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Technology for
Large Space Systems
A Special
Bibliography
with Indexes

NASA SP-7046
April 1979

National Aeronautics and
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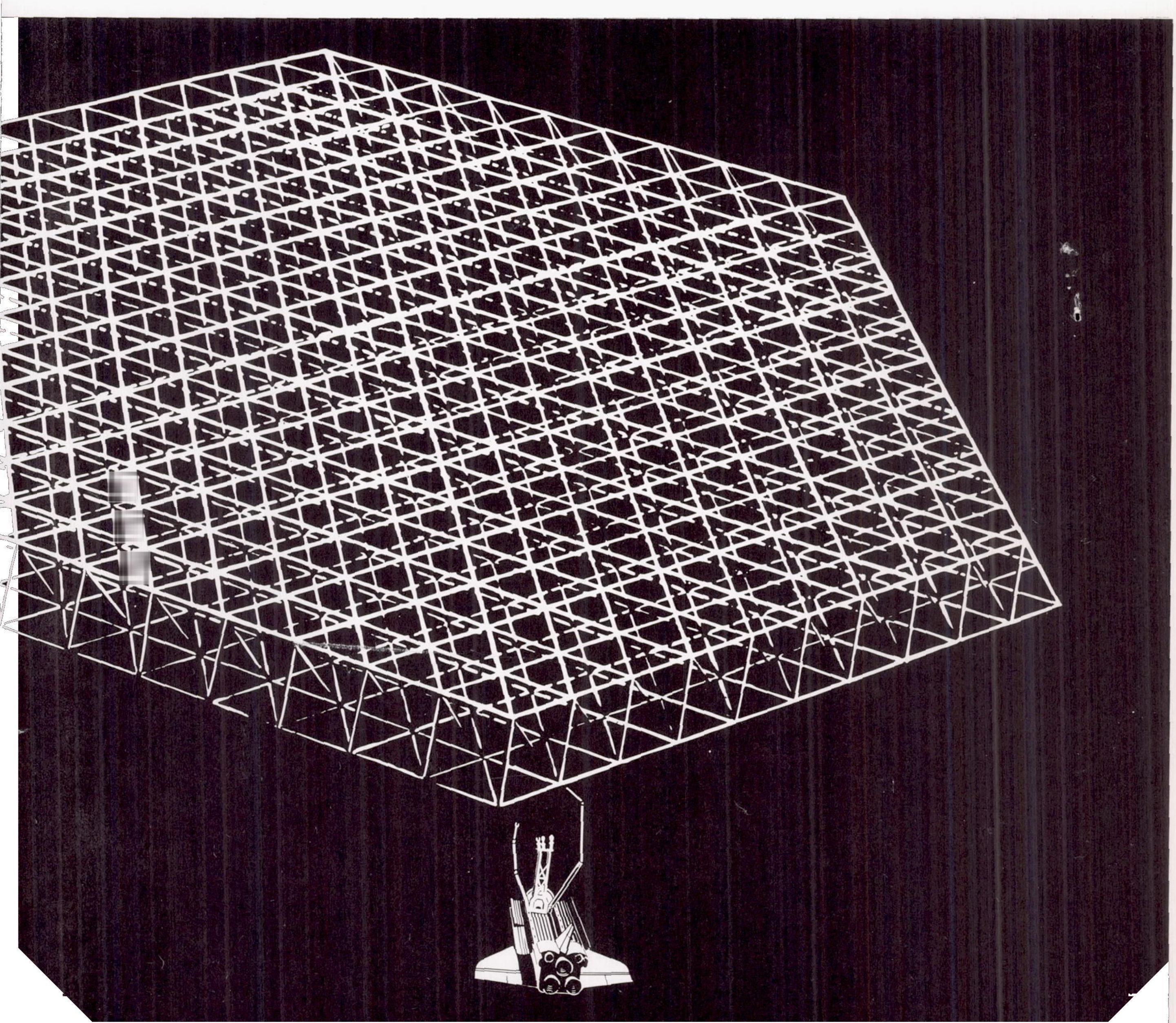

NASA SP-7046

TECHNOLOGY FOR LARGE SPACE SYSTEMS

A Special Bibliography With Indexes

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced between January 1, 1968 and December 31, 1978

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

NASA Scientific and Technical Information Branch 1979
National Aeronautics and Space Administration
Washington, DC

INTRODUCTION

This special bibliography is designed to be helpful to the researcher and manager engaged in developing technology within the discipline areas of the Large Space Systems Technology (LSST) Program. 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 460 reports, articles and other documents announced between January 1968 and December 1978 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 are also addressed.

