the Seventh* International SAMPE Conference, European Chapter, Munich, West Germany, June 10-12, 1986 . Amsterdam and New York, Elsevier Science Publishers, 1986, p. 187-200. refs

Carbon-fiber-reinforced PEEK injected-mold composites have been developed which reduce weight and cost while optimizing mechanical properties and improving the dimensional stability of injection molding conditions. Attention is presently given to the influence of thermal posttreatment of the resin and the effect of its crystallinity on such aspects of long-term behavior as creep and fatigue properties. The method in question is used to produce a prototype nozzle for a deployable antenna mast, and the various difficulties encountered are discussed. O.C.

A87-44741
MATERIALS FOR SPACE APPLICATIONS
M. D. JUDD (ESA, Product Assurance Div., Noordwijk, Netherlands) IN: Materials in aerospace; Proceedings of the *First International Conference, London, England, Apr. 2-4, 1986.* Volume 2 . London, Royal Aeronautical Society, 1986, p. 240-248.

An account is given of aerospace industry performance requirements for materials that are to be subjected to orbital space conditions as constituents of such spacecraft as Columbus and Hermes. The residual oxygen atoms in low earth orbit can drastically degrade a number of otherwise structurally useful polymeric materials; such effects will be felt in combination with high UV ionizing radiation fluxes, vacuum-outgassing conditions, etc. Instances of materials currently being developed to meet space requirements are solar cell and cover glass adhesives with low outgassing properties, conductive and nonconductive thermal control paints with good UV radiation stability, and UV exposure-curing resin systems for inflatable antenna construction. O.C.

A87-47327
EVALUATION OF THE BUILT-IN STRESSES AND RESIDUAL DISTORTIONS ON CURED COMPOSITES FOR SPACE ANTENNA REFLECTORS APPLICATIONS
M. MARCHETTI, S. TIZZI (Roma I, Universita, Rome, Italy), and F. MORGANTI (Selenia Spazio S.p.A., Rome, Italy) Composite Structures (ISSN 0263-8223), vol. 7, no. 4, 1987, p. 267-283. Research supported by the Ministero della Pubblica Istruzione. refs

Manufacturing and thermal distortion RMS is an important dimensional parameter which can be correlated with the antenna performances. For this reason it is used to characterize their allowed dimensional stability in order to guarantee the mission requirements. The antenna reflectors on board of space platforms are generally manufactured with composite materials. The RMS of these structures is very tightly connected with the technologies like curing cycles, kind of materials, lay up tipology, mould configuration etc. The maximum effort is produced to minimize this parameter due to the manufacturing, while the prediction methods able to correlate the residual distortions versus the applied technology can be very useful to optimize the hardware performances. Author

A87-51772
DEVELOPMENT OF METAL MATRIX COMPOSITES IN R & D INSTITUTE OF METALS & COMPOSITES FOR FUTURE INDUSTRIES
YOSHIO MINODA (Research and Development Institut of Metals *and Composites for Future Industries, Tokyo, Japan)* IN: Composites '86: Recent advances in Japan and the United States; Proceedings of the Third Japan-U.S. Conference on Composite Materials, Tokyo, Japan, June 23-25, 1986 . Tokyo, Japan Society for Composite Materials, 1986, p. 475-481. refs

The latest status of a research and development program to develop basic industrial technology for metal matrix composites suitable for aerospace structures in the 1990's is discussed. Findings to date and remaining problems in the three parts of the program are summarized, including the development of graphite/Al and SiC (Nicalon)/Al preformed wires, the development of primary forming technology for them, and related structural or quality evaluation technologies necessary for application to end items. It has been found that both aluminum-infiltrated graphite and SiC (Nicalon) yarn seem to be very useful intermediate material for producing metal matrix composites. Titanium matrix composites show superior mechanical properties compared to aluminum matrix composites. C.D.

A87-51794
TAYLORED LAMINATES WITH NULL OR ARBITRARY COEFFICIENT OF THERMAL EXPANSION
TAKASHI ISHIKAWA and HISAO FUKUNAGA (National Aerospace Laboratory, Chofu, Japan) IN: Composites '86: Recent advances in Japan and the United States; Proceedings of the Third Japan-U.S. Conference on Composite Materials, Tokyo, Japan, June 23-25, 1986 . Tokyo, Japan Society for Composite Materials, 1986, p. 701-708. refs

A lamination tayloring theory is proposed in order to control the coefficient of thermal expansion of graphite/epoxy composites in a principal direction. This technique consists of the concepts of thermoelastic invariants and lamination parameters. The expansion-free condition yields to a parabola in the feasible region of the lamination parameters. The calculated curves for a wide range of temperature intersect almost at a point. A laminate with the lay-up construction corresponding to this point will exhibit an approximately null coefficient in one direction in that temperature range. Some preliminary experimental results indicate that the present procedure is possible and promising. The taylored material will be appropriate for the Space Station. Author

A87-53888
HIGH-TEMPERATURE POLYMERS FOR ADHESIVE AND COMPOSITE APPLICATIONS
S. J. SHAW (Royal Armament Research and Development Establishment, Waltham Abbey, England) Materials Science and Technology (ISSN 0267-0836), vol. 3, Aug. 1987, p. 589-599. refs

The aerospace industry is currently making extensive use of both structural adhesives and composite materials in aircraft and space vehicle construction. Within the past decade, there has been a growing requirement for adhesives and composites capable of withstanding temperatures in excess of 150 C for both short- and long-term applications. Substantial efforts have been made to develop high-temperature resistant polymers having considerably improved processing characteristics. In this paper, a critical assessment is given of the use of high-temperature polymers in both adhesive and composite applications with particular emphasis on some of the newer, more easily processed types which are, or will probably be, commercially acceptable. Author

A87-53946
TESTING OF MATERIALS FOR SOLAR POWER SPACE APPLICATIONS
BRUCE J. FARADAY, RICHARD L. STATLER, and DELORES H. WALKER (U.S. Navy, Naval Research Laboratory, Washington, DC) Solar Energy Materials (ISSN 0165-1633), vol. 15, July 1987, p. 313-336. refs

This paper summarizes the results of a program initiated at the Naval Research Laboratory to test conventional and state-of-the-art solar power space systems by flying them aboard satellites. The program confirmed the practicality of improvements in advanced Si solar cells such as textured surfaces, shallow *junctions, back surface field, and back surface reflector techniques.* The performance of GaAlAs solar cells was demonstrated to be satisfactory. Finally, advanced Si cells such as Li-diffused and vertical junction cells were found unsuitable for extended space application. Author

N87-20374# Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.
DEVELOPMENT OF PRECISION STRUCTURAL JOINTS FOR LARGE SPACE STRUCTURES
HAROLD C. CROOP and ANDREW R. ROBERTSON (General Dynamics Corp., San Diego, Calif.) *In* AGARD Mechanical Qualification of Large Flexible Spacecraft Structures 7 p Jul. 1986
Avail: NTIS HC A12/MF A01

Many anticipated future space systems will employ deployable structural assemblies to meet the packaging constraints of the Space transporatation System. Recent developments in deployable structures are described relative to the use of advanced composite materials in the joint designs of such systems. Specific design requirements of interest are dimensional stability, zero free play, minimum weight, and thermal/electrical conductivity through the joints. Several design approaches are presented, along with results of material characterization tests. Author

N87-23678# TRW Space Technology Labs., Redondo Beach, Calif. System Integration Lab.
SPACECRAFT ENVIRONMENT INTERACTION INVESTIGATION Final Report, Oct. 1983 - Sep. 1986
N. J. STEVENS and MARC E. KIRKPATRICK Oct. 1986 175 p (Contract F19628-84-C-0038)
(AD-A179183; TRW-43543-6011-UE-00; AFGL-TR-86-0214)
Avail: NTIS HC A08/MF A01 CSCL 22B

This report summarizes the results of the spacecraft environment interaction investigation. The objectives of this investigation were to characterize environmental interaction technology and to determine the adequacy of present military standards and handbooks for future, large AF missions. The characterization of the technology status was accomplished by literature searches and key-expert questionnaires. The determination of military standard adequacy was accomplished by considering interactions with five concepts synthesized from those available in the MSSTP. Based on these concepts studies, critical interactions were identified. The available military documentation was searched for applicability. A recommended document development plan was prepared along with a discussion of technology gaps. GRA

N87-23736* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
OXIDATION PROTECTION COATINGS FOR POLYMERS Patent
JAMES S. SOVEY, inventor (to NASA), BRUCE A. BANKS, inventor (to NASA), and MICHAEL J. MIRTICH, inventor (to NASA) 12 May 1987 7 p Filed 27 Feb. 1986 Supersedes N86-26434 (24 - 17, p 2709) Division of US-Patent-4,604,181, Patent-Appl-SN-761235, which is a division of US-Patent-4,560,577, US-Patent-Appl-SN-649330
(NASA-CASE-LEW-14072-3; US-PATENT-4,664,980; US-PATENT-APPL-SN-834977; US-PATENT-CLASS-428-421; US-PATENT-CLASS-428-422; US-PATENT-CLASS-428-447; US-PATENT-CLASS-428-473.5; US-PATENT-CLASS-428-702)
Avail: US Patent and Trademark Office CSCL 11B

A polymeric substrate is coated with a metal oxide film to provide oxidation protection in low Earth orbital environments. The film contains about four volume percent polymer to provide flexibility. NASA

N87-25430# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
FIBER COMPOSITES IN SATELLITES
ARMIN SCHEDLER 28 Jul. 1986 16 p Presented at the Conference on ICMC Nonmetallic Materials and Composites at Low Temperatures 4, Heidelberg, West Germany, 28-29 Jul. 1986 (MBB-UD-492/86; ETN-87-99932) Avail: Issuing Activity

The advantages of the low specific weight, high strength, and adjustable values of stiffness, thermal expansion, and thermal conductivity of fiber composites for spacecraft construction are reviewed. Utilizations between 4 and 450K are illustrated. ESA

N87-25480*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
AN EVALUATION OF CANDIDATE OXIDATION RESISTANT MATERIALS FOR SPACE APPLICATIONS IN LEO
SHARON RUTLEDGE, BRUCE BANKS, FRANK DIFILIPPO, JOYCE BRADY, THERESE DEVER, and DEBORAH HOTES (Cleveland State Univ., Ohio.) 1986 16 p Presented at the Workshop on Atomic Oxygen Effects, Pasadena, Calif., 10-11 Nov. 1986; sponsored by JPL
(NASA-TM-100122; E-3669; NAS 1.15:100122) Avail: NTIS HC A02/MF A01 CSCL 11C

Ground based testing of materials considered for polyimide (Kapton) solar array blanket protection and graphite-epoxy structural member protection was performed in an RF plasma asher. Protective coatings on Kapton from various commercial sources and from NASA Lewis Research Center were exposed to the air plasma; and mass loss per unit area was measured for each sample. All samples evaluated provided some protection to the underlying surface, but metal-oxide-fluoropolymer coatings *provided the best protection by exhibiting very little degradation* after 47 hr of asher exposure. Mica paint was evaluated as a protective coating for graphite-epoxy structural members. Mica appeared to be resistant to attack by atomic oxygen, but only offered limited protection as a paint. this is believed to be due to the paint vehicle ashing underneath the mica leaving unattached mica flakes lying on the surface. The protective coatings on Kapton evaluated so far are promising but further research on protection of graphite-epoxy support structures is needed. Author

N87-26175*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
MATERIAL INTERACTIONS WITH THE LOW EARTH ORBITAL (LEO) ENVIRONMENT: ACCURATE REACTION RATE MEASUREMENTS
JAMES T. VISENTINE and LUBERT J. LEGER *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 11-20 1 Jun. 1987
Avail: NTIS HC A09/MF A01 CSCL 07D

To resolve uncertainties in estimated LEO atomic oxygen fluence and provide reaction product composition data for comparison to data obtained in ground-based simulation laboratories, a flight experiment has been proposed for the space

shuttle which utilizes an ion-neutral mass spectrometer to obtain in-situ ambient density measurements and identify reaction products from modeled polymers exposed to the atomic oxygen environment. An overview of this experiment is presented and the methodology of calibrating the flight mass spectrometer in a neutral beam facility prior to its use on the space shuttle is established. The experiment, designated EOIM-3 (Evaluation of Oxygen Interactions with Materials, third series), will provide a reliable materials interaction data base for future spacecraft design and will furnish insight into the basic chemical mechanisms leading to atomic oxygen interactions with surfaces. M.G.

N87-26186*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

HIGH INTENSITY 5 EV ATOMIC OXYGEN SOURCE AND LOW EARTH ORBIT (LEO) SIMULATION FACILITY

J. B. CROSS, L. H. SPANGLER, M. A. HOFFBAUER, F. A. ARCHULETA (Los Alamos National Lab., N. Mex.), LUBERT LEGER, and JAMES VISENTINE *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 105-117 1 Jun. 1987

Avail: NTIS HC A09/MF A01 CSCL 07D

An atomic oxygen exposure facility has been 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 LEO. The studies that are being undertaken using the facility will provide: absolute reaction cross sections for use in engineering design problems; formulations of reaction mechanisms; and calibration of flight hardware (mass spectrometers, etc.) in order to directly relate experiments performed in LEO to ground based investigations. The facility consists of: (1) a CW laser sustained discharge source of O atoms having a variable energy up to 5 eV and an intensity between 10(15) and 10(17) O atoms s(-1) cm(-2); (2) an atomic beam formation and diagnostics system consisting of various stages of differential pumping, a mass spectrometer detector, and a time of flight analyzer; (3) a spinning rotor viscometer for absolute O atom flux measurements; and (4) provision for using the system for calibration of actual flight instruments. Surface analysis equipment is available for the characterization of material surfaces before and after exposure to O atoms. Author

N87-26192*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.

AN ELECTRICALLY CONDUCTIVE THERMAL CONTROL SURFACE FOR SPACECRAFT ENCOUNTERING LOW-EARTH ORBIT (LEO) ATOMIC OXYGEN INDIUM TIN OXIDE-COATED THERMAL BLANKETS Abstract Only

J. L. BAUER *In its* Proceedings of the NASA Workshop on Atomic Oxygen Effects p 156 1 Jun. 1987

Avail: NTIS HC A09/MF A01 CSCL 22B

An organic black thermal blanket material was coated with indium tin oxide (ITO) to prevent blanket degradation in the low Earth orbit (LEO) atomic oxygen environment. The blankets were designed for the Galileo spacecraft. Galileo was initially intended for space shuttle launch and would, therefore, have been exposed to atomic oxygen in LEO for between 10 and 25 hours. Two processes for depositing ITO are described. Thermooptical, electrical, and chemical properties of the ITO film are presented as a function of the deposition process. Results of exposure of the ITO film to atomic oxygen (from a shuttle flight) and radiation exposure (simulated Jovian environment) are also presented. It is shown that the ITO-protected thermal blankets would resist the anticipated LEO oxygen and Jovian radiation yet provide adequate thermooptical and electrical resistance. Reference is made to the ESA Ulysses spacecraft, which also used ITO protection on thermal control surfaces. Author

N87-26200*# Princeton Univ., N. J. Plasma Physics Lab.

GROUNDBASED STUDIES OF SPACECRAFT GLOW AND EROSION CAUSED BY IMPACT OF OXYGEN AND NITROGEN BEAMS Abstract Only

W. D. LANGER, S. A. COHEN, D. M. MANOS, R. W. MOTLEY, and S. F. PAUL *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 164 1 Jun. 1987 (Contract NAG8-521)

Avail: NTIS HC A09/MF A01 CSCL 22B

To simulate surface reactions in the space environment a ground-based facility was developed that produces a very high flux 10(14) to 10(16)/sq cm/s of low energy (2 to 20 eV) neutral atoms and molecules. The neutral beams are created using a method involving neutralization and reflection of ions from a biased limiter, where the ions are extracted from a toroidal plasma source. The spectra of emission due to beam-solid interactions on targets of Chemglaze Z-306 optical paint and Kapton are presented. Erosion yields for carbon and Kapton targets with low energy (approx. 10 eV) nitrogen and oxygen beams were measured. The reaction rates and surface morphology for the erosion of Kapton are similar to those measured in experiments on STS-5. Author

N87-26202*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.