A wide range of structural concepts are identified. These include erectable structures which are Earth fabricated and space assembled, deployable platforms and 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 Interactive Analysis and Design, Control Systems, Electronics, Advanced Materials, Assembly Concepts, and Propulsion. Electronics is a very limited field in this bibliography, primarily addressing power and data distribution techniques.

The reader will not find references to material that has been designated as "limited" distribution or security classified material. These types of documents will be identified by the LSST Program Office, and a separate listing will be distributed to selected recipients.

This bibliography does not contain citations to documents dealing primarily with the Solar Power Satellite System (SPS). The SPS is a specialized subject such that if a bibliography is required it should be a separate publication.

A Flight Experiments category and a General category complete the list of subjects addressed by this document.

The selected items are grouped into ten categories as listed in the Table of Contents with notes regarding the scope of each category. These categories were especially selected for this publication and differ from those normally found in *STAR* and *IAA*.

Each entry consists of a standard bibliographic citation accompanied by an abstract where available. The citations and abstracts are reproduced exactly as they appeared originally in *STAR* or *IAA* including the original accession numbers from the respective announcement journals. This procedure accounts for the variation in citation appearance.

Under each of the ten categories, the entries are presented in one of two groups that appear in the following order:

1) *IAA* entries identified by accession number series AXX-10,000 in ascending accession number order;
2) *STAR* entries identified by accession number series NXX-10,000 in ascending accession number order.

After the abstract section there are five indexes – subject, personal author, corporate source, contract number, and report/accession number.

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NASA ACCESSION NUMBER — CORPORATE SOURCE

TITLE

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REPORT NUMBER

N78-13106*# Boeing Aerospace Co., Huntsville, Ala.
SIMPLIFIED THERMAL ESTIMATION TECHNIQUES FOR LARGE SPACE STRUCTURES
E. W. Brogren, D. L. Barclay, and J. W. Straayer Oct. 1977
119 p refs
(Contract NAS1-13967)
(NASA-CR-145253; D180-19334-2) Avail: NTIS
HC A06/MF A01 CSCL 22B

A tool for making rapid estimates of the response of space structures to thermal environments encountered in earth orbits is provided for the designer of these structures. Charts giving heating rates and temperatures for certain typical large spacecraft structural elements are provided. Background information for spacecraft thermal design considerations is presented. Environments, requirements, thermal control techniques, design guidelines, and approaches available for more detailed thermal response analysis are discussed. Author

TYPICAL CITATION AND ABSTRACT FROM *IAA*

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AIAA ACCESSION NUMBER — TITLE

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A78-51999 * # **Thermal control requirements for large space structures.** M. Manoff (Rockwell International Corp., Downey, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1675.* 7 p. Contract No. NAS1-14116.

Performance capabilities and weight requirements of large space structure systems will be significantly influenced by thermal response characteristics. Analyses have been performed to determine temperature levels and gradients for structural configurations and elemental concepts proposed for advanced system applications ranging from relatively small, low-power communication antennas to extremely large, high-power Satellite Power Systems (SPS). Results are presented for selected platform configurations, candidate strut elements, and potential mission environments. The analyses also incorporate material and surface optical property variation. The results illustrate many of the thermal problems which may be encountered in the development of three systems. (Author)

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TECHNOLOGY FOR LARGE SPACE SYSTEMS

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APRIL 1979

01
SYSTEMS

Includes mission requirements, focus missions, conceptual studies, technology planning, and systems integration.

A73-14990 **Signal relay systems using large space arrays.** J. C. Yater (Autumn Lane, Lincoln, Mass.). *IEEE Transactions on Communications,* vol. COM-20, Dec. 1972, p. 1108-1121. 24 refs. Contract No. F19628-71-C-0002.

The results of an investigation of the feasibility of using passive space arrays as highly efficient signal reflectors are reported. The design selected as having the maximum efficiency in terms of the ratio of the signal energy reflected in the required direction to the weight of the space array is a gravity gradient stabilized planar array of dipoles connected and supported by lightweight dielectric filaments. The system and space array parameters required to give a high capacity system output are examined together with the flexibility of the system parameters and operations. (Author)

A74-14121 **Use of Shuttle in establishing large space installations.** K. A. Ehricke (North American Rockwell Corp., Space Div., Downey, Calif.). In: Space Shuttle payloads; Proceedings of the Symposium, Washington, D.C., December 27, 28, 1972. Tarzana, Calif., American Astronautical Society, 1973, p. 397-447. 23 refs.

Consideration of the feasibility of setting up an orbiting solar reflector and orbiting space power generation and distribution plants. A system called Lunetta, designed for practically useful night illumination of areas of the earth's surface by a reflector in equatorial geosynchronous orbit, is described. The socio-economic value of the Lunetta is stressed by citing the possibility of conducting agricultural activities with its aid at night. Problems connected with the choice of the size, location, and brightness of Lunetta are discussed, as well as problems of weight minimization and radiation-pressure compensation. The possibility of large-scale power generation in space, using nuclear, solar-thermal, and photovoltaic-reflector systems, is considered, as well as a power relay concept involving large antennas in geosynchronous orbit, reflecting and redirecting the energy flow of microwave beams. The ability of the Integrated Space Shuttle configuration selected by NASA and the Geospace Interorbital Transportation vehicle (incorporated in the Shuttle payload and then released in low orbit) to assist in the construction of large installations in geosynchronous orbit is evaluated. A.B.K.

A74-23086 **Anticipated developments in communications satellite technology.** D. C. MacLellan (MIT, Lexington, Mass.). In: Communications satellite systems. Cambridge, Mass., MIT Press, 1974, p. 145-171. 30 refs. USAF-sponsored research.

Within the decade of the 1970s, it will be possible to build large, sophisticated, three-axis stabilized spacecraft which will operate with several kilowatts of dc power and be able to furnish thousands of TV channels and hundreds of thousands of voice circuits. These spacecraft will operate to a mixture of large and small space diversity ground stations in the 15- to 40-GHz band. By means of multiple narrow beam, low sidelobe antennas employing polarization isolation, a given frequency band will be reused several times on an individual spacecraft. The message traffic over these spacecraft will be digital, and will be switched inside the spacecraft to furnish connections as needed for low-traffic-density routes between small, inexpensive ground terminals. (Author)

A76-45888 ***NASA contemplates radio Search for Extraterrestrial Intelligence.*** R. Sheaffer. *Spaceflight,* vol. 18, Oct. 1976, p. 343-347.

The paper examines the Search for Extra-terrestrial Intelligence (SETI), with emphasis on the nature of the SETI advisory panel, the Project Cyclops (a giant array of radio telescopes whose performance would imitate that of a single radio dish up to 5 km in diameter) the possibility of an orbiting SETI system assembled by Space Shuttle, and the possibility of a lunar far side Cyclops. Attention is also given to the preliminary study of the Stanford Research Institute, the establishment of a SETI program, the question of support, and the magnitude of the search. B.J.

A77-32440 **Space: A resource for earth - An AIAA review.** Edited by J. Grey (American Institute of Aeronautics and Astronautics, Inc., New York, N.Y.), P. Downey (Boeing Aerospace Co., Seattle, Wash.), and B. Davis (Battelle Columbus Laboratories, Columbus, Ohio). New York, American Institute of Aeronautics and Astronautics, Inc., 1977. 73 p. $8.50.