NASA MARSHALL SPACE FLIGHT CENTER ATOMIC OXYGEN INVESTIGATIONS Abstract Only

In Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 166 1 Jun. 1987

Avail: NTIS HC A09/MF A01 CSCL 07D

An overview of the MSFC atomic oxygen investigations is provided, including descriptions of flight studies, ground-based testing, contractual efforts, and future focus. Summary results of flight experiments on STS-5, STS-8, and STS 41-G are presented. The development of the MSFC Atomic Oxygen Resistive Monitor for the upcoming EOIM-3 (Evaluation of Oxygen Interaction with Materials 3) flight experiment is reviewed. Materials characterization work and ground-based testing are described. Contractual efforts, such as the development of atomic oxygen resistant coatings for the space station, are discussed. Future emphasis is placed on ground-based testing via the development and operation of a state-of-the-art atomic oxygen simulation system and on the continuation of flight studies in support of multi-programs.

Author

N87-26203*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

AN EVALUATION OF CANDIDATE OXIDATION RESISTANT MATERIALS Abstract Only

SHARON RUTLEDGE, BRUCE BANKS, MICHAEL MIRTICH, FRANK DIFILIPPO, DEBORAH HOTES, RICHARD LABED, TERESE DEVER, and MICHAEL KUSSMAUL (Cleveland State Univ., Ohio.) *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 167 1 Jun. 1987

Avail: NTIS HC A09/MF A01 CSCL 07D

Ground based testing of materials considered for Kapton solar array blanket protection, graphite epoxy structural member protection, and high temperature radiators was performed in an RF plasma asher. Ashing rates for Kapton were correlated with rates measured on STS-8 to determine the exposure time equivalent to one year in low Earth orbit (LEO) at a constant density space station orbital flux. Protective coatings on Kapton from Tekmat, Andus Corporation, and LeRC were evaluated in the plasma asher and mass loss rates per unit area were measured for each sample. All samples evaluated provided some protection to the underlying surface but ion beam sputter deposited samples of SiO2 and SiO2 with 8% polytetrafluoroethylene (PTFE) showed no evidence of degradation after 47 hours of exposure. Mica paint was evaluated as a protective coating for graphite epoxy structural members. Mica appears to be resistant to attack by atomic oxygen but only offers some limited protection as a paint because the paint vehicles evaluated to date were not resistant to atomic oxygen. Four materials were selected for evaluation as candidate radiator materials: stainless steel, copper, niobium-1% zirconium,

and titanium-6% aluminum-4% vanadium. These materials were surface textured by various means to improve their emittance. Emittances as high as 0.93 at 2.5 microns for stainless steel and 0.89 at 2.5 microns for Nb-1 Zr were obtained from surface texturing. There were no significant changes in emittance after asher exposure. Author

N87-26206*# Boeing Aerospace Co., Seattle, Wash.
COMMENTS ON THE INTERACTION OF MATERIALS WITH ATOMIC OXYGEN Abstract Only
LARRY P. TORRE and H. GARY PIPPIN *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 170 1 Jun. 1987
Avail: NTIS HC A09/MF A01 CSCL 07D

An explanation of the relative resistance of various materials to attack by atomic oxygen is presented. Data from both ground based and on-orbit experiments is interpreted. The results indicate the importance of bond strengths, size and structure of pendant groups, and fluorination to the resistance of certain polymers to atomic oxygen. A theory which provides a partial explanation of the degradation of materials in low Earth orbit due to surface recombination of oxygen atoms is also included. Finally, a section commenting on mechanisms of material degradation is provided. Author

N87-26207*# Communications Research Centre, Ottawa (Ontario).
EFFECT OF LONG-TERM EXPOSURE TO LOW EARTH ORBIT (LEO) SPACE ENVIRONMENT
D. G. ZIMCIK *In* Jet Propulsion Lab., Proceedings of the NASA Workshop on Atomic Oxygen Effects p 171 1 Jun. 1987
Avail: NTIS HC A09/MF A01 CSCL 07D

Data obtained from components and materials from the Solar Maximum Mission satellite are presented and compared to data for similar materials obtained from the Advanced Composite Materials Exposure to Space Experiment (ACOMEX) flown on Shuttle mission STS-41G. In addition to evaluation of surface erosion and mass loss that may be of importance to very long-term missions, comparisons of solar absorptance and thermal emittance measurements for both long and short term exposures were made. Although the ratio of absorptance over emittance can be altered by proper choice of materials to ensure a proper operating environment for the spacecraft, once the thermal design is established, it is important that the material properties not change in order to maintain the operating environment for many payload and bus items such as electronics, batteries, fuel, etc. However, data presented show significant changes after short exposure in low Earth environment. Moreover, the measured changes are shown to differ according to the manner of exposure, i.e., normal or oblique, which also affects the resultant eroded surface morphology. These results identify constraints to be considered in development of flight experiments or laboratory testing. Author

N87-26929# Aerodyne Products Corp., Billerica, Mass.
HYPERVELOCITY OXYGEN SOURCE FOR THE STUDY OF ATOM-SURFACE INTERACTIONS Final Report
ANDREW FREEDMAN and WILLIAM UNKEL Apr. 1987 62 p
(Contract F49620-86-C-0091)
(AD-A181618; ARI-RR-588; AFOSR-87-0661TR) Avail: NTIS HC A04/MF A01 CSCL 07D

Space-based facilities face an unexpectedly hostile environment at orbital altitudes due to chemical interaction with atomic oxygen at high velocities (typically 8 km/s). Shuttle-based experiments indicate substantial degradation and erosion of various materials which face into the atmospheric wind. This document reports the efforts of a project intended to design a high velocity, high flux atomic oxygen beam source capable of simulating the space environment. Also included are plans for a vacuum apparatus which will provide for the diagnostic techniques needed to evaluate the source peformances as well as allow for materials testing. The oxygen atom beam source is based on the concept of admixing a small quantity of molecular oxygen into a gas stream of helium that had been electric discharge heated using a commercially available plasma touch. Extensive modeling has suggested improvements in a previous version of the source that should allow production of 8 km/s beams with atomic oxygen fluxes of 1 x 10 to the 17th power/cm sq/s at 10 cm distance from the source aperture. GRA

N87-26959# Atomic Energy Research Establishment, Harwell (England).
SURFACE MODIFICATION TO MINIMISE THE ELECTROSTATIC CHARGING OF KAPTON IN THE SPACE ENVIRONMENT
D. VERDIN and M. J. DUCK *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 12 p May 1987 Sponsored in part by the Royal Aircraft Establishment, Farnborough, England
Avail: NTIS HC A13/MF A01

The electrostatic charging of Kapton under electron irradiation is reduced by coating it with a dispersion of indium oxide in a soluble polyimide. The proportion of oxide in the coating and its thickness are chosen to give an optimum balance between the surface resistivity and the thermo-optical properties of the film. Author

N87-27809# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Chemistry.
AROMATIC POLYESTER POLYSILOXANE BLOCK COPOLYMERS: MULTIPHASE TRANSPARENT DAMPING MATERIALS Final Report, 1 May 1984 - 30 Apr. 1985
JAMES E. MCGRATH 2 Oct. 1986 341 p
(Contract AF-AFOSR-0201-83)
(AD-A182623; AFOSR-87-0176TR) Avail: NTIS HC A15/MF A01 CSCL 11I

The synthesis and characterization of multiphase, transparent block copolymers that are potential candidates for passive damping applications in large space structures are described. Relatively high molecular weight polysiloxane-polyarylester block copolymers were prepared by two different synthetic routes. A solution technique was used to synthesize well-defined, perfectly alternating block copolymers by reacting a disfunctional hydroxyl-terminated polyarylester obligomer. A second approach involved the preparation of a segmented (or random) block copolymer by an interfacial, phase-transfer technique in which various polyarylester block lengths are formed during the copolymerization by reacting bisphenol-A, terephthaloyl chloride, and isophthaloyl chloride with a disfunctional aminopropyl-terminated siloxane block compositions (dimethyl, dimethyl-diphenyl, or dimethyl-trifluoro propylmethyl) were controlled. New siloxane-ester block copolymers were prepared and characterized. They are believed to be potentially useful materials for passive damping applications in the space environment. GRA

N87-28574# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands).
MATERIALS AND PROCEDURES FOR SPACE TECHNOLOGY: THE ESTEC APPROACH [MATERIAUX ET PROCEDES POUR LA TECHNOLOGIE SPATIALE: L'APPROCHE DE L'ESTEC]
J. DAUPHIN and W. R. BURKE, ed. Feb. 1987 11 p In FRENCH
(ESA-STM-237; ISSN-0379-4075; ETN-87-90481) Avail: NTIS HC A02/MF A01

The procurement policy of ESA for space materials is outlined. The policy is based on the use of commercial materials and extensive testing. ESA

N87-28980# Centre d'Etudes et de Recherches, Toulouse (France). Dept. Technologie Spatiale.
MARECS AND ECS ANOMALIES: ATTEMPT AT INSULATION DEFECT PRODUCTION IN KAPTON
L. LEVY, R. REULET, D. SARRAIL, J. M. SIGUIER, and H. LECHTE (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 161-169 Nov. 1986
Avail: NTIS HC A21/MF A01

Experiments were conducted on solar array samples to reproduce the short circuits assumed to be responsible for the ECS and MARECS in-orbit power losses. Discharges were produced between the interconnects and the cover-slides according to the inverted gradient voltage concept in presence of the solar array voltage. The theory that such low voltages could maintain an arc, leading to a permanent short circuit, burning away the Kapton, provided the discharge be triggered by a higher voltage was assessed. It was not possible to produce any permanent insulation defect through the insulation Kapton layer. The discharges by themselves are clearly not sufficient to produce the failure. ESA

N87-28981# Fraunhofer-Inst. fuer Kurzzeitdynamik, Weil am Rhein (West Germany).
MICROMETEORITE IMPACT ON SOLAR PANELS
E. SCHNEIDER *In* ESA Proceedings on the Fifth European Symposium on Photovoltaic Generators in Space p 171-174 Nov. 1986
Avail: NTIS HC A21/MF A01

A micrometeorite simulation program studied damage phenomena and failure mechanisms of solar panels under hypervelocity impact conditions, to see if space debris and micrometeorites cause short circuits in solar arrays, e.g., of MARECS-A satellite. Experiments demonstrate that transient and permanent short circuits can be produced by particle impact. Arc discharges can be initiated under realistic electrical power conditions. There is evidence that failures caused by impact induced short circuits can be minimized by improving the geometrical arrangement of the panels and by optimizing the electrical circuitry. ESA

N87-28982# Technische Univ., Munich (West Germany). Lehrstuhl fuer Raumfahrttechnik.
MICROMETEORITE EXPOSURE OF SOLAR ARRAYS
U. WEISHAUPT, H. KUCZERA, and M. ROTT *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 175-180 Nov. 1986
(Contract ESA-6238/85-NL-AN)
Avail: NTIS HC A21/MF A01

Permanent losses of a part of the available power on solar arrays of ESA satellites, possibly caused by micrometeoroid or space debris impacts were studied in hypervelocity impact simulations at a plasma accelerator using ECS and Olympus solar panel structures. Results confirm that significant damage of the solar arrays can be caused by small hypervelocity particles. Using a solar array simulator connected to the test sample, penetration phenomena and arc triggering effects were investigated within the efficiency range of the accelerator. Temporary or permanent short circuits between the solar cells and the panel structure may lead to a loss of solar array power and additional damage may be created if arcing occurs. ESA

N87-29709# Aerospace Corp., El Segundo, Calif. Materials Sciences Lab.
EFFECTS ON ADVANCED MATERIALS: RESULTS OF THE STS-8 EOIM (EFFECTS OF OXYGEN INTERACTION WITH MATERIALS) EXPERIMENT
M. J. MESHISHNEK, W. K. STUCKEY, J. S. EVANGELIDES, L. A. FELDMAN, and R. V. PETERSON 20 Jul. 1987 89 p
(Contract F04701-85-C-0086)
(AD-A182931; TR-0086(6935-05)-2; SD-TR-87-34) Avail: NTIS HC A05/MF A01 CSCL 11D

A variety of materials were exposed to the low Earth orbit space environment on shuttle flight STS-8 as a part of NASA's Effects of Oxygen Atoms Interaction with Materials experiment. These materials include carbon and graphites, optical materials, organic and metal films, Kevlar and fiberglass fabric, and high-temperature coatings. The effects noted on these materials included oxidative erosion of the carbon and graphite, loss of tensile strength for the Kevlar fabric, erosion and oxidation of organic films, partial oxidation of infrared optical materials, and loss of reflectance for the high-temperature coatings. GRA

N87-29713*# Catholic Univ. of America, Washington, D.C. Dept. of Mechanical Engineering.
EFFECT OF BONDING ON THE PERFORMANCE OF A PIEZOACTUATOR-BASED ACTIVE CONTROL SYSTEM
A. BAZ and S. POH 28 Oct. 1987 36 p
(Contract NAG5-520; NAG5-749)
(NASA-CR-181414; NAS 1.26:181414) Avail: NTIS HC A03/MF A01 CSCL 13H

The utilization of piezoelectric actuators in controlling the structural vibrations of flexible beams is studied. A Modified Independent Modal Space Control (MIMSC) method is devised to select the optimal location, control gains and excitation voltage of the piezoelectric actuators in a way that would minimize the amplitudes of vibrations of beams to which these actuators are bonded, as well as the input control energy necessary to suppress these vibrations. The presented method accounts for the effects that the piezoelectric actuators and the bonding layers have on changing the elastic and inertial properties of the flexible beams. Numerical examples are presented to illustrate the application of the MIMSC method and to demonstrate the effect of the physical and geometrical properties of the bonding layer on the dynamic performance of the actively controlled beams. The obtained results emphasize the importance of the devised method in designing more realistic active control systems for flexible beams, in particular, and large flexible structures in general. Author

N87-29923*# Hughes Aircraft Co., Los Angeles, Calif.
ADVANCED NICKEL-CADMIUM BATTERIES FOR GEOSYNCHRONOUS SPACECRAFT
DAVID F. PICKETT, HONG S. LIM, STANLEY J. KRAUSE, and SCOTT A. VERZWYVELT *In* NASA-Lewis Research Center, Space Electrochemical Research and Technology (SERT) p 63-80 Sep. 1987
Avail: NTIS HC A16/MF A01 CSCL 10C

A nickel cadmium battery was developed that can be operated at 80 percent depth of discharge in excess of 10 years in a geosynchronous orbit application, and has about a 30 percent weight savings per spacecraft over present nickel cadmium batteries when used with a 1000 watts eclipse load. The approach used in the development was to replace nylon separators with inert polymer impregnated zirconia, use electrochemically deposited plates in place of conventional chemically precipitated ones, and use an additive to extend negative plate lifetime. The design has undergone extensive testing using both engineering and protoflight cell configurations. Author

08

ASSEMBLY CONCEPTS

Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.

A87-32545
STUDY OF ACTUATOR FOR LARGE SPACE MANIPULATOR ARM
K. MACHIDA, T. IWATA, Y. TODA, M. KAWADA (Ministry of International Trade and Industry, Electrotechnical Laboratory, Sakura, Japan), Y. KURITA (Toshiba Corp., Kawasaki, Japan) et al. IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 2017-2022.

Results are reported from studies of basic technologies for a long-life RMS for the Space Station, mostly for use with the Japan Module. The new arm will provide 10 m reach and will need high torque and a lifetime of more than 10 yr. The research covered an actuator model developing 700 Nm torque at 0.05 rad/sec and 3.4 Nm at 17.6 rad/sec with a reduction ratio of 351 in the planetary gear box, a ratio which permits use of a solid lubricant. A cutaway view is provided of the actuator, which has a dc brushless motor with 3-phase windings and a rare-earth metal magnet. The gear testing equipment employed in 1111 hr tests to validate the actuator performance in vacuum is also described. Gear alloys and greases which exhibited satisfactory durability in the tests are identified. M.S.K.

A87-32549
EVALUATION TESTING OF A MECHANICAL ACTUATOR COMPONENT OPERATING IN A SIMULATED SPACE ENVIRONMENT
YASUO KUMAGIRI, HARUKI MARUIZUMI, KOHE OHKAWA (Nissan Motor Co., Ltd., Aeronautical and Space Div., Tokyo, Japan), MAKOTO NISHIMURA, YOSHINORI FUJIMORI (National Aerospace Laboratory, Chofu, Japan) et al. IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 2041-2046.

The conceptual design and lubrication technology development for mechanical actuators for LEO applications are described. The actuators are to function in the deployment/retraction mechanism for a deployable mast for the Japanese experiment module (JEM). Details of the actuator housing are presented, including the interface between the Space Station and typical exposed experiment package to be manipulated. Experimental programs being followed to evaluate dry lubricants and processing technologies are outlined, noting the necessity of identifying areas of complex sliding and rolling friction and wear mechanisms, as well as the effects of space radiation. Electron beam irradiation of MoS2 resulted in no significant chemical or mechanical changes. The form further tests of more integrated systems will take is discussed. M.S.K.

A87-32632
COMPUTER SIMULATION OF ON-ORBIT MANNED MANEUVERING UNIT OPERATIONS
GARY M. STUART and KATHY D. GARCIA (Martin Marietta Corp., Bethesda, MD) SAE, Aerospace Technology Conference and Exposition, Long Beach, CA, Oct. 13-16, 1986. 7 p. Previously announced in STAR as N87-12245.
(SAE PAPER 861783)

Simulation of spacecraft on-orbit operations is discussed in reference to Martin Marietta's Space Operations Simulation laboratory's use of computer software models to drive a six-degree-of-freedom moving base carriage and two target gimbal systems. In particular, key simulation issues and related computer software models associated with providing real-time, man-in-the-loop simulations of the Manned Maneuvering Unit (MMU) are addressed with special attention given to how effectively these models and motion systems simulated the MMU's actual on-orbit operations. The weightless effects of the space environment require the development of entirely new devices for locomotion. Since the access to space is very limited, it is necessary to design, build, and test these new devices within the physical constraints of earth using simulators. The simulation method that is discussed here is the technique of using computer software models to drive a Moving Base Carriage (MBC) that is capable of providing simultaneous six-degree-of-freedom motions. This method, utilized at Martin Marietta's Space Operations Simulation (SOS) laboratory, provides the ability to simulate the opertion of manned spacecraft, provides the pilot with proper three-dimensional visual cues, and allows training of on-orbit operations. The purpose here is to discuss significant MMU simulation issues, the related models that were developed in response to these issues and how effectively these models simlate the MMU's actual on-orbiter operations. Author

A87-32733* Ball Aerospace Systems Div., Boulder, Colo.
RENDEZVOUS AND DOCKING TRACKER
ART J. RAY, SUSAN E. ROSS, and DOUGLAS R. DEMING (Ball Corp., Aerospace Systems Div., Boulder, CO) IN: Guidance and control 1986; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 1-5, 1986 . San Diego, CA, Univelt, Inc., 1986, p. 109-118. NASA-supported research.
(AAS PAPER 86-014)

A conceptual solid-state rendezvous and docking tracker (RDT) has been devised for generating range and attitude data for a docking vehicle relative to a target vehicle. Emphasis is placed on the approach of the Orbiter to a link with the Space Station. Three laser illuminators ring the optical axis of the lens a directed toward retroreflectors on the target vehicle. Each retroreflector is equipped with a bandpass filter for a designated illumination frequency. Data are collected sequentially over a 20 deg field of view as the range closes to 100-1000 m. A fourth ranging retroreflector 0.3 m from center is employed during close-in maneuvers. The system provides tracking data on motions with 6 deg of freedom, and furnishes 500 msec updates (to be enhanced to 100 msec) to the operator at a computer console. M.S.K.

A87-33867*# National Aeronautics and Space Administration, Washington, D.C.
OVERVIEW OF THE NASA AUTOMATION AND ROBOTICS RESEARCH PROGRAM
LEE HOLCOMB and RON LARSEN (NASA, Washington, DC) IN: Association for Unmanned Vehicle Systems; Annual Meeting, 12th, Anaheim, CA, July 15-17, 1985, Preliminary Proceedings . Washington, DC, Association for Unmanned Vehicle Systems, 1985, 20 p. refs

NASA studies over the last eight years have identified five opportunities for the application of automation and robotics technology: (1) satellite servicing; (2) system monitoring, control, sequencing and diagnosis; (3) space manufacturing; (4) space structure assembly; and (5) planetary rovers. The development of these opportunities entails two technology R&D thrusts: telerobotics and system autonomy; both encompass such concerns as operator interface, task planning and reasoning, control execution, sensing, and systems integration. O.C.

A87-35076#
DEVELOPMENT OF HARMONIC DRIVE ACTUATOR FOR SPACE MANIPULATOR
TOSHIAKI IWATA, KAZUO MACHIDA, and YOSHITSUGU TODA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 34, no. 395, 1986, p. 652-660. In Japanese, with abstract in English. refs

This paper presents the development of a harmonic drive actuator which features vacuum environment durability and the light-weight for a 1-m class space manipulator. A tribological study of bearings and gears is carried out experimentally. Some candidate materials and lubricants are tested in a vacuum chamber, and the

wear properties are investigated. The ball bearing with MoS2-sputtered ball and race and a PTFE composite retainer had excellent characteristics and lifetime. An operation lifetime over 1,000 hours was attained for the harmonic gear by employing a nitrided steel spline and a PFPE grease. An actuator with a high torque/weight ratio, which was integrated with a rare-earth brushless servo motor, an optical encoder, drive electronics, and a harmonic gear compactly, was developed. Author

A87-35877
PROBLEMS OF MECHANICAL SYSTEM CONFIGURATION CONTROL [ZADACHI UPRAVLENIIA KONFIGURATSIEI MEKHANICHESKOI SISTEMY]
L. M. ARTIUSHIN (Kievskoe Vysshee Voennoe Aviatsionnoe Inzhenernoe Uchilishche, Kiev, Ukrainian SSR) Prikladnaia Mekhanika (ISSN 0032-8243), vol. 23, Feb. 1987, p. 89-95. In Russian. refs

The problem of the configuration control of mechanical systems is analyzed using the method of inverse dynamics problems and a game theory approach. It is shown that the method of inverse dynamics problems makes it possible to resolve the difficulties associated with the determination of control law parameters on the basis of game theory. Control functions of the system elements are obtained analytically. For the algorithmic implementation of the control functions, a rigorous procedure is presented for determining the control law coefficients. V.L.

A87-38609* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
ASSESSMENT OF SPACE ENVIRONMENT INDUCED MICRODAMAGE IN TOUGHENED COMPOSITE MATERIALS
GEORGE F. SYKES, JOAN G. FUNK, and WAYNE S. SLEMP (NASA, Langley Research Center, Hampton, VA) IN: International SAMPE Technical Conference, 18th, Seattle, WA, Oct. 7-9, 1986, Proceedings . Covina, CA, Society for the Advancement of Material and Process Engineering, 1986, p. 520-534.

The effects of simulated space environments on the microdamage in a series of commercially available toughened matrix composite systems was determined. Low-earth orbit (LEO) exposures were simulated by thermal cycling; geosynchronous orbit (GEO) exposures were simulated by electron irradiation plus thermal cycling. Material response was characterized by assessing the induced microcracking and its influence on chemical and mechanical property changes. All materials, including several advanced, tough thermoplastics microcracked when exposed to the simulated LEO environment except a 177 C cured single phase toughened epoxy composite. The GEO simulated environment produced microdamage in all materials. The results suggest that increased matrix toughness may not be the overriding factor leading to improved durability in the space environment. Author

A87-38767
SPACE STATION EVA SYSTEMS TRADE-OFF MODEL
MAURICE A. CARSON (Eagle Engineering, Inc., Houston, TX), LARRY PRICE (McDonnell Douglas Astronautics Co., Saint Louis, MO), and BRUCE JAGOW (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 691-709.
(SAE PAPER 860990)

A procedure has been developed to predict program costs for conducting extravehicular activity from Space Station. Space Transportation System EMU historical data has been used as a basis for performing the development and production phases. Complexity and risk factors are used to compare costs for various configuration options. Operations costs utilize ground, launch, and on-orbit penalty factors derived from operations analysis and EVA hardware configuration and performance data. Scar costs are based upon weight and flight or ground personnel overhead factors. The model compares nine separate configurations and extends from FY 1987 through the first ten years of Space Station operations. A spreadsheet format together with a grouping of the program constraints promotes rapid recalculations when new input data is desired. Author

A87-38780
AN EVALUATION OF OPTIONS TO SATISFY SPACE STATION EVA REQUIREMENTS
JOSEPH J. THOMPSON, KENNETH S. BROSSEL (Boeing Aerospace Co., Seattle, WA), and BRUCE W. WEBBON (SRI International, Menlo Park, CA) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 845-861.
(SAE PAPER 861008)

The Space Station mission requirements for initial frequent use of EVA require the modification of the existing Shuttle suit and the Shuttle Extravehicular Mobility Unit (EMU). Options for a Space Station EVA space suit are described and evaluated in light of the Space Station mission human and environmental requirements. The evaluation is made to select the most cost-effective and technologically feasible alternative that meets the requirements. Requirements considered include: (1) the heavy, almost industrial use, of the suit; (2) long operational life; (3) on-orbit maintenance and fit check; (4) high mobility; (5) rapid don/doff; (6) high pressure for zero pre-breath; (7) radiation protection; (8) micrometeoroid/space debris protection; (9) thermal insulation; (10) contamination/decontamination factors; (11) automatic checkout; and (12) low development and recurring costs. Author

A87-38782
SPACE STATION EVA USING A MANEUVERING ENCLOSURE UNIT
D. PAUL MEYER, JOE J. THOMPSON, and RICHARD L. OLSON (Boeing Aerospace Co., Seattle, WA) IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 873-882. refs
(SAE PAPER 861010)

An evaluation is made of an EVA enclosure concept that combines features of the Extravehicular Mobility Unit (EMU) and the Manned Maneuvering Unit, and incorporates robotic elements. This Maneuvering Enclosure Unit (MEU) encompasses docking ring and latching mechanisms, an attachment structure for the grappler and manipulator arms, and packaging facilities for life support and data systems. Prospected performance comparisons are made between the MEU and EMU with respect to versatility, consumables usage, operator acceptance, operations, and design/development factors. O.C.

A87-40376
ON-ORBIT ASSEMBLY AND REPAIR
A. JUSTAFERRO, S. C. DEBROCK, H. T. FISHER, G. J. GOULD, S. J. HOUSTON (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) et al. IN: EASCON '86; Proceedings of the Nineteenth Annual Electronics and Aerospace Systems Conference, Washington, DC, Sept. 8-10, 1986 . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 221-243.

The concept of on-oribt assembly and repair is introduced including users, tasks, Space Station and NSTS Interfaces. Representative missions and spacecraft requiring assembly and repair are briefly described along with the specific service requested. Considerations for setting the level of on-orbit replaceable unit (ORU) indenture or packaging size are discussed along with the feasibility of intravehicular activity (IVA) repair at the component and board level. A discussion of broad design guidelines is presented with reference data in easy-acess, tabular form and finally a listing of more than 15 years of servicing design lessons learned are presented. Author

A87-40844#
ROBOTS ON THE SPACE STATION
ERIC J. LERNER Aerospace America (ISSN 0740-722X), vol. 25, June 1987, p. 42-45.

Teleoperated robotic devices, or 'telerobots', such as those in use at nuclear processing facilities, are undergoing Space Station applicability evaluations which give attention to such questions as the degree of autonomy feasible or desirable for such devices and their most advantageous location. The mechanical elements of the telerobot are noted to require the most intensive modification for operations in a microgravity environment, due to the presence of backlash in many of its operations. A torque feedback loop has been developed which directly controls the force borne by arm joints. O.C.

A87-44836*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THERMAL-STRESS-FREE FASTENERS FOR JOINING ORTHOTROPIC MATERIALS
MAX L. BLOSSER (NASA, Langley Research Center, Hampton, VA) AIAA, Thermophysics Conference, 22nd, Honolulu, HI, June 8-10, 1987. 10 p. refs
(AIAA PAPER 87-1609)

Hot structures fabricated from orthotropic materials are an attractive design option for future high speed vehicles. Joining subassemblies of these materials with standard cylindrical fasteners can lead to loose joints or highly stressed joints due to thermal stress. A method has been developed to eliminate thermal stress and maintain a tight joint by shaping the fastener and mating hole. This method allows both materials (fastener and structure), with different coefficients of thermal expansion (CTE's) in each of the three principal material directions, to expand freely with temperature yet remain in contact. For the assumptions made in the analysis, the joint will remain snug, yet free of thermal stress at any temperature. Finite element analysis was used to verify several thermal-stress-free fasteners and to show that conical fasteners, which are thermal-stress-free for isotropic materials, can reduce thermal stresses for transversely isotropic materials compared to a cylindrical fastener. Equations for thermal-stress-free shapes are presented and typical fastener shapes are shown. Author

A87-45797* Catholic Univ. of America, Washington, D.C.
CONTROL OF ROBOT MANIPULATOR COMPLIANCE
CHARLES C. NGUYEN, FARHAD J. POORAN (Catholic University of America, Washington, DC), and TIMOTHY PREMACK (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Recent trends in robotics: Modeling, control and education. Amsterdam, North-Holland, 1986, p. 237-242. refs
(Contract NAG5-780)

Robotic assembly operations such as mating and fastening of parts are more successful if the robot manipulator compliance can be controlled so that various coordinates are free to comply with external constraints. This paper presents the design of a hybrid controller to provide active compliance to a six-degree-of-freedom robot built at NASA/GSFC using force and position feedback. Simulation results of a 2 degree-of-freedom model is presented and discussed. Author

A87-46704#
ROBOTIC TELEPRESENCE
GEORGE C. MOHR (USAF, Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH) IN: 1987 Annual Reliability and Maintainability Symposium, Philadelphia, PA, Jan. 27-29, 1987, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1987, p. 25-30. refs

The concept of robotic telepresence, the linking of human hands and eyes with a robot's hands and eyes to permit viewing and manipulating objects from a remote location, is discussed. A 'master-slave' relationship between the human controller and robot is based on closed loop visual, tactile, and force sensing and display, coupled with head, eye, arm, hand, and finger position control of the robotic system. Technological areas requiring increased emphasis include hand-finger position sensing, tactile-force displays, and time-delay control compensation. The concept has application to the performance of maintenance, repair, and construction tasks in a hostile environment to enhance military capability, and for manned operations in both orbital and deep space environments. R.R.

A87-50426#
FLEXIBLE MANIPULATOR MODELING FOR CONTROL SYSTEM DEVELOPMENT
V. A. SPECTOR and H. FLASHNER (Southern California, University, Los Angeles, CA) IN: AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 17-19, 1987, Technical Papers. Volume 1 . New York, American Institute of Aeronautics and Astronautics, 1987, p. 213-220. refs
(AIAA PAPER 87-2264)

An analytical study of control system development for compliant manipulators is presented. Analysis of flexible manipulator links is performed using Euler-Bernoulli and Timoshenko beam theories. Alternatives to the usual partial fraction expansion approach are presented using Mittag-Leffler product expansion and wave propagation theory. Transform techniques are used to obtain a wave propagation solution. Dispersion equations are analyzed to explain characteristics pertiment to control design, including propagation delay time. Frequency domain analysis of two pinned-free links with hollow and solid cross sections is performed. Preliminary control system design results in the frequency domain are presented. Author

A87-51979#
DEVELOPMENT OF A SMALL-SIZED SPACE MANIPULATOR
YOSHITUGU TODA, KAZUO MACHIDA, TOSHIAKI IWATA, MASAO INOUE, KATSUHIKO YAMADA et al. Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 401, 1987, p. 294-302. In Japanese, with abstract in English. refs

Future space stations and space factories which require many types of manipulators or robots for assembling and servicing in space, especially demand small-sized manipulators for dexterous tasks. A 1-meter class articulated manipulator with space environment durability and light weight has been developed. This paper presents the system design of the manipulator and development efforts of its components. The design of actuators and a hand, a tribological investigation of mechanical elements in the vacuum environment, the multiprocessor control system, and the dynamic control algorithm of the arm, are described. Author

N87-20351*# McDonnell-Douglas Astronautics Co., St. Louis, Mo.
ADVANCED EVA SYSTEM DESIGN REQUIREMENTS STUDY: EVAS/SPACE STATION SYSTEM INTERFACE REQUIREMENTS
T. G. WOODS 15 Nov. 1985 122 p
(Contract NAS9-17299)
(NASA-CR-171981; NAS 1.26:171981; MDC-W0070) Avail: NTIS HC A06/MF A01 CSCL 22B

The definition of the Extravehicular Activity (EVA) systems interface requirements and accomodations for effective integration of a production EVA capability into the space station are contained. A description of the EVA systems for which the space station must provide the various interfaces and accomodations are provided. The discussion and analyses of the various space station areas in which the EVA interfaces are required and/or from which implications for EVA system design requirements are derived, are included. The rationale is provided for all EVAS mechanical, fluid, electrical, communications, and data system interfaces as well as exterior and interior requirements necessary to facilitate EVA operations. Results of the studies supporting these discussions are presented in the appendix. B.G.