The present review identifies and documents the many applications of space systems that have improved the quality of human life on earth. It provides a sourcebook of information on the technical elements, histories, uses, and impacts of communication satellite systems, navigation satellite systems, land-observation systems, satellites designed for sea and maritime observations, meteorological and other atmospheric-observation satellites, as well as on the future potential of space processing, life-science programs in space, and space-based solar power. Specific satellites and space systems discussed include Echo I, Syncom, ATS, Intelsat/Comsat, the Defense Satellite Communication Systems, Aerosat, Marisat, Transit I, the Navstar/GPS system, the Defense Meteorological Satellite Program, Skylab, the Landsat system, GEOS-3, Seasat, Tiros, Nimbus, ITOS, SMS, GOES, the space shuttle, and Spacelab. Detailed attention is given to the utilization and benefits of each system, Landsat results, meteorological observations, various space-processing experiments, and proposed designs for space-based solar power plants. F.G.M.

A77-46627 **New themes for space: Mankind's future needs and aspirations; Proceedings of the Bicentennial Space Symposium, Washington, D.C., October 6-8, 1976.** Symposium sponsored by the American Astronautical Society and American Institute of Aeronautics and Astronautics. Edited by W. C. Schneider (NASA, Washington, D.C.). San Diego, Calif., American Astronautical Society (Advances in the Astronautical Sciences. Volume 35), 1977. 229 p. $25.

Satellite communications, space manufacturing, remote sensing, and environmental observation are discussed. In the field of satellite communications, the special requirements of a military satellite communication system are explained, the use of satellites for mobile communications service is considered, and public service programs using NASA's ATS-6 and CTS satellites are discussed. Space stations and space manufacturing are examined with attention to equipment design, prospective products, and economic feasibility. Other topics include satellite power stations and the monitoring of crops and forests from space. M.L.

A77-46747 * Searching for extraterrestrial intelligence - The ultimate exploration. D. Black, J. Tarter, J. N. Cuzzi, M. Conners (NASA, Ames Research Center, Moffett Field, Calif.), and T. A. Clark (NASA, Goddard Space Flight Center, Greenbelt, Md.). *Mercury,* vol. 6, July-Aug. 1977, p. 3-7.

A survey highlighting the central issues of the SETI program (Search for Extraterrestrial Intelligence), including its rationale, scope, search problems, and goals is presented. Electromagnetic radiation is suggested as the most likely means via which knowledge of extraterrestrial intelligence will be obtained, and the variables governing these signals are discussed, including: signal frequency and polarization, state, possible coordinates, and signal duration. The modern history of SETI and NASA's involvement is briefly reviewed, and the search strategies used by the Jet Propulsion Laboratory and the Ames Research Center are discussed and compared. Some of the potential scientific and cultural impacts of the SETI program are mentioned, noting advancements in technological, biological, and chemical research. S.C.S.

A77-51395 Communication satellite technologies in the early twenty-first century - A projection into the post Intelsat-V era. C. L. Cuccia (Ford Aerospace and Communications Corp., Palo Alto, Calif.). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-34.* 73 p.

The paper is concerned with future communication satellite technology. It is thought that a multiple beam antenna satellite system using baseband switching and demodulation and remodulation technologies might be used in the future. Candidate designs for large multiple beam satellites which can be assembled in space are discussed with attention to the advantages of very large parabolic antennas in multiple-beam multiple-horn systems which achieve required beam effectively isotropically radiated power by use of gain achieved by means of large antenna structures. User communities and worldwide traffic scenarios are examined, and several technical topics, such as conservation of spectrum-bandwidth efficiency and computer control of spaceborne switching centers, are analyzed. M.L.

A77-51399 Impact of shuttle on technology and utility of national and regional communications satellites. H. S. Braham (General Electric Co., Space Div., Philadelphia, Pa.). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-38.* 11 p.

This paper describes the profound increase in spacecraft technology, system capability, and user utility provided by the shuttle. The shuttle provides this enhanced capability at a cost much less than that of today's expendable boosters, Thor-Delta and Atlas-Centaur. The shuttle-launched spacecraft can be much heavier and have larger dimensions to accommodate greater antenna sizes, larger solar arrays and thermal dissipation area, more communications transponders, and complex on-board communications switching devices. The high performance shuttle spacecraft will simultaneously permit many more communications channels and much lower cost earth stations. The result is low cost utilization by a much larger number of users, thereby opening up new classes of services worldwide. The paper quantifies a variety of typical national and regional 1985 satellite systems utilizing shuttle capability. This description includes satellites, earth stations, system characteristics and overall utility. (Author)

A77-51524 On the active and passive CETI from earth satellite orbit. M. Subotowicz (Lublin, Universytet, Lublin; Polskie Towarzystwo Astronautyczne, Katowice, Poland), J. Usowicz (Torun, Uniwersytet, Torun; Polskie Towarzystwo Astronautyczne, Warsaw, Poland), and Z. Paprotny (Polskie Towarzystwo Astronautyczne, Katowice, Poland). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper A-77-48.* 14 p. 7 refs.