N87-20774# Oak Ridge National Lab., Tenn.
THE OAK RIDGE NATIONAL LABORATORY'S ROBOTICS AND INTELLIGENT SYSTEMS PROGRAM
S. A. MEACHAM 23 Jan. 1987 8 p Presented at the Roane-Anderson Economic Council Meeting, Oak Ridge, Tenn., 23 Jan. 1987
(Contract DE-AC05-84OR-21400)
(DE87-004627; CONF-870148-1) Avail: NTIS HC A02/MF A01

The goals of the newly formed Robotics and Intelligent Systems Program are discussed. The application of the remote systems technology developed by the Consolidated Fuel Reprocessing Program for the Department of Energy is presented. The activities (satellite refueling and space station truss assembly) with the National Aeronautics and Space Administration are presented in a videotape format with narration by the presenter. The goals of technology transfer to the private sector and the potential positive impact on the community conclude the oral presentation. DOE

N87-22706*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
MICROPROCESSOR CONTROLLED PROOF-MASS ACTUATOR
GARNETT C. HORNER *In* NASA. Marshall Space Flight Center Structural Dynamics and Control Interaction of Flexible Structures p 101-118 Apr. 1987
Avail: NTIS HC A99/MF E03 CSCL 14B

The objective of the microprocessor controlled proof-mass actuator is to develop the capability to mount a small programmable device on laboratory models. This capability will allow research in the active control of flexible structures. The approach in developing the actuator will be to mount all components as a single unit. All sensors, electronic and control devices will be mounted with the actuator. The goal for the force output capability of the actuator will be one pound force. The programmable force actuator developed has approximately a one pound force capability over the usable frequency range, which is above 2 Hz. Author

N87-24490# Aeritalia S.p.A., Naples (Italy). Space Systems Group.
ATTITUDE AND ORIENTATION SYSTEM (AOCS) TASKS ON RENDEZVOUS AND DOCKING (RVD) (DOCKING-UNDOCKING PHASES). ARCHITECTURE OF THE WHOLE SIMULATOR, VOLUME 2 Final Report
Paris, France ESA Feb. 1986 270 p
(Contract ESA-4750/81-NL-AK(SC))
(LP-RP-AI-204-VOL-2; ESA-CR(P)-2313-VOL-2; ETN-87-99869)
Avail: NTIS HC A12/MF A01

The architecture of a spacecraft docking simulator is described. The main functions are: geometrical definition of the spacecraft shape and of the interfacing docking mechanism; dynamic definition of the spacecraft in terms of mass, inertia, stiffness, damping, flexible eigenvectors, and eigenvalues; geometrical interference analysis, localization of the impact point, force or impulse exchanged, integration step control (PREP); preparation and manipulation of the input-output information flow between PREP and DCAP-1; motion simulation (DCAP-1); postelaboration of the output of DCAP-1, reconstruction of the whole geometry; and its visualization. ESA

N87-24491# Aeritalia S.p.A., Naples (Italy). Space Systems Group.
ATTITUDE AND ORIENTATION CONTROL SYSTEM (AOCS) TASKS ON RENDEZVOUS AND DOCKING (RVD) (DOCKING-UNDOCKING PHASES). SIMULATION SET-UP AND RESULTS, VOLUME 3 Final Report
Paris, France ESA Feb. 1986 151 p
(Contract ESA-4750/81-NL-AK(SC))
(LP-RP-AI-204-VOL-3; ESA-CR(P)-2313-VOL-3; ETN-87-99870)
Avail: NTIS HC A08/MF A01

Simulations of cone-cone docking between two rigid bodies; cone-cone docking with a flexible target; and probe-cone docking with rigid target and chaser were performed. Results show that a general purpose DCAP-1 integrated software dedicated to docking is unfeasible. The DCAP code has problems in handling system nontopology due to the way it considers hinges. Ways to overcome these problems are suggested. ESA

N87-25336# Royal Netherlands Aircraft Factories Fokker, Amsterdam. Attitude Control Dept.
END EFFECTOR DEVELOPMENT STUDY, VOLUME 1 Final Report
AAD VANSWIETEN Paris, France ESA 15 Jul. 1986 162 p
(Contract ESA-1682/84-NL-AN)
(FOK-TR-R-86-091-VOL-1; ESA-CR(P)-2346-VOL-1;
ETN-87-99886) Avail: NTIS HC A08/MF A01

The application of an end-effector mounted on a service manipulator system was investigated, and requirements for the service end-effector subsystem for in-orbit servicing, comprising the end-effector and the associated tools to perform the tasks, were identified. As a result of trade-offs a design was selected, and was developed further resulting in a new design with assembly drawings of the basic end-effector containing the grapple mechanism, the grapple fixture, the integrated service tool, the connector drive unit and the electronic box. The service tools, the definition of the interface between grapple fixture and service tool or orbit replaceable unit, the locking of the service tool in the tool rack for the back-up integrated service tool, and two preliminary designs of service tools, i.e., the multifunctional gripper and the angled wrench, are described. ESA

N87-25337# Royal Netherlands Aircraft Factories Fokker, Amsterdam. Attitude Control Dept.
END EFFECTOR DEVELOPMENT STUDY. VOLUME 3: APPENDICES Final Report
AAD VANSWIETEN Paris, France ESA 15 Jul. 1986 235 p
(Contract ESA-1682/84-NL-AN)
(FOK-TR-R-86-091-VOL-3; ESA-CR(P)-2346-VOL-3;
ETN-87-99888) Avail: NTIS HC A11/MF A01

This third of three volumes presents the appendices of the other two volumes. The design rationale of the end effector concept; the multifunctional gripper; the angled wrench; logistic operations; maintenance and repair; assembly; and electrical architecture are discussed. ESA

N87-25582* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
PRELOADABLE VECTOR SENSITIVE LATCH Patent
WILLIAM R. ACRES, inventor (to NASA) 28 Jul. 1987 13 p
Filed 3 Oct. 1985 Supersedes N86-19613 (24 - 10, p 1584)
(NASA-CASE-MSC-20910-1; US-PATENT-4,682,745;
US-PATENT-APPL-SN-783888; US-PATENT-CLASS-244-161;
US-PATENT-CLASS-292-DIG.49; US-PATENT-CLASS-292-201;
US-PATENT-CLASS-292-64) Avail: US Patent and Trademark Office CSCL 13K

A preloadable vector-sensitive latch which automatically releases when the force vector from a latch memebr reaches a specified release angle is presented. In addition, it contains means to remove clearance between the latched members and to preload the latch to prevent separation at angles less than the specified release angle. The latch comprises a triangular main link, a free link connected between a first corner of the main link and a yoke member, a housing, and an actuator connected between the yoke member and the housing. A return spring bias means connects the main link to a portion of the housing. A second corner of the main link is slidably and pivotally connected to the housing via a slot in a web portion of the housing. The latch housing has a rigid docking ring alignable with a mating locking ring which is engageable by a locking roller journalled on the third corner of the triangular main link.

Official Gazette of the U.S. Patent and Trademark Office

N87-26355 Rochester Univ., N. Y.
SELF-CALIBRATION STRATEGIES FOR ROBOT MANIPULATORS Ph.D. Thesis
AMITABHA MUKERJEE 1986 114 p
Avail: Univ. Microfilms Order No. DA8708242

One of the requirements of intelligent machines is the ability to adapt to changes in themselves. This ability is called self-calibration to emphasize its autonomous nature. A self-calibration methodology was developed for the class of mechanisms called active articulated chains, which includes robot manipulators, teleoperators and space structures. The two parts of this effort are: (1) estimating the link inertias, and (2) modeling the friction at manipulator joints. Inertia parameters are determined using the equations of motion for each link. These equations are linear in the inertia parameters and the generalized least squares approach was used to solve for them. The inputs are joint reaction forces, obtained through load sensors. Link velocities and accelerations are used to determine the mapping between the joint reactions and the inertia parameters. Singularity parameters are automatically removed from the calibration model. The calibration algorithm does not require the manipulator to execute any particular motion, although the efficiency of calibration will depend on the nature of the movement. Simulation tests were performed to test the robustness of the algorithm against sensor noise. Dissert. Abstr.

N87-26970 Virginia Univ., Charlottesville.
THEORY AND APPLICATION OF LINEAR SERVO DAMPERS FOR LARGE SCALE SPACE STRUCTURES Ph.D. Thesis
MICHAEL FREDERICK MALLETTE 1986 244 p
Avail: Univ. Microfilms Order No. DA8705681

An investigation was made of control laws of several different servo control circuits for use in damping the vibrations of large scale space structures. A proof-mass type, structure-borne displacement device was tested as a linear servo actuator that is a component of digital control systems. These systems are hardware implementations of certain mathematical models of governing equations that show higher damping figures of merit for certain control circuits in regard to stability and response. The result was a general approach to removal of structural energy from the standpoint of design criterion that includes control law shaping predicted from open loop design, frequency limitations, and selectability of integral exponents as gain values. The critical elements in the development of the damper are the electronic digital signal processor and the associated software used to boot-strap the system up to the final Z-80 microprocessor ground based simulator, and the nearly pure iron pole pieces for the toroidal magnetic field containment into which is coupled a solenoid coil to produce control forces. Dissert. Abstr.

N87-27408# Oak Ridge National Lab., Tenn.
REMOTE HANDLING FACILITY AND EQUIPMENT USED FOR SPACE TRUSS ASSEMBLY
T. W. BURGESS 1987 8 p Presented at the Goddard Conference on Space Applications of Artificial Intelligence and Robotics, Greenbelt, Md., 14 May 1987
(Contract DE-AC05-84OR-21400)
(DE87-009121; CONF-870591-3) Avail: NTIS HC A02/MF A01

The ACCESS truss remote handling experiments were performed at Oak Ridge National Laboratory's (ORNL's) Remote Operation and Maintenance Demonstration (ROMD) facility. The ROMD facility has been developed by the US Department of Energy's (DOE's) Consolidated Fuel Reprocessing Program to develop and demonstrate remote maintenance techniques for advanced nuclear fuel reprocessing equipment and other programs of national interest. The facility is a large-volume, high-bay area that encloses a complete, technologically advanced remote maintenance system that first began operation in FY 1982. The maintenance system consists of a full complement of teleoperated manipulators, manipulator transport systems, and overhead hoists that provide the capability of performing a large variety of remote handling tasks. ACCESS truss remote assembly was performed in the ROMD facility using the Central Research Laboratory's (CRL) model M-2 servomanipulator. The model M-2 is a dual-arm, bilateral force-reflecting, master/slave servomanipulator which was jointly developed by CRL and ORNL and represents the state of the art in teleoperated manipulators commercially available in the United States today. The model M-2 servomanipulator incorporates a distributed, microprocessor-based digital control system and was the first successful implementation of an entirely digitally controlled servomanipulator. The system has been in operation since FY 1983. DOE

N87-28588# Selenia S.p.A., Rome (Italy).
RENDEZVOUS AND DOCKING (RVD) LONG RANGE RF SENSOR DEFINITION STUDY, EXECUTIVE SUMMARY
Paris, France ESA 1986 114 p
(Contract ESA-6093/84-NL-GM(SC))
(SES/ENG/ES-519/86; ESA-CR(P)-2367; ETN-87-90471) Avail: NTIS HC A06/MF A01

A 90 GHz radar, an S-band lobe switching sensor, and S-band phase switching sensors were compared for use as rendezvous and docking long range sensor aboard the chaser satellite. The lobe switching concept best meets requirements of target satellite acquisition (at a range of the order of 100 km) and operation at a range less than 100 m; measurement of relative distance (between chaser and target) with accuracy of 1 m (at short range); measurement of relative velocity (between chaser and target) with accuracy of 1 cm/sec (at short range); measurement of relative position (between chaser and target) expressed as bearing angles with respect to reference frame in the chaser, with accuracy of 0.5 deg in the field of view of +/- 30 deg; and measurement of bearing angle rates with respect to the reference frame in the chaser with accuracy of 0.05 deg/sec. ESA

N87-29009# Societe Europeenne de Propulsion, Vernon (France).
SPOT/MEGS DESIGN AND FLIGHT RESULTS OBTAINED
G. ATLAS and M. SOULIAC (MATRA Espace, Paris-Velizy, France) *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 359-364 Nov. 1986
Avail: NTIS HC A21/MF A01

The SPOT MEGS rotation actuator, whose purpose is to ensure that the solar array is always perpendicular to the solar flux, is described. Solar arrays on the SPOT satellites are very flexible, and can be easily excited by the motors that are fitted in the MEGS. To avoid speed stability troubles, a synchronous motor was selected, fed with a compensated current waveform, which leads to a smoother motion of the solar array. Consequently, ultra precise photographs can be taken without stops for repositioning of the satellite. The specifications, performances of MEGS, the stabilization method, and MEGS behavior in orbit are summarized. ESA

N87-29118* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
MOBILE REMOTE MANIPULATOR VEHICLE SYSTEM Patent
HAROLD G. BUSH, inventor (to NASA), MARTIN M. MIKULAS, JR., inventor (to NASA), RICHARD E. WALLSOM, inventor (to NASA), and J. KERMIT JENSEN, inventor (to NASA) (Kentron International, Inc., Hampton, Va.) 11 Aug. 1987 17 p Filed 31 Jul. 1985 Supersedes N86-21147 (24 - 11, p 1842)
(NASA-CASE-LAR-13393-1; US-PATENT-4,685,535; US-PATENT-APPL-SN-760799; US-PATENT-CLASS-182-63; US-PATENT-CLASS-182-82; US-PATENT-CLASS-182-223)
Avail: US Patent and Trademark Office CSCL 05H

A mobile remote manipulator system is disclosed for assembly, repair and logistics transport on, around and about a space station square bay truss structure. The vehicle is supported by a square track arrangement supported by guide pins integral with the space station truss structure and located at each truss node. Propulsion is provided by a central push-pull drive mechanism that extends out from the vehicle one full structural bay over the truss and locks drive rods into the guide pins. The draw bar is now retracted and the mobile remote manipulator system is pulled onto the next adjacent structural bay. Thus, translation of the vehicle is inchworm

style. The drive bar can be locked onto two guide pins while the extendable draw bar is within the vehicle and then push the vehicle away one bay providing bidirectional push-pull drive. The track switches allow the vehicle to travel in two orthogonal directions over the truss structure which coupled with the bidirectional drive, allow movement in four directions on one plane. The top layer of this trilayered vehicle is a logistics platform. This platform is capable of 369 degees of rotation and will have two astronaut foot restraint platforms and a space crane integral. NASA

N87-29868*# Societe Europeenne de Propulsion, Vernon (France).
EXPERIENCES OF CNES AND SEP ON SPACE MECHANISMS ROTATING AT LOW SPEED
G. ATLAS and G. THOMIN (Centre National d'Etudes Spatiales, Toulouse, France) *In* NASA-Lyndon B. Johnson Space Center, The 21st Aerospace Mechanisms Symposium p 131-144 May 1987
Avail: NTIS HC A16/MF A01 CSCL 13I

Some aspects of knowledge acquired in the field of space mechanisms by Societe Europeenne de Propulsion and Centre National d'Etudes Spatiales in International and French National space programs are described. The experience described centers on the development of these programs: The MEGS (Mechanisme d'Etrainement du Generateur Solaire), and the MOGS (Mechanisme d'Orientation de Generateur Solaire), both solar array drive mechanisms. Key design areas and the mechanism performance obtained are highlighted. Some test problems with the MEGS sliprings are discussed. Author

N87-29869*# Sperry Space Systems, Durham, N.C.
COMMON DRIVE UNIT
R. C. ELLIS, R. A. FINK, and E. A. MOORE *In* NASA-Lyndon B. Johnson Space Center, The 21st Aerospace Mechanisms Symposium p 145-163 May 1987
Avail: NTIS HC A16/MF A01 CSCL 13I

The Common Drive Unit (CDU) is a high reliability rotary actuator with many versatile applications in mechanism designs. The CDU incorporates a set of redundant motor-brake assemblies driving a single output shaft through differential. Tachometers provide speed information in the AC version. Operation of both motors, as compared to the operation of one motor, will yield the same output torque with twice the output speed. Author

N87-29876*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
THE PRELOADABLE VECTOR SENSITIVE LATCH FOR ORBITAL DOCKING/BERTHING
WILLIAM R. ACRES and JOHN J. KENNEDY *In its* The 21st Aerospace Mechanisms Symposium p 247-259 May 1987
Avail: NTIS HC A16/MF A01 CSCL 13I

The workings and function of the Preloader Vector Sensitive Latch are described. A discussion of docking systems used in the U.S. manned space flight programs is included to show how docking systems have evolved, and to highlight the potential advantages of a preloadable vector sensitive latch in such systems. Author

N87-29877*# Rockwell International Corp., Downey, Calif. Space Station Systems Div.
SPACE STATION BASED OPTIONS FOR ORBITER DOCKING/BERTHING
DANIEL J. HOOVER *In* NASA-Lyndon B. Johnson Space Center, The 21st Aerospace Mechanisms Symposium p 261-273 May 1987
Avail: NTIS HC A16/MF A01 CSCL 22B

Conceptual efforts to develop a Space Station based system for docking and/or berthing the NSTS Orbiter are described. Past docking and berthing systems are reviewed, the general requirements and options for mating the Orbiter and Space Station are discussed, and the rationale for locating the system on the Station is established. One class of Station-based system is developed in several variations and evaluated with respect to weight distribution, loads, safety, reliability, viewing, and maintainability. An evolutionary presentation of the variations provides insight into the development process and the problems encountered. An overall evaluation of the Station-based variations compared to an optimized Orbiter-based system demonstrates the potential benefits of this approach as well as the issues that must be resolved to realize the benefits. Author

N87-29878*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
AN ELECTROMECHANICAL ATTENUATOR/ACTUATOR FOR SPACE STATION DOCKING
LEBARIAN STOKES, DEAN GLENN, and MONTY B. CARROLL (Lockheed Engineering and Management Services Co., Inc., Houston, Tex.) *In its* The 21st Aerospace Mechanisms Symposium p 275-284 May 1987
Avail: NTIS HC A16/MF A01 CSCL 22B

The development of a docking system for aerospace vehicles has identified the need for reusable and variably controlled attenuators/actuators for energy absorption and compliance. One approach to providing both the attenuator and the actuator functions is by way of an electromechanical attenuator/actuator (EMAA) as opposed to a hydraulic system. The use of the electromechanical devices is considered to be more suitable for a space environment because of the absence of contamination from hydraulic fluid leaks and because of the cost effectiveness of maintenance. A smart EMAA that uses range/rate/attitude sensor information to preadjust a docking interface to eliminate misalignments and to minimize contact and stroking forces is described. A prototype EMAA was fabricated and is being tested and evaluated. Results of preliminary testing and analysis already performed have established confidence that this concept is feasible and will provide the desired reliability and low maintenance for repetitive long term operation typical of Space Station requirements. Author

09

PROPULSION

Includes propulsion concepts and designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.

A87-38003#
THE USE OF ELECTRIC PROPULSION ON LOW EARTH ORBIT SPACECRAFT
A. R. MARTIN and M. T. CRESDEE (Culham Laboratory, Abingdon, England) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 19th, Colorado Springs, CO, May 11-13, 1987. 10 p. Research supported by the British National Space Centre. refs
(AIAA PAPER 87-0989)

In the past, in the United Kingdom the analysis of missions for electric propulsion systems has been concerned with north-south station keeping of a satellite in a geostationary orbit, orbit raising of spacecraft from low earth orbit to geostationary orbit, and interplanetary missions to regions of the solar system outside the gravitational influence of the earth. A further class of mission not discussed as yet is the application of electric propulsion to systems operating in low earth orbit, and this is the subject of the present paper. In particular, the different elements of the United States of America/International Space Station are considered. This is appropriate at the present time as a result of the European Columbus activities on the various station elements. Author

A87-38015#
A UK LARGE DIAMETER ION THRUSTER FOR PRIMARY PROPULSION
A. R. MARTIN, A. BOND, K. E. LAVENDER, M. S. HARVEY, and P. M. LATHAM (Culham Laboratory, Abingdon, England) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 19th, Colorado Springs, CO, May 11-13, 1987. 10 p. Research supported by the British National Space Centre. refs
(AIAA PAPER 87-1031)

Attention is given to recent research efforts in the UK concerning the use of ion thrusters for orbit-raising of LEO platforms, for large spacecraft drag compensation, and for general space system control and positioning tasks; these applications require thrust levels of a few hundred mN. Development work has accordingly concentrated on a 25-cm diameter Kaufman-type ion thruster with a nominal output of 200 mN, using Xe as a propellant. Initial test results are presented. O.C.

A87-41122#
1987 STATUS REPORT - UNITED STATES AIR FORCE ELECTRIC PROPULSION RESEARCH AND DEVELOPMENT
ROBERT D. MEYA and TONY H. Q. NGUYEN (USAF, Astronautics Laboratory, Edwards AFB, CA) AIAA, DGLR, and JSASS, International Electric Propulsion Conference, 19th, Colorado Springs, CO, May 11-13, 1987. 14 p. refs
(AIAA PAPER 87-1036)

The Air Force Astronautics Laboratory (AFAL) is currently developing electric propulsion technology to meet USAF and DOD requirements for military space missions. The AFAL's three-tiered R&D program is presented. In order of priority, the first tier is the space demonstration of a space-qualified 30-kWe-class arcjet propulsion system, while the second tier is the continued industrial development of arcjet technology to increase specific impulse and lifetime; the third tier is the continued university development of steady-state multimegawatt MPD thrusters to guarantee the availability of MPD technology upon USAF deployment of operational multimegawatt space power supplies. K.K.

A87-45310#
LOW THRUST CRYOGENIC ENGINE TECHNOLOGY
BARBARA E. SCHNEIDER, ROY W. MICHEL, and JOHN A. GIBB (Aerojet TechSystems Co., Sacramento, CA) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 23rd, San Diego, CA, June 29-July 2, 1987. 5 p.
(AIAA PAPER 87-1932)

The Air Force Rocket Propulsion Laboratory is sponsoring a program to develop the technology for a 500-lbF 02/H2 rocket engine intended to provide low thrust propulsion for delivery of large space structures to geosynchronous orbit, following deployment and checkout in low earth orbit. The engine design incorporates such innovative technology as a dual spool fuel turbopump for subcritical operation and a fuel regenerator for ample operating point margin. The engine design concept and major components are described in this paper. Author

N87-26452*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
HIGH POWER/LARGE AREA PV SYSTEMS
JOSEPH WISE (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.) and COSMO BARAONA *In its* Space Photovoltaic Research and Technology 1986. High Efficiency, Space Environment and Array Technology p 355-359 Jun. 1987
Avail: NTIS HC A16/MF A01 CSCL 10B

The major photovoltaic power system technology drivers for a wide variety of mission types were ranked. Each technology driver was ranked on a scale of high, medium, or low in terms of importance to each particular mission type. The rankings were then compiled to determine the overall importance of each driver over the entire range of space missions. In each case cost was ranked the highest. 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.

A87-31505
FIBER-OPTIC MONITORS FOR SPACE STRUCTURES
W. S. OTAGURO, R. J. MICHAL, and S. F. WATANABE (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: Digital Avionics Systems Conference, 7th, Fort Worth, TX, Oct. 13-16, 1986, Proceedings . New York, Institute of Electrical and Electronics Engineers, Inc., 1986, p. 433-436. refs

The application of fiber-optic interferometric sensors for space use is becoming very attractive due to significant progress made in recent years in the development of producible fiber-optic modules. Both Mach-Zehnder or Sagnac configurations can be used to provide either length and area structural monitors. Fiber-optic length monitors can measure strains (elongations and compressions) from 0.1 micrometers to 1.0 millimeters from dc to 2000 Hz with a temperature compensation. Fiber-optic acoustic area monitors can locate and quantify structural damage caused by micrometeorite impacts or surface defects. By incorporating the fiber-optic sensor technology from related efforts, the development of these fiber-optic structural monitors is reduced to transducer design and packaging. A description of the Mach-Zehnder and Sagnac fiber interferometers configured to monitor strain is provided. Data from a breadboard Sagnac strain sensor is presented. Author

A87-32276
INTERNATIONAL SYMPOSIUM ON SPACE TECHNOLOGY AND SCIENCE, 15TH, TOKYO, JAPAN, MAY 19-23, 1986, PROCEEDINGS. VOLUMES 1 & 2
HIROKI MATSUO, ED. (Tokyo, University, Japan) Symposium sponsored by Ad-Melco Co., Ltd., Fujitsu, Ltd., Hitachi, Ltd., et al. Tokyo, AGNE Publishing, Inc., 1986. Vol. 1, 1159 p.; vol. 2, 1111 p. For individual items see A87-32277 to A87-32571.

Papers are presented on national space programs, the future utilization of space, propulsion, materials and structure, flight dynamics and astrodynamics, fluid dynamics, and thermophysics and thermochemistry. Topics discussed include electronic components and devices, space communications, guidance, navigation, and control, systems engineering, space transportation systems. Consideration is given to balloons, space science, the Space Station and space platforms, life sciences, and microgravity. I.F.

A87-32435
VISUAL INFORMATION PROCESSING SYSTEM FOR AUTONOMOUS TELEOPERATED SPACECRAFT
TORU TANABE (Tokyo University, Japan), EIMEI OHYAMA, and HIROSHI KOYAMA IN: International Symposium on Space Technology and Science, 15th, Tokyo, Japan, May 19-23, 1986, Proceedings. Volume 2 . Tokyo, AGNE Publishing, Inc., 1986, p. 1201-1206. refs

A visual information processing system to be used for target spacecraft identification is proposed. The system utilizes image data from multiple view points in order to construct the three-dimensional structure of the target spacecraft. The functions of the multiple view visual information processing system components, which are the CCD type image sensors, image processing system, three-dimensional model construction system, spacecraft identification system, initial information acquisition system, moving image processing system, and data base, are described. The laboratory experiments and computer simulations conducted to evaluate the usefulness of the system are discussed. The experimental data reveal that the visual information processing

system effectively identifies spacecraft, and that the system provides accurate relative position, velocity, and attitude, and angular rate data. I.F.

A87-32726
GUIDANCE AND CONTROL 1986; PROCEEDINGS OF THE ANNUAL ROCKY MOUNTAIN GUIDANCE AND CONTROL CONFERENCE, KEYSTONE, CO, FEB. 1-5, 1986
ROBERT D. CULP, ED. (Colorado, University, Boulder) and JOHN C. DURRETT, ED. (Martin Marietta Corp., Denver, CO) Conference sponsored by AAS. San Diego, CA, Univelt, Inc. , 1986, 459 p. For individual items see A87-32727 to A87-32751.

The development state of the art, and future designs of guidance and control systems for space applications are explored. The discussions cover control and pointing systems for large space structures such as the Space Station, passive damping and isolation techniques, and active vibration control for a Shuttle-based dynamic structural laboratory. Recent advances in control theory and in sensor, actuator and computational hardware and sophisticated guidance and control systems installed on the Galileo, Gamma Ray Observatory, Cosmic Background Explorer and Multi-Mission Modular Spacecraft are described. Conceptual designs and analyses being performed to support development of the Transfer Orbit Stage and the Orbital Maneuvering Vehicle are summarized, as are design features and test data from the SPACELAB Instrument Pointing System, the Solar Array Flight Dynamic Experiment, and Giotto guidance systems. Also, control systems and design features of telerobotic systems being studied as adjuncts to Shuttle and Space Station crew operations are discussed. M.S.K.

A87-33001
HUMAN FACTORS SOCIETY, ANNUAL MEETING, 30TH, DAYTON, OH, SEPT. 29-OCT. 3, 1986, PROCEEDINGS. VOLUMES 1 & 2
Meeting supported by the Human Factors Society, USAF, University of Dayton, et al. Santa Monica, CA, Human Factors Society, 1986. Vol. 1, 758 p.; vol. 2, 754 p. For individual items see A87-33002 to A87-33073.

The conference presents papers on the habitability and facilities of space environments, Forecast II, the validation and application of the criterion task set, visual display research, three-dimensional anthropometry, lifting, visual processes and visual detection, human factors in space, and simulator aftereffects. Other topics include the integration and display of multidimensional information, human factors applications in nonmilitary systems, aviation psychology, design applications in consumer products, and the evaluation of display characteristics. Particular attention is given to the super cockpit and its human factors challenges; individual differences in criterion task set performance; linguistic processing; the use of eye control to select switches; simulated daylight; multimodal interfaces in supervisory control; man/system integration standards for space systems; and USAF experience with simulator sickness, research, and training. K.K.

A87-33013
A COMPARISON BETWEEN SPACE SUITED AND UNSUITED REACH ENVELOPES
J. H. STRAMLER (Northrop Services, Inc., Houston, TX) IN: Human Factors Society, Annual Meeting, 30th, Dayton, OH, Sept. 29-Oct. 3, 1986, Proceedings. Volume 1 . Santa Monica, CA, Human Factors Society, 1986, p. 221-224.

A comparison was made for the reach capability of Shuttle space suit vs unsuited. Graphics were generated and reach envelope volumes computed. The space suit reduces the reach envelope volume from about 64 to 97 percent, depending on the type of envelope measured. Author

A87-33021
HUMAN PERFORMANCE IN SPACE
DAVID M. REGAL (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: Human Factors Society, Annual Meeting, 30th, Dayton, OH, Sept. 29-Oct. 3, 1986, Proceedings. Volume 1 . Santa Monica, CA, Human Factors Society, 1986, p. 365-369.

Space provides a unique living and working environment. Humans in space are, in many respects, different creatures than their earth-bound counterparts (e.g., they float). The paper describes some of the ways in which human capabilities in space are different from those on earth. Psychological and social factors that can affect crew performance on long-duration space missions are discussed. Author

A87-33551
STRUCTURES, STRUCTURAL DYNAMICS AND MATERIALS CONFERENCE, 28TH, MONTEREY, CA, APR. 6-8, 1987, TECHNICAL PAPERS. PART 1
Conference sponsored by AIAA, ASME, ASCE, and AHS. New York, American Institute of Aeronautics and Astronautics, 1987, 884 p. For individual items see A87-33552 to A87-33653.

The present conference considers the structural behavior of solid rocket motor field joints, design engineering technologies for aerospace vehicles, the generalization of an equivalent plate representation for aircraft structural analysis, control-augmented structural synthesis with transient response constraints, the optimal design of flexible arches, compressive deformation in polymer fibers, a probabilistic Hu-Washizu variational principle, the extension-twist coupling of composite circular tubes for tilt rotor blade applications, and a creep-rupture model of filament-wound spherical pressure vessels. Also discussed are tough advanced composite structures, simultaneous structure/control optimization of large flexible spacecraft, improved optimum design of dewar supports, the shear strength of structural adhesives, the performance of trigonometric-basis function finite elements in Timoshenko beams, on-orbit damage assessment for large space structures, and the structural tailoring of advanced turboprops. O.C.