Technical problems involving the antennas considered for use in a communication with extraterrestrial intelligence (CETI) satellite project are discussed. The antenna system and monitoring are considered with reference to a search strategy. Topics examined include frequency range, thermal noises and deformations, Doppler shift correction, compensation of the dispersal effects, transmission time and distance, costs, and energy supply by the solar satellite power station. Attention is directed to the problems of possible perturbations of the orbit, undesireable motion of the antenna, and antenna mechanical oscillations. M.L.

A78-13323 * Antenna concepts for interstellar search systems. R. P. Basler, G. L. Johnson, and R. R. Vondrak (Stanford Research Institute, Menlo Park, Calif.). *Radio Science,* vol. 12, Sept.-Oct. 1977, p. 845-858. 16 refs. NASA-supported research.

An evaluation is made of microwave receiving systems designed to search for signals from extraterrestrial intelligence. Specific design concepts are analyzed parametrically to determine whether the optimum antenna system location is on earth, in space, or on the moon. Parameters considered include the hypothesized number of transmitting civilizations, the number of stars that must be searched to give any desired probability of receiving a signal, the antenna collecting area, the search time, the search range, and the cost. This analysis suggests that (1) search systems based on the moon are not cost-competitive, (2) if the search is extended only a few hundred light years from the earth, a Cyclops-type array on earth may be the most cost-effective system, (3) for a search extending to 500 light years or more, a substantial cost and search-time advantage can be achieved with a large spherical reflector in space with multiple feeds, (4) radio frequency interference shields can be provided for space systems, and (5) cost can range from a few hundred million to tens of billions of dollars, depending on the parameter values assumed. (Author)

A78-15423 # Film reflectors in space (Plenochnye otrazhateli v kosmose). A. V. Luk'ianov. Moscow, Izdatel'stvo Moskovskogo Universiteta, 1977. 70 p. 98 refs. In Russian.

The prospects for using large-scale film reflectors and collectors are discussed. Attention is given to studies of superlight rotating reflectors, noting their construction, orientation, and motion control. It is suggested that such reflectors may be used in climate and weather control, orbiting solar power stations, and as solar sails. S.C.S.

A78-16699 * # An entree for large space antennas. R. V. Powell and A. R. Hibbs (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Astronautics and Aeronautics,* vol. 15, Dec. 1977, p. 58-64. 5 refs.

Some of the possible areas of application for large antennas placed in space are discussed, and some initial design concepts for various antenna proposals are described. Applications include rural mobile communications, an orbiting deep space relay station, submillimeter radio astronomy, and multispectral radiometry of earth surface features. As a first step in developing the needed technology, a deployable 30-m antenna with 1-mm surface accuracy is proposed. Flight experience with such an antenna system would enable validation of performance prediction models. The 30-m-diam mesh deployable-defurlable antenna experiment would be carried out with the shuttle. P.T.H.

A78-16768 # **Searching for extraterrestrial life - The SETI gamble.** R. Sheaffer. *AIAA Student Journal,* vol. 15, Winter 1977-1978, p. 34-38. 8 refs.

A brief historical account of the Search for Extraterrestrial Intelligence (SETI) program is presented. Projects Ozma I and II are discussed in terms of the apparatus employed, the stars examined, and the choice of the hydrogen wavelength, felt to be the most likely channel for interstellar communication. SETI programs conducted at Ohio State University are reviewed, as are those at the Algonquin Radio Observatory in Ontario, Canada. Possible future SETI projects planned by NASA are outlined, including Project Cyclops, an orbiting SETI system, and a lunar-based Cyclops. S.C.S.