A87-33654
STRUCTURES, STRUCTURAL DYNAMICS AND MATERIALS CONFERENCE, 28TH, MONTEREY, CA, APR. 6-8, 1987 AND AIAA DYNAMICS SPECIALISTS CONFERENCE, MONTEREY, CA, APR. 9, 10, 1987, TECHNICAL PAPERS. PARTS 2A & 2B
Conferences sponsored by AIAA, ASME, ASCE, and AHS. New York, American Institute of Aeronautics and Astronautics, 1987. Pt. 2A, 585 p.; pt. 2B, 572 p. For individual items see A87-33655 to A87-33761.

Papers are presented on an aeroelatic analysis of launch vehicles in transonic flight, the dynamical response to pulse excitations in large space structures, an analytical flutter investigation of a composite propfan model, and an analysis of Intelsat V flight data. Also considered are the effective stiffness of a structural component under parametric dynamic loading, the effect of nonlinearities on the dynamic response of a large Shuttle payload, and active suppression of an apparent shock induced instability. Other topics include positive position feedback control for large space structures, a flutter analysis of aeronautical composite structures by an improved supersonic kernel function method, and aeroelastic characteristics of swept circulation control wings. Papers are also presented on dynamic and attitude control characteristics of an International Space Station, wave propagation in periodic truss structures, and the hingeless rotor response to random gusts in forward flight. R.R.

A87-35282
COMPUTERIZED AEROSPACE MATERIALS DATA; PROCEEDINGS OF THE WORKSHOP ON COMPUTERIZED PROPERTY MATERIALS AND DESIGN DATA FOR THE AEROSPACE INDUSTRY, EL SEGUNDO, CA, JUNE 23-25, 1986
JACK H. WESTBROOK, ED. (Sci-Tech Knowledge Systems, Scotia, NY) and LOUIS R. MCCREIGHT, ED. (Aerospace Corp., El Segundo, CA) Workshop sponsored by the Aerospace Corp., Strategic Defense Initiative Organization, AIAA, et al. New York, American Institute of Aeronautics and Astronautics, Inc., 1987, 213 p. For individual items see A87-35283 to A87-35285.

Recommendations and guidelines are presented for the development of The National Materials Property Data Network. The underlying motivations for extablishing the Network are delineated, particularly its necessity for maintaining the competitiveness of U.S. industries. Providing on-line access to published technical documentation and research data, the Network subject matter will cover the physical, mechanical, corrosion and chemical properties of materials from indigenous and worldwise sources. The coverage will eventually extend to the optical and electrical properties of materials, along with access to hardcopy information. Information on metals, composites, polymers, structural materials for microapplications, ceramics and adhesives is to be available. Plans for the access procedures and the use interface are explored. Consideration is also given to applying CAD capabilities for integrated life-cycle planning during the design phase. M.S.K.

A87-38567* Howard Univ., Washington, D. C.
TETHERS IN SPACE; PROCEEDINGS OF THE INTERNATIONAL CONFERENCE, ARLINGTON, VA, SEPT. 17-19, 1986
PETER M. BAINUM, ED. (Howard University, Washington, DC), IVAN BEKEY, ED. (NASA, Office of Space Flight, Washington, DC), LUCIANO GUERRIERO, ED. (CNR, Rome, Italy), and PAUL A. PENZO, ED. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Conference sponsored by NASA, CNR, AIAA, AAS, et al. San Diego, CA, Univelt, Inc. , 1987, 765 p. For individual items see A87-38568 to A87-38574.

A collection of papers on the applications of tethers in space is presented. Tether flight experiments of the past, in planning stages, and in the future are examined. Tether dynamics and the applications and technical aspects of electrodynamic tethers are addressed. The use of tethers on the Space Station and applications in the Space Station era are considered. Individual tether technology issues, including tether materials and instrumentation for atmospheric measurements are discussed. C.D.

A87-38576
INTERNATIONAL SAMPE TECHNICAL CONFERENCE, 18TH, SEATTLE, WA, OCT. 7-9, 1986, PROCEEDINGS
J. T. HOGGATT, ED., S. G. HILL, ED., and J. C. JOHNSON, ED. (Boeing Co., Seattle, WA) Conference sponsored by SAMPE. Covina, CA, Society for the Advancement of Material and Process Engineering (International SAMPE Technical Conference Series. Volume 18), 1986, 1137 p. For individual items see A87-38577 to A87-38584, A87-38586 to A87-38643.

The present conference on advanced materials applicable to *spacecraft structures and components discusses low distortion* tooling for high precision space components, thermoplastic matrix composites, an industrial space facility, composite fabrication process automation, the fusion bonding of thermoplastic composites, failure-resistant bismaleimide/carbon composites, a solvent-resistant thermoplastic, the degradation of teflon in an oxidizing plasma, microgravity processing of zeolites in space, and joint technology for the Space Station truss structure. Also considered are space environment-induced microdamage, composite tubes for the Space Station truss structure, novel polyarylene ethers, composite space antenna structures, the thermal expansion behavior of graphite/glass and graphite/magnesium, an atomic oxygen beam facility, encapsulants for electronic components, high temperature aromatic matrix systems, and materials issues associated with the Space Station. O.C.

A87-38701
AEROSPACE ENVIRONMENTAL SYSTEMS; PROCEEDINGS OF THE SIXTEENTH INTERSOCIETY CONFERENCE ON ENVIRONMENTAL SYSTEMS, SAN DIEGO, CA, JULY 14-16, 1986
Conference sponsored by SAE. Warrendale, PA, Society of Automotive Engineers, Inc. (SAE P-177), 1986, 908 p. For individual items see A87-38702 to A87-38784.
(SAE P-177)

The present conference discusses integrated aircraft fuel thermal management, aircraft fog control systems, food and nutrition in manned spacecraft, a NASA Space Station health maintenance facility, Space Station personal hygiene, radiation dose prediction for the Space Station, the NASA Space Station's Habitation Module, an analysis of crew functions as an aid in Space Station interior layout, the thermal performance of Giotto, systems aspects of Columbus thermal control, and regenerative life support system hardware testing. Also considered are a comparison of environmental control and life support systems *requirements for nuclear submarines and the NASA Space Station,* space suit reach and strength envelope considerations, an EVA universal work station, a thermal analyzer for two-phase loops, a cryogenic methane heat pipe diode, Space Station air revitalization, long duration botanical experiments in space, plant and animal accommodations aboard the Space Station, spacecraft water recovery, physiological aspects of EVA, the integrated management of water and wastes, and advanced extravehicular crew enclosures. O.C.

A87-38713
ENERGY EXPENDITURE DURING SIMULATED EVA WORKLOADS
REBECCA S. INDERBITZEN (USAF, School of Aerospace Medicine, Brooks AFB, TX) and JAMES J. DECARLIS, JR. IN: Aerospace environmental systems; Proceedings of the Sixteenth Intersociety Conference on Environmental Systems, San Diego, CA, July 14-16, 1986 . Warrendale, PA, Society of Automotive Engineers, Inc., 1986, p. 109-112. refs
(SAE PAPER 860921)

In ongoing decompression sickness studies at the USAF School of Aerospace Medicine, an exercise regimen is used in which EVA is simulated. A ground-based study was undertaken in order to assess, for the protocol, the currently accepted value of energy expenditure (150-200 kcal/hr) which was based on very limited data. Six male and five female subjects performed an hour of *exerise comprised of three tasks analogous to actual tasks* performed by astronauts during EVA. Metabolic data were collected using an open-loop oxygen consumption meter during rest and exercise. Gender differences in energy expenditure during performance disappeared when the values were expressed in terms of added energy cost, body weight or lean-body mass. Author

A87-38785
SYMPOSIUM ON MICROGRAVITY FLUID MECHANICS, PROCEEDINGS OF THE WINTER ANNUAL MEETING, ANAHEIM, CA, DEC. 7-12, 1986
D. J. NORTON, ED. (Houston Area Research Center, TX) Symposium sponsored by ASME. New York, American Society of Mechanical Engineers, 1986, 77 p. For individual items see A87-38786 to A87-38797.

Papers are presented on the development of two-phase computer codes for microgravity applications, diffusion flame extinction in slow convective flow under microgravity environment, a differential approach to heat pipe priming in microgravity, an experimental study using flow visualization on the effect of an acoustic field on heat transfer, and equilibrium fluid interfaces in the absence of gravity. Consideration is given to microcirculatory fluid dynamics in weightlessness and simulated weightlessness, zero-G fluid mechanics in animals and man, cardiovascular adaptation to zero-G, microgravity-induced fluid and electrolyte

balance changes, and continuous flow electrophoresis in microgravity. Additional papers are on Space Station fluid management systems, low-G fluid motion test and analysis, the transient flow analysis and testing of the Space Shuttle Reaction Control System's low-G propellant acquisition system, and propellant tank forces resulting from fluid motion in a low-gravity field. I.S.

A87-40051
U.S. NATIONAL CONGRESS OF APPLIED MECHANICS, 10TH, UNIVERSITY OF TEXAS, AUSTIN, JUNE 16-20, 1986, PROCEEDINGS
J. PARKER LAMB, ED. (Texas, University, Austin) Congress organized by the National Academy of Sciences and National Academy of Engineering; Supported by NSF, U.S. Navy, Dow Chemical Co., et al. New York, American Society of Mechanical Engineers, 1987, 558 p. For individual items see A87-40052 to A87-40085.
(AD-A181962)

Recent advances in applied mechanics are addressed in reviews and reports of theoretical and experimental investigations. Topics examined include cellular biomechanics, computational fluid mechanics, continuum damage mechanics, dispersed systems, the dynamic stability of structures, experimental methods in mechanics, and fluid mechanics in material processing. Consideration is given to manufacturing processes, material modeling for fracture, the mechanics of particulate media, NDE, space structures, stability and the transition to turbulence, temporal and spatial chaos, and unsteady aerodynamics. T.K.

A87-40351
EASCON '86; PROCEEDINGS OF THE NINETEENTH ANNUAL ELECTRONICS AND AEROSPACE SYSTEMS CONFERENCE, WASHINGTON, DC, SEPT. 8-10, 1986
Conference sponsored by IEEE, Armed Forces Communications and Electronics Association, and National Space Club. New York, Institute of Electrical and Electronics Engineers, Inc., 1986, 296 p. For individual items see A87-40352 to A87-40381.

Papers are presented on civilian space programs, military space programs, the status of the Space Station, and satellite communications in the fiber era. Topics discussed include remote sensing programs, Space Station communications and data management, communications satellite systems, and advanced software and microelectronics technology. Consideration is given to Space Station experiments, near-term science missions, communications technology, very small aperture terminals, future science missions, and avionics, robotic, and support technology. I.F.

A87-41568
SPACE: NEW OPPORTUNITIES FOR ALL PEOPLE; SELECTED PROCEEDINGS OF THE THIRTY-SEVENTH INTERNATIONAL ASTRONAUTICAL CONGRESS, INNSBRUCK, AUSTRIA, OCT. 4-11, 1986
L. G. NAPOLITANO, ED. (Napoli, Universita, Naples, Italy) Congress sponsored by IAF. Acta Astronautica (ISSN 0094-5765), vol. 16, 1987, 402 p. For individual items see A87-41570 to A87-41575.

The present conference on astronautics considers the NASA Automation and Robotics Technology Program, the objectives and design of the Columbus system, a NASA Space Station development status assessment, international commonality for the Space Station, the Voyager Uranus mission, trends in space transportation, advanced space propulsion concepts, a model test vehicle for hypersonic aerospace system development, and satellite autonomous navigation employing Navsat. Also discussed are the DORIS orbitography and positioning system, a quality assessment of SPOT 1 images, an evaluation of mobile satellite systems, mobile communications, navigation and surveillance, a closed Brayton solar dynamic power system for the Space Station, hydrocarbon rocket propulsion technology, and the Hermes shuttle thermal protection system. O.C.

A87-41615*# Colorado Univ., Boulder.
INADEQUACY OF SINGLE-IMPULSE TRANSFERS FOR PATH CONSTRAINED RENDEZVOUS
S. A. STERN (Colorado, University, Boulder) and K. M. SOILEAU (NASA, Johnson Space Center, Houston, TX) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 24, May-June 1987, p. 282-284. refs

The use of single-impulse techniques to maneuver from point to point about a large space structure (LSS) with an arbitrary geometrical configuration and spin is examined. Particular consideration is given to transfers with both endpoints on the forbidden zone surface. Clohessy-Wiltshire equations of relative motion are employed to solve path constrained rendezvous problems. External and internal transfers between arbitrary points are analyzed in terms of tangential departure and arrival conditions. It is observed that single-impulse techniques are inadequate for transferring about the exterior of any LSS; however, single-impulse transfers are applicable for transfers in the interior of LSSs. It is concluded that single-impulse transducers are not applicable for path constrained rendezvous guidance. I.F.

A87-44176* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
REMOTE SENSING; PROCEEDINGS OF THE MEETING, ORLANDO, FL, APR. 3, 4, 1986
ROBERT T. MENZIES, ED. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 644), 1986, 115 p. For individual items see A87-44177 to A87-44187.
(SPIE-644)

Advances in optical technology for remote sensing are discussed in reviews and reports of recent experimental investigations. Topics examined include industrial applications, laser diagnostics for combustion research, laser remote sensing for ranging and altimetry, and imaging systems for terrestrial remote sensing from space. Consideration is given to LIF in forensic diagnostics, time-resolved laser-induced-breakdown spectrometry for rapid analysis of alloys, CARS in practical combustion environments, airborne inertial surveying using laser tracking and profiling techniques, earth-resources instrumentation for the EOS polar platform of the Space Station, and the SAR for EOS. T.K.

A87-44393
COLLISION PROBABILITIES IN GEOSYNCHRONOUS ORBIT AND TECHNIQUES TO CONTROL THE ENVIRONMENT
BERNELL MCCORMICK (McDonnell Douglas Astronautics Co., Houston, TX) (COSPAR and IAF, Plenary Meeting, 26th, Topical Meetings and Workshop on Cosmic Dust and Space Debris, 6th, Toulouse, France, June 30-July 11, 1986) Advances in Space Research (ISSN 0273-1177), vol. 6, no. 7, 1986, p. 119-126. refs

This paper addresses the physical crowding problem of geosynchronous satellites by summarizing two independent analyses. The first analysis included developing a new technique for predicting the expected time between collisions of active geosynchronous satellites with expired geosynchronous satellites. The unique feature of this new technique is that deterministic methods are used to model the motion of satellites and statistical techniques are employed to estimate collision probability. This allows realistic distributions of active and expired satellites to be used in the prediction process. The results of this new technique compare very closely to the results of previously used techniques. The second analysis addresses disposal options for spent upper stages (PAM-D, IUS, etc.) that are currently left in stable elliptical orbits. These spent upper stages are a hazard to the geosynchronous region as well as low earth orbits. Two propulsive techniques are presented that will reduce the orbit lifetime of the spent upper stages. Author

A87-44533* Perkin-Elmer Corp., Danbury, Conn.
OPTICAL ARRAYS FOR FUTURE ASTRONOMICAL TELESCOPES IN SPACE
ALAN N. BUNNER (Perkin-Elmer Corp., Space Science Div., Danbury, CT) IN: Infrared, adaptive, and synthetic aperture optical systems; Proceedings of the Meetings, Arlington, VA, Apr. 8, 1985 and Orlando, FL, Apr. 1, 2, 1986 . Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1986, p. 180-188. refs (Contract NAS8-36105)

NASA's Marshall Space Flight Center is currently evaluating several advanced optical space telescope concepts for the achievement of both higher sensitivity and greater angular resolution than the Hubble Space Telescope; their designs encompass one- and two-dimensional coherent arrays of mirrors in both focal and afocal configurations. Attention is given to those arrays that appear capable of fabrication and orbital deployment by the year 2005, and to the tradeoff involved between synthetic aperture concepts that furnish high angular resolution and those that yield sensitivity for faint, extended source imaging. O.C.