A78-22524 * **Extraterrestrial intelligence - An observational approach.** B. Murray, S. Gulkis, and R. E. Edelson (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Science,* vol. 199, Feb. 3, 1978, p. 485-492. 30 refs.

The article surveys present and proposed search techniques for extraterrestrial intelligence in terms of technological requirements. It is proposed that computer systems used along with existing antennas may be utilized to search for radio signals over a broad frequency range. A general search within the electromagnetic spectrum would explore frequency, received power flux, spatial locations, and modulation. Previous SETI projects (beginning in 1960) are briefly described. An observation project is proposed in which the earth's rotational motion would scan the antenna beam along one declination circle in 24 hours. The 15 degree beam width would yield a mapping of 75% of the sky in an 8-day period if the beam were shifted 15 degrees per day. With the proposed instrument parameters, a sensitivity of about 10 to the -21 watt/sq m is achieved at a 0 degree declination and 1.5 GHz. In a second phase, a 26 m antenna would yield an HPBW of 0.8 degrees at 1 GHz and 0.03 degrees at 25 GHz. It is noted that the described technology would provide secondary benefits for radio astronomy, radio communications, and other fields. S.C.S.

A78-24453 # **Future space systems /A survey of the next 25 years/.** A. K. Thiel (TRW Defense and Space Systems Group, Redondo Beach, Calif.). *Deutsche Gesellschaft für Luft- und Raumfahrt, Jahrestagung, 10th, Berlin, West Germany, Sept. 13-15, 1977, Paper.* 33 p.

The future of the space program is evaluated in terms of present technology and likely improvements in technological capability during the next 25 years. Attention is given to the Space Transportation System (STS), based on use of the Space Shuttle. For the immediate future, LEO Shuttle missions are planned for scientific experiments and equipment development, especially Spacelab and the Interim Upper Stage. The Shuttle will be used during this period to launch spin-stabilized satellites into LEO and GEO. By the end of the 1980s, STS will expand to include deployment and assembly or large space structures, serviced by groups of manned modules and able to begin the manufacture of industrial and medical products. In the closing years of the century, large, permanently manned space stations are foreseen, together with energy production in the gigawatt range for earth use, and large-scale, commercially profitable space factories. D.M.W.

A78-26827 **Future communications concepts. I - The switchboard-in-the-sky.** S. W. Fordyce and L. Jaffe. *Satellite Communications,* vol. 2, Feb. 1978, p. 22-26.

The geostationary orbit has become very popular for communications satellites. Operational geostationary satellites on a global basis and the ten satellites over North America are considered. Attention is given to aspects of orbital crowding, traffic projections, plans for a new satellite system which is to provide additional capacities during the 1980's, and the employment of scanning and fixed spot beams. NASA is studying the concept of a switchboard-in-the-sky which provides a geostationary platform carried up to a low altitude earth orbit in three flights of the space shuttle. The payloads under consideration for inclusion on the space platform are not limited to domestic satellite communications applications. The services to be provided include also fixed communications satellite service (point-to-point), mobile satellite communications service, and broadcasting satellite service. Attention is also given to payloads for space research, meteorological studies, earth observation, navigation, ship surveillance, search and rescue services, and thin-route communications to small terminals as proposed for experimental rural communications satellites. G.R.

A78-32891 # **The OAF concept extended.** W. L. Morgan and B. I. Edelson (COMSAT Laboratories, Clarksburg, Md.). In: Communications Satellite Systems Conference, 7th, San Diego, Calif., April 24-27, 1978, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1978, p. 120-130. 6 refs. (AIAA 78-546)

The concept of the orbital antenna farm (OAF) involves the use of a large space station in geostationary orbit to provide varied applications services to numerous users. A small number of these platforms could provide both higher levels of performance and more cost-effective communications and sensor services than a large number of single-purpose satellites. This paper expands the previously published OAF concept and describes some of the special capabilities, problems, mission considerations and other details of an OAF. In particular, a concept for a platform serving North America, Central America, and South America (the OAF Americas) is developed. This platform, which has an estimated weight of more than 6000 kg, generates 20 kW, and accommodates 17 missions, would be launched on several Space Shuttles in the 1990s. (Author)