A87-45476
GLOBECOM '86 - GLOBAL TELECOMMUNICATIONS CONFERENCE, HOUSTON, TX, DEC. 1-4, 1986, CONFERENCE RECORD. VOLUMES 1, 2, & 3
Conference sponsored by IEEE. New York, Institute of Electrical and Electronics Engineers, Inc., 1986. Vol. 1, 664 p.; vol. 2, 619 p.; vol. 3, 660—p. For individual items see A87-45477 to A87-45559.

Papers are presented on local area networks; formal methods for communication protocols; computer simulation of communication systems; spread spectrum and coded communications; tropical radio propagation; VLSI for communications; strategies for increasing software productivity; multiple access communications; advanced communication satellite technologies; and spread spectrum systems. Topics discussed include Space Station communication and tracking development and design; transmission networks; modulation; data communications; computer network protocols and performance; and coding and synchronization. Consideration is given to free space optical communications systems; VSAT communication networks; network topology design; advances in adaptive filtering echo cancellation and adaptive equalization; advanced signal processing for satellite communications; the elements, design, and analysis of fiber-optic networks; and advances in digital microwave systems. I.F.

A87-48600*# National Aeronautics and Space Administration, Washington, D.C.
TECHNICAL AND MANAGEMENT INFORMATION SYSTEM (TMIS)
TIMOTHY R. RAU (NASA, Washington, DC) AIAA and NASA, International Symposium on Space Information Systems in the Space Station Era, Washington, DC, June 22, 23, 1987. 10 p.
(AIAA PAPER 87-2217)

The TMIS goals developed to support the Space Station Program (SSP) mission requirements are outlined. The TMIS will provide common capabilities to all SSP centers and facilitate the flow of technical and management information throughout the program as well as SSP decision-making processes. A summary is presented of the various TMIS phases. K.K.

A87-50401
AIAA GUIDANCE, NAVIGATION AND CONTROL CONFERENCE, MONTEREY, CA, AUG. 17-19, 1987, TECHNICAL PAPERS. VOLUMES 1 & 2
Conference sponsored by AIAA. New York, American Institute of Aeronautics and Astronautics, 1987, p. Vol. 1, 829 p.; vol. 2, 676 p. For individual items see A87-50402 to A87-50570.

The conference presents papers on control system synthesis and analysis, differential games, control of large flexible space structures, integrated flight systems applications, and robotics for space applications. Other topics include the artificial intelligence design challenge, aircraft guidance and control in severe windshear, and missile estimation and guidance strategies. Consideration is also given to guidance and navigation for space applications, inertial instrumentation and system testing and geokinetics, missile nonlinear control and trajectory optimization, computer-aided control design, man-in-the-flight control loop, spacecraft attitude determination and control, and fault tolerant systems. K.K.

A87-53082* United Technologies Corp., East Hartford, Conn.
THE HUMAN QUEST IN SPACE; PROCEEDINGS OF THE TWENTY-FOURTH GODDARD MEMORIAL SYMPOSIUM, GREENBELT, MD, MAR. 20, 21, 1986
GERALD L. BURDETT, ED. (United Technologies Corp., Hartford, CT) and GERALD A. SOFFEN, ED. (NASA, Goddard Space Flight Center, Greenbelt, MD) Symposium organized by AAS; Sponsored by AAS, AIAA, National Space Club, and National Space Institute. San Diego, CA, Univelt, Inc. (Science and Technology Series. Volume 65), 1987, 310 p. For individual items see A87-53083 to A87-53093.

Papers are presented on the Space Station, materials processing in space, the status of space remote sensing, the evolution of space infrastructure, and the NASA Teacher Program. Topics discussed include visionary technologies, the effect of intelligent machines on space operations, future information technology, and the role of nuclear power in future space missions. Consideration is given to the role of humans in space exploration; medical problems associated with long-duration space flights; lunar and Martian settlements, and Biosphere II (the closed ecology project). I.F.

A87-53089
HUMAN CAPABILITIES IN SPACE
BYRON K. LICHTENBERG (Payload Systems, Inc., Wellesley, MA) IN: The human quest in space; Proceedings of the Twenty-fourth Goddard Memorial Symposium, Greenbelt, MD, Mar. 20, 21, 1986 . San Diego, CA, Univelt, Inc., 1987, p. 183-194.
(AAS PAPER 86-114)

The role of humans in space is discussed. The crew is concerned with flying the vehicle, operating experiments, participating in biomedical studies, and exploring outside the spacecraft. The use of the crew to construct large structures, such as the Space Station, in space and the functions of the crew on the Space Station are examined. I.F.

N87-20306*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md. Space Welding Project.
GAS TUNGSTEN ARC WELDING IN A MICROGRAVITY ENVIRONMENT: WORK DONE ON GAS PAYLOAD G-169
BLAKE A. WELCHER, FAYSAL A. KOLKAILAH, and ARTHUR H. MUIR, JR. (Rockwell International Corp., Thousand Oaks, Calif.) *In* NASA. Goddard Space Flight Center The 1986 Get Away Special Experimenter's Symposium p 23-29 Feb. 1987
Avail: NTIS HC A11/MF A01 CSCL 11F

GAS payload G-169 is discussed. G-169 contains a computer-controlled Gas Tungsten Arc Welder. The equipment design, problem analysis, and problem solutions are presented. Analysis of data gathered from other microgravity arc welding and terrestrial Gas Tungsten Arc Welding (GTAW) experiments are discussed in relation to the predicted results for the GTAW to be performed in microgravity with payload G-169. Author

N87-20355# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
MECHANICAL QUALIFICATION OF LARGE FLEXIBLE SPACECRAFT STRUCTURES
Jul. 1986 269 p In ENGLISH and FRENCH Meeting held in Oberammergau, West Germany, 9-13 Sep. 1985
(AD-A175529; AGARD-CP-397; ISBN-92-835-0396-1) Avail: NTIS HC A12/MF A01

An account is given of Conference Proceedings of a Specialists' Meeting held by the Structures and Materials Panel in Oberammergau in the Fall of 1985. The problems associated with

the mechanical qualification of flexible spacecraft are discussed, and details of relevant methods and techniques are given. The final discussion highlights the difficulties associated with advanced methods of experimental and theoretical dynamic analysis and the handling of larger and larger amounts of data.

N87-20574# Shock and Vibration Information Center (Defense), Washington, D. C.
THE SHOCK AND VIBRATION BULLETIN. PART 1: WELCOME, INVITED PAPERS, SHIPBOARD SHOCK, BLAST AND GROUND SHOCK, SHOCK TESTING AND ANALYSIS
Aug. 1986 297 p Proceedings of the 56th Shock and Vibration Symposium, Monterey, Calif., 22-24 Oct. 1985
(AD-A175224; SVIC-BULL-56-PT-1) Avail: NTIS HC A13/MF A01

Topics addressed include: solid mechanics; shock mechanics; dynamics and control of large space structures; structural dynamic response analysis methods; shipborne shock; blast and ground shock; and shock testing and analysis.

N87-20621# European Space Agency, Paris (France).
PROCEEDINGS OF THE EUROPEAN SYMPOSIUM ON POLAR PLATFORM OPPORTUNITIES AND INSTRUMENTATION FOR REMOTE-SENSING (ESPOIR)
E. J. ROLFE, ed. and B. BATTRICK, ed. Nov. 1986 127 p Symposium held in Avignon, France, 16-18 Jun. 1986
(ESA-SP-266; ISSN-0379-6566; ETN-87-99434) Avail: NTIS HC A07/MF A01

European activities in preparing the Columbus polar platforms; United States cooperation with Europe; atmosphere, land, ocean/ice, and solid Earth missions; and platform instruments, calibrating, data management, orbit configuration, and servicing were discussed.

ESA

N87-20665*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
UPPER AND MIDDLE ATMOSPHERIC DENSITY MODELING REQUIREMENTS FOR SPACECRAFT DESIGN AND OPERATIONS
M. H. DAVIS, ed. (Universities Space Research Association, Boulder, Colo.), R. E. SMITH, ed., and D. L. JOHNSON, ed. Feb. 1987 290 p Workshop held in Huntsville, Ala., 19-21 1985
(Contract NAS8-36400)
(NASA-CP-2460; M-548; NAS 1.55:2460) Avail: NTIS HC A13/MF A01 CSCL 04A

Presented and discussed are concerns with applications of neutral atmospheric density models to space vehicle engineering design and operational problems. The area of concern which the atmospheric model developers and the model users considered, involved middle atmosphere (50 to 90 km altitude) and thermospheric (above 90 km) models and their engineering application. Engineering emphasis involved areas such as orbital decay and lifetime prediction along with attitude and control studies for different types of space and reentry vehicles.

N87-21141*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
MICROGRAVITY FLUID MANAGEMENT SYMPOSIUM
Apr. 1987 225 p Symposium held in Cleveland, Ohio, 9-10 Sep. 1986
(NASA-CP-2465; E-3386; NAS 1.55:2465) Avail: NTIS HC A10/MF A01 CSCL 22A

The NASA Microgravity Fluid Management Symposium, held at the NASA Lewis Research Center, September 9 to 10, 1986, focused on future research in the microgravity fluid management field. The symposium allowed researchers and managers to review space applications that require fluid management technology, to present the current status of technology development, and to identify the technology developments required for future missions. The 19 papers covered three major categories: (1) fluid storage, acquisition, and transfer; (2) fluid management applications, i.e., space power and thermal management systems, and environmental control and life support systems; (3) project activities and insights including two descriptions of previous flight experiments and a summary of typical activities required during development of a shuttle flight experiment.

N87-21151*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
SUPERFLUID HELIUM ON ORBIT TRANSFER (SHOOT)
MICHAEL J. DIPIRRO *In* NASA. Lewis Research Center Microgravity Fluid Management Symposium p 125-136 Apr. 1987
Avail: NTIS HC A10/MF A01 CSCL 22A

A number of space flight experiments and entire facilities require superfluid helium as a coolant. Among these are the Space Infrared Telescope Facility (SIRTF), the Large Deployable Reflector (LDR), the Advanced X-ray Astrophysics Facility (AXAF), the Particle Astrophysics Magnet Facility (PAMF or Astromag), and perhaps even a future Hubble Space Telescope (HST) instrument. Because these systems are required to have long operational lifetimes, a means to replenish the liquid helium, which is exhausted in the cooling process, is required. The most efficient method of replenishment is to refill the helium dewars on orbit with superfluid helium (liquid helium below 2.17 Kelvin). To develop and prove the technology required for this liquid helium refill, a program of ground and flight testing was begun. The flight demonstration is baselined as a two flight program. The first, described in this paper, will prove the concepts involved at both the component and system level. The second flight will demonstrate active astronaut involvement and semi-automated operation. The current target date for the first launch is early 1991.

N87-22702*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
STRUCTURAL DYNAMICS AND CONTROL INTERACTION OF FLEXIBLE STRUCTURES
ROBERT S. RYAN, ed. and HAROLD N. SCOFIELD, ed. Apr. 1987 680 p Workshop held in Huntsville, ALa., 22-24 Apr. 1986
(NASA-CP-2467-PT-1; M-554-PT-1; NAS 1.55:2467-PT-1) Avail: NTIS HC A99/MF E03 CSCL 22B

A workshop on structural dynamics and control interaction of flexible structures was held to promote technical exchange between the structural dynamics and control disciplines, foster joint technology, and provide a forum for discussing and focusing critical issues in the separate and combined areas. Issues and areas of emphasis were identified in structure-control interaction for the next generation of flexible systems.

N87-22762# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
DEVELOPING A VOICE-CONTROLLED, COMPUTER-GENERATED DISPLAY TO ASSIST SPACE STATION ASTRONAUTS DURING MAINTENANCE ACTIVITY M.S. Thesis
PAUL J. PABICH Dec. 1986 240 p
(AD-A178997; AFIT/GSO/ENG/86D-1) Avail: NTIS HC A11/MF A01 CSCL 22B

This thesis illustrated a planning strategy for a voice-controlled, computer-generated maintenance display which would be used by astronauts when completing maintenance activity outside the proposed U.S. space station. After justifying the usefulness of a proposed systems engineering approach, five main objectives were provided: (1) the vertical stanchion of the Manipulator Foot Restraint would provide an adequate base for the display so it could be moved to and from the worksite; (2) liquid crystal display technology should be used; (3) for voice-controlled operations, the best type of recognition unit to use would be one where the unit understands only one speaker at a time and only one word at a time; (4) experimental data suggest that a hierarchical scheme should be used for the menu format; (5) use of text, audio, graphics, and color for the proposed display. Only text and graphics were recommended for use. A proposed display format was presented showing the placement of the menu, text and graphics using some

known data about how the human brain processes information.
GRA

N87-23677# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
A QUANTITATIVE COMPARISON OF SEVERAL ORBITAL MANEUVERING VEHICLE CONFIGURATIONS FOR SATELLITE REPAIR/REPLENISHMENT M.S. Thesis
JOSEPH H. CAVALLARO 16 Jun. 1987 75 p
(AD-A179106; AFIT/GSO/AA/86D-2) Avail: NTIS HC A04/MF A01 CSCL 22A

The history of spaceflight is full of examples of astronaut crewmembers returning damaged/malfunctioning spacecraft to an operational status. The recent Space Shuttle rescues of Solar Max, Westar and Palapa B-11 are perhaps the most dramatic of these. The current operational concept of servicing the target vehicle on board the shuttle however limits the potential number of spacecraft which can be reached. A potential solution is to use the Orbital Maneuvering Vehicle (OMV) that NASA is developing as a multi-role spacecraft. Use of the OMV has the potential of extending the reach of servicing to spacecraft beyond the range of the Shuttle. This paper examines three OMV/Servicer configurations, including both telepresence and manned version. The Analytic Hierarchy Process is used to rank order the alternatives for further study. A computer program was used to solve for the weights of the various measures of the effectiveness, and resulting priority vector was calculated. Preliminary results show the telepresence servicer rated highest, followed by the full environment manned system. GRA

N87-24162*# National Academy of Sciences - National Research Council, Washington, D. C. Committee on Hearing, Bioacoustics, and Biomechanics.
GUIDELINES FOR NOISE AND VIBRATION LEVELS FOR THE SPACE STATION
Jun. 1987 39 p
(Contract NASA ORDER L-76724-B)
(NASA-CR-178310; NAS 1.26:178310) Avail: NTIS HC A03/MF A01 CSCL 20A

Human habitability noise and vibration guidelines for the Space Station are presented. These were developed by a working group of experts established by the Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) of the National Research Council's Commission on Behavioral and Social Science and Education. Noise exposure limits are suggested that will permit adequate speech communication, sleep, and hearing safety. Vibration exposure limits are suggested which will provide adequate comfort and permit adequate task performance. These are provided for guidance only for setting criteria. The exact criteria will depend on Space Station design and duty cycles. Author

N87-24495*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
NASA/DOD CONTROL/STRUCTURES INTERACTION TECHNOLOGY, 1986
ROBERT L. WRIGHT, comp. Jun. 1987 314 p Conference held in Norfolk, Va., 18-21 Nov. 1986
(NASA-CP-2447-PT-2; L-16242-PT-2; NAS 1.55:2447-PT-2)
Avail: NTIS HC A14/MF A01 CSCL 22B

Papers presented at the CSI Technology Conference are given. The conference was jointly sponsored by the NASA Office of Aeronautics and Space Technology and the Department of Defense. The conference is the beginning of a series of annual conferences whose purpose is to report to industry, academia, and government agencies the current status of Control/Structures Interaction technology. The conference program was divided into five sessions: (1) Future spacecraft requirements; Technology issues and impact; (2) DOD special topics; (3) Large space systems technology; (4) Control of flexible structures, and (5) Selected NASA research in control structures interaction.