A78-32928 * # **A future for large space antennas.** R. V. Powell (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). In: Communications Satellite Systems Conference, 7th, San Diego, Calif., April 24-27, 1978, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1978, p. 407-414. 12 refs. Contract No. NAS7-100. (AIAA 78-588)

An investigation was conducted regarding the near-term applications of large aperture microwave antennas in space. The investigation had the objective to find out whether the initiation of a NASA development program concerning large space antennas would be justified. From a broad spectrum of possible uses for large atennas, those applications of interest to NASA were selected which singly or in aggregate appeared to offer significant benefits. Single point configuration studies were then conducted for promising applications. It was concluded that there are a number of applications which warrant an active program in large space antennas. The implementation of these applications will require a number of antenna types. The outward looking applications, such as radio astronomy and deep space communications, will be characterized by low noise receivers, single beams, and relatively slow scans. Earth-looking applications, such as radiometry for earth observations, spectrum monitoring, and terrestrial communications, will be characterized by high beam efficiency and multiple beams. G.R.

A78-36723 **Assembly in space of large communication structures.** F. Zylius and R. Donavan (Rockwell International Corp., Space Div., Downey, Calif.). In: The industrialization of space; Proceedings of the Twenty-third Annual Meeting, San Francisco, Calif., October 18-20, 1977. Part 1. San Diego, Calif., American Astronautical Society; Univelt, Inc., 1978, p. 501-523. (AAS 77-259)

An electronic mail satellite system conceptual design was carried out which addressed two major areas: the preliminary design of the communication payload, and a comparison of a variety of space construction concepts to assemble the mission hardware in earth orbit. The initial selection of 3 GHz as the carrier frequency resulted in a structure of a size which made it a viable candidate for use in the analysis of a variety of construction alternatives; Shuttle-based or Shuttle-tended construction base; and a range of levels of construction automation from full manual component assembly to fully automated fabrication and assembly. Comparative analyses included factors of cost, construction efficiency, productivity, and construction process duration. In general, conclusions tended toward the selection of Shuttle-based, nonautomated fabrication and assembly for any foreseeable construction tasks in space, short of SPS (Satellite Power System) development articles. (Author)

A78-37243 * **Switchboard in the sky.** S. W. Fordyce, L. Jaffe (NASA, Office of Application, Washington, D.C.), and E. C. Hamilton (NASA, Marshall Space Flight Center, Huntsville, Ala.). *Spaceflight,* vol. 20, June 1978, p. 203-217. 6 refs.

Geostationary parking orbits for the present generation of communications satellites, e.g., Intelsat, Westar, Molniya, Navsat, etc., are becoming crowded. It is noted that the C-band over North America will in future be subject to still less attenuation with the introduction of smaller (4.5 m) antennas for earth-bound receive-only applications. It is suggested, at least for the present, that more bands be added, e.g., K-, Ku-, and S-bands. To handle the potential market for communications satellite services during the years after 1985, much larger facilities will be needed. The fabrication of large platforms using the STS is discussed as the most practical solution, stressing that virtually every geosynchronous communications antenna for U.S. domestic use can be assembled on one platform positioned at an especially favorable location. D.M.W.

N76-14974*# Aerospace Corp., El Segundo, Calif. Advanced Orbital Systems Div.
STUDY OF THE COMMONALITY OF SPACE VEHICLE APPLICATIONS TO FUTURE NATIONAL NEEDS (UNCLASSIFIED PORTION)
24 Mar. 1975 407 p ref
(Contract NASw-2727)
(ATR-75(7365)-2) Avail: NTIS HC $11.00 CSCL 05C

A midterm progress report was presented on the study of commonality of space vehicle applications to future national needs. Two of the four objectives in the entire study were discussed. The first one involved deriving functional requirements for space systems based on future needs and environments for the military and civilian communities. Possible space initiatives based on extrapolations of technology were compiled without regard as to need but only with respect to feasibility, given the advanced state of technology which could exist through the year 2,000. The second one involved matching the initiatives against the requirements, developing a methodology to match and select the initiatives with each of the separate plans based on the future environments, and deriving common features of the military and civilian support requirements for these programs. Author