N87-24503*# Martin Marietta Aerospace, Denver, Colo.
BOX TRUSS ANTENNA TECHNOLOGY STATUS
J. V. COYNER and E. E. BACHTELL *In* NASA-Langley Research Center NASA/DOD Control/Structures Interaction Technology, 1986 p 717-736 Jun. 1987 Previously announced as 87N-16023
Avail: NTIS HC A14/MF A01 CSCL 22B

Recent technology development activities for box truss structures and box truss antennas are summarized. Three primary activities are discussed: the development of an integrated analysis system for box truss mesh antennae; dynamic testing to characterize the effect of joint free play on the dynamic behavior of box truss structures; and fabrication of a 4.5 meter diameter offset fed mesh reflector integrated to an all graphite epoxy box truss cube. Author

N87-24515 Colorado Univ., Boulder.
SIMULATION OF ON-ORBIT SATELLITE FRAGMENTATIONS Ph.D. Thesis
DARREN SCOTT MCKNIGHT 1986 241 p
Avail: Univ. Microfilms Order No. DA8706439

The debris from nearly ninety satellites that have fragmented pose a serious hazard to all space systems in Earth orbit. A program has been developed which simulates fragmentation events whose magnitude, size distribution, velocity distribution, geometry, and location of breakup may all be controlled. This numerical model simulates in-orbit satellite fragmentations generating debris fragments across the entire size spectrum, many of which would be nondetectable by the NORAD Space Network. Monte Carlo methods are used to generate the size and velocity distributions of fragments according to hypothetical distributions derived from laboratory experiments. After breakup, the particles' orbits are propagated under the influence of drag and the J sub 2 gravitational term. This simulation program provides insight into the nontrackable debris population available through no other means. The simulation of the Kosmos 1275 breakup supports the speculation that it is the first accidental collision-induced satellite breakup.
Dissert. Abstr.

N87-25354# European Space Agency, Paris (France).
PROCEEDINGS OF THE SECOND INTERNATIONAL SYMPOSIUM ON SPACECRAFT FLIGHT DYNAMICS
T. D. GUYENNE, comp. and J. J. HUNT, comp. Dec. 1986 501 p Symposium held in Darmstadt, West Germany, 20-23 Oct. 1986
(ESA-SP-255; ISSN-079-6566; ETN-87-99862) Avail: NTIS HC A22/MF A01

Flexible spacecraft dynamics; halo orbits; interplanetary trajectories; geostationary satellites; precise orbit determination; onboard systems and spacecraft hardware; orbital mechanics; spinning spacecraft; satellite tracking; and ground systems were discussed.
ESA

N87-25760*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
WORKSHOP ON WORKLOAD AND TRAINING, AND EXAMINATION OF THEIR INTERACTIONS: EXECUTIVE SUMMARY
EMANUEL DONCHIN (Illinois Univ., Urbana-Champaign.), SANDRA G. HART, and EARL J. HARTZELL Jul. 1987 40 p Workshop held in Carmel, Calif., 5-10 Jan. 1986
(NASA-TM-89459; A-87212; NAS 1.15:89459) Avail: NTIS HC A03/MF A01 CSCL 05H

The goal of the workshop was to bring together experts in the fields of workload and training and representatives from the Dept. of Defense and industrial organizations who are reponsible for specifying, building, and managing advanced, complex systems. The challenging environments and requirements imposed by military helicopter missions and space station operations were presented as the focus for the panel discussions. The workshop permitted a detailed examination of the theoretical foundations of the fields of training and workload, as well as their practical applications.

Furthermore, it created a forum where government, industry, and academic experts were able to examine each other's concepts, values, and goals. The discussions pointed out the necessity for a more efficient and effective flow of information among the groups respresented. The executive summary describes the rationale of the meeting, summarizes the primary points of discussion, and lists the participants and some of their summary comments.
Author

N87-26073* National Aeronautics and Space Administration, Washington, D.C.
SPACE STATION SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 4)
May 1987 220 p
(NASA-SP-7056(04); NAS 1.21:7056(04)) Avail: NTIS HC A10 CSCL 22B

This bibliography lists 832 reports, articles, and other documents introduced into the NASA scientific and technical information system between July 1, 1986 and December 31, 1986. 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

N87-26173*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PROCEEDINGS OF THE NASA WORKSHOP ON ATOMIC OXYGEN EFFECTS
DAVID E. BRINZA, ed. 1 Jun. 1987 195 p Workshop held in Pasadena, Calif., 10-11 Nov. 1986
(Contract NAS7-918)
(NASA-CR-181163; JPL-PUB-87-14; NAS 1.26:181163) Avail: NTIS HC A09/MF A01 CSCL 07D

A workshop was held to address the scientific issues concerning the effects of atomic oxygen on materials in the low Earth orbital (LEO) environment. The program included 18 invited speakers plus contributed posters covering topics such as LEO spaceflight experiments, interaction mechanisms, and atomic oxygen source development. Discussion sessions were also held to organize a test program to evaluate atomic oxygen exposure facilities. The key issues raised in the workshop were: (1) the need to develop a reliable predictive model of the effects of long-term exposure of materials to the LEO environment; (2) the ability of ground-based exposure facilities to provide useful data for development of durable materials; and (3) accurate determination of the composition of the LEO environment. These proceedings include the invited papers, the abstracts for the contributed posters, and an account of the test program discussion sessions.

N87-26937# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Electromagnetic Wave Propagation Panel.
THE AEROSPACE ENVIRONMENT AT HIGH ALTITUDES AND ITS IMPLICATIONS FOR SPACECRAFT CHARGING AND COMMUNICATIONS
May 1987 286 p In ENGLISH and FRENCH Symposium held in The Hague, Netherlands, 2-6 Jun. 1986
(AGARD-CP-406; ISBN-92-835-0418-6; AD-A185880) Avail: NTIS HC A13/MF A01 CSCL 22B

The symposium examined how the magnetosphere and polar plasmas vary as a result of natural causes and man-made perturbations, and the implications of these variations for the charging and differential charging of spacecraft with their effects, in turn, on spacecraft systems and communications. A better understanding of these phenomena can help to design of spacecraft systems and subsystems to minimize the effects of these disturbances.

N87-26957# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Community Satellites Dept.
ELECTROSTATIC IMMUNITY OF GEOSTATIONARY SATELLITES
HORST G. LECHTE *In* AGARD, The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications 8 p May 1987
Avail: NTIS HC A13/MF A01

It is demonstrated that electrostatic immunity of telecommunication satellites can be achieved to a large extent by relatively simple means. Those means include the selection of antistatic external materials and the desensitization of electronic actuators and memories regarding fast transients. The dual approach is considered necessary because not all external surfaces can be made antistatic. Protection of operationally critical circuitries against single event upsets is achieved by the same means.
Author

N87-26967# Systems Science and Software, La Jolla, Calif.
DOCUMENTATION FOR THE SHADO PARTICLE WAKE ROUTINE Technical Report, Oct. 1986 - Jan. 1987
D. L. PETERKA and I. KATZ Jan. 1987 25 p
(Contract F19668-86-C-0056)
(AD-A181531; SSS-R-87-8495; AFGL-TR-87-0042; SR-5) Avail: NTIS HC A02/MF A01 CSCL 22B

This report documents the computational algorithms of the SHADO routine for computing the particle wake behind large spacecraft in low polar orbit. SHADO will replace the existing module for computing particle densities in the POLAR code and achieves a significant improvement in computational speed.
GRA

N87-28959# European Space Agency, Paris (France).
PROCEEDINGS OF THE FIFTH EUROPEAN SYMPOSIUM ON PHOTOVOLTAIC GENERATORS IN SPACE
W. R. BURKE, comp. Nov. 1986 486 p Symposium held in The Hague/Scheveningen, The Netherlands 30 Sep. - 2 Oct. 1986; sponsored by ESA, the Netherlands Agengy for Aerospace Programs, and the Royal Netherlands Aircraft Factories
(ESA-SP-267; ISSN-0379-6566; ETN-87-90157) Avail: NTIS HC A21/MF A01

Some areas of discussion at the symposium are solar cell technology, module technology, solar arrays, environmental interaction, in-flight performance,and alternative power generation. Also, cell assembly technology, solar array analytical modeling, and tests and measurements were discussed.
ESA

N87-29015# Physikalisch-Technische Bundesanstalt, Brunswick (West Germany).
ABSOLUTE INDOOR CALIBRATION OF LARGE AREA SOLAR CELLS
J. METZDORF, T. WITTCHEN, and H. KAASE *In* ESA Proceedings of the Fifth European Symposium on Photovoltaic Generators in Space p 397-401 Nov. 1986 Sponsored by the BMFT
Avail: NTIS HC A21/MF A01

Equipment for the calibration of reference solar cells which is traceable back to their primary radiometric standards is presented. The apparatus, based on the differential spectral responsivity method is an absolute indoor procedure without reference solar cells, and needs no solar simulator. The method is applicable to all kinds of test devices up to solar cell areas of 10 x 10 cm without any requirements on linearity and spectral responsivity of the cells.
ESA

N87-29124*# National Aeronautics and Space Administration, Washington, D.C.
PROCEEDINGS: COMPUTER SCIENCE AND DATA SYSTEMS TECHNICAL SYMPOSIUM, VOLUME 1
RONALD L. LARSEN and KENNETH WALLGREN Aug. 1985 353 p Symposium held in Leesburg, Va., 16-18 Apr. 1985
(NASA-TM-89285; NAS 1.15:89285) Avail: NTIS HC A16/MF A01 CSCL 09B

Progress reports and technical updates of programs being performed by NASA centers are covered. Presentations in viewgraph form are included for topics in three categories: computer science, data systems and space station applications.

N87-29144*# National Aeronautics and Space Administration, Washington, D.C.
PROCEEDINGS: COMPUTER SCIENCE AND DATA SYSTEMS TECHNICAL SYMPOSIUM, VOLUME 2
RONALD L. LARSEN and KENNETH WALLGREN Aug. 1985 381 p Symposium held in Leesburg, Va., 16-18 Apr. 1985
(NASA-TM-89286; NAS 1.15:89286) Avail: NTIS HC A17/MF *A01 CSCL 09B*

Progress reports and technical updates of programs being performed by NASA centers are covered. Presentations in viewgraph form, along with abstracts, are included for topics in three catagories: computer science, data systems, and space station applications.

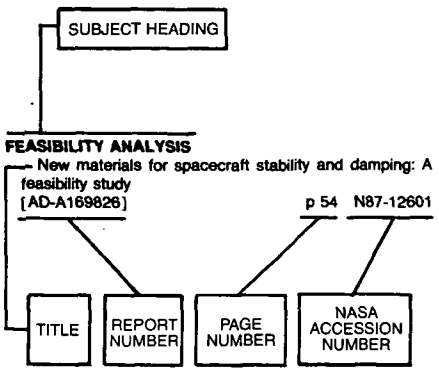
N87-29858*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
THE 21ST AEROSPACE MECHANISMS SYMPOSIUM
May 1987 356 p Symposium held in Houston, Tex., 29 Apr. - 1 May 1987; sponsored by NASA, California Inst. of Tech., and LMSC
(NASA-CP-2470; S-560; NAS 1.55:2470) Avail: NTIS HC A16/MF A01 CSCL 20K

During the symposium technical topics addressed included deployable structures, electromagnetic devices, tribology, actuators, latching devices, positioning mechanisms, robotic manipulators, and automated mechanisms synthesis. A summary of the 20th Aerospace Mechanisms Symposium panel discussions is included as an appendix. However, panel discussions on robotics for space and large space structures which were held are not presented herein.

N87-29914*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
SPACE ELECTROCHEMICAL RESEARCH AND TECHNOLOGY (SERT)
Sep. 1987 364 p Conference held in Cleveland, Ohio, 14-16 Apr. 1987
(NASA-CP-2484; E-3506; NAS 1.55:2484) Avail: NTIS HC A16/MF A01 CSCL 10C

The conference provided a forum to assess critical needs and technologies for the NASA electrochemical energy conversion and storage program. It was aimed at providing guidance to NASA on the appropriate direction and emphasis of that program. A series of related overviews were presented in the areas of NASA advanced mission models (space stations, low and geosynchronous Earth orbit missions, planetary missions, and space transportation). Papers were presented and workshops conducted in a variety of technical areas, including advanced rechargeables, advanced concepts, critical physical electrochemical issues, and modeling.

Typical Subject Index Listing



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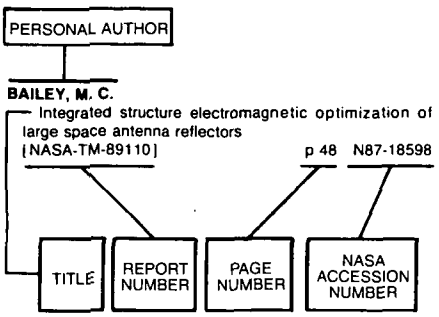

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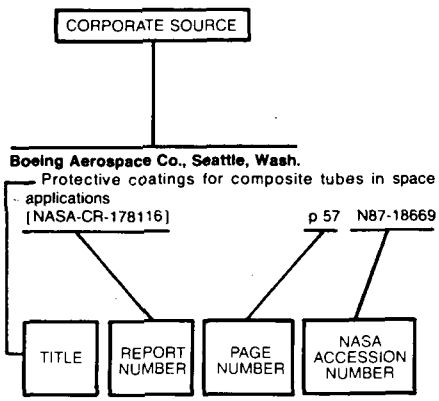

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A

Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
Mechanical Qualification of Large Flexible Spacecraft Structures
[AD-A175529] p 86 N87-20355

The Aerospace Environment at High Altitudes and its Implications for Spacecraft Charging and Communications
[AGARD-CP-406] p 89 N87-26937

AEC-Able Engineering Co., Inc., Goleta, Calif.
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AEG-Telefunken, Wedel (West Germany).
AMOC: An alternative module configuration for advanced solar arrays in low Earth orbits
p 24 N87-28968

Aeritalia S.p.A., Naples (Italy).
Attitude and Orientation System (AOCS) tasks on Rendezvous and Docking (RVD) (docking-undocking phases). Architecture of the whole simulator, volume 2
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[LP-RP-AI-204-VOL-3] p 79 N87-24491

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Potential modulations on SCATHA (Spacecraft Charging At High Altitude) spacecraft
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Air Force Inst. of Tech., Wright-Patterson AFB, Ohio.
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Air Force Office of Scientific Research, Bolling AFB, Washington, D.C.
Air Force basic research in dynamics and control of large space structures p 48 N87-20577

Air Force Rocket Propulsion Lab., Edwards AFB, Calif.
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Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
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Bionetics Corp., Hampton, Va.
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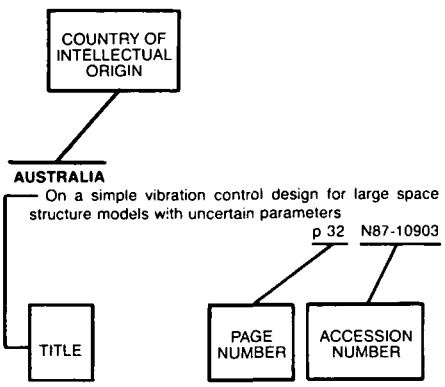

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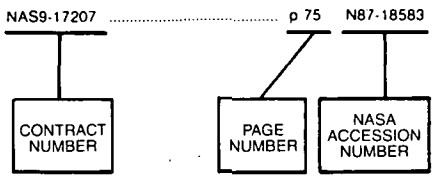

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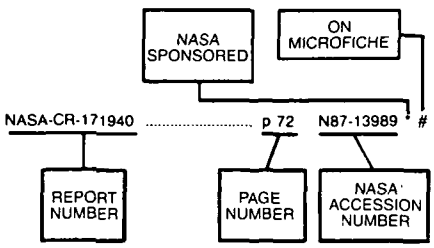

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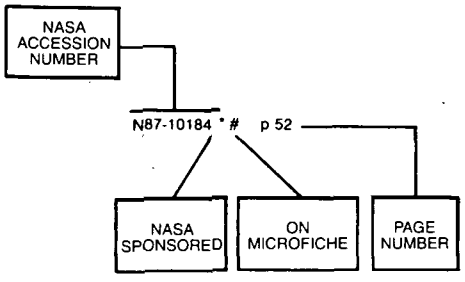

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