N76-15596*# *Raytheon Co., Sudbury, Mass. Equipment Div.*
MICROWAVE POWER TRANSMISSION SYSTEM STUDIES. VOLUME 3, SECTION 8: MECHANICAL SYSTEMS AND FLIGHT OPERATIONS
O. E. Maynard, W. C. Brown, A. Edwards, J. T. Haley, G. Meltz, J. M. Howell, and A. Nathan (Grumman Aerospace Corp., Bethpage, N. Y.) Dec. 1975 234 p refs
(Contract NAS3-17835)
(NASA-CR-134886-Vol-3; ER75-4368-Vol-3) Avail: NTIS HC $8.00 CSCL 10B

The efforts and recommendations associated with preliminary design and concept definition for mechanical systems and flight operations are presented. Technical discussion in the areas of mission analysis, antenna structural concept, configuration analysis, assembly and packaging with associated costs are presented. Technology issues for the control system, structural system, thermal system and assembly including cost and man's role in assembly and maintenance are identified. Background and desired outputs for future efforts are discussed. Author

N76-30244*# Aerospace Corp., El Segundo, Calif. Systems Engineering Operations.
ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980 - 2000). VOLUME 1: EXECUTIVE SUMMARY
I. Bekey, H. L. Mayer, and M. G. Wolfe Apr. 1976 53 p 4 Vol.
(Contract NASw-2727)
(NASA-CR-148704; ATR-76(7365)-1-Vol-1) Avail: NTIS HC $4.50 CSCL 22A

The likely system concepts which might be representative of NASA and DoD space programs in the 1980-2000 time period were studied along with the programs' likely needs for major space transportation vehicles, orbital support vehicles, and technology developments which could be shared by the military and civilian space establishments in that time period. Such needs could then be used by NASA as an input in determining the nature of its long-range development plan. The approach used was to develop a list of possible space system concepts (initiatives) in parallel with a list of needs based on consideration of the likely environments and goals of the future. The two lists thus obtained represented what could be done, regardless of need; and what should be done, regardless of capability, respectively. A set of development program plans for space application concepts was then assembled, matching needs against capabilities, and the requirements of the space concepts for support vehicles, transportation, and technology were extracted. The process was pursued in parallel for likely military and civilian programs, and the common support needs thus identified. Author

N76-30245*# Aerospace Corp., El Segundo, Calif.
ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980 - 2000). VOLUME 2: FINAL REPORT
I. Bekey, H. L. Mayer, and M. G. Wolfe Apr. 1976 188 p
(Contract NASw-2727)
(NASA-CR-148703; ATR-76(7365)-1-Vol-2) Avail: NTIS HC $7.50 CSCL 22A

The results are presented of a study which identifies over 100 new and highly capable space systems for the 1980-2000 time period: civilian systems which could bring benefits to large numbers of average citizens in everyday life, much enhance the kinds and levels of public services, increase the economic motivation for industrial investment in space, expand scientific horizons; and, in the military area, systems which could materially alter current concepts of tactical and strategic engagements. The requirements for space transportation, orbital support, and technology for these systems are derived, and those requirements likely to be shared between NASA and the DoD in the time period identified. The high leverage technologies for the time period are identified as very large microwave antennas and optics, high energy power subsystems, high precision and high power lasers, microelectronic circuit complexes and data processors, mosaic solid state sensing devices, and long-life cryogenic refrigerators. Author

N76-30246*# Aerospace Corp., El Segundo, Calif. Systems Engineering Operations.
ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980 - 2000). VOLUME 3: DETAILED DATA. PART 1: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS

I. Bekey, H. L. Mayer, and M. G. Wolfe Apr. 1976 146 p 4 Vol.
(Contract NASw-2727)
(NASA-CR-148710; ATR-76(7365)-1-Vol-3-Pt-1) Avail: NTIS HC $6.00 CSCL 22A

The following areas were discussed in relation to a study of the commonality of space vehicle applications to future national needs: (1) index of initiatives (civilian observation, communication, support), brief illustrated description of each initiative, time periods (from 1980 to 2000+) for implementation of these initiatives; (2) data bank of functional system options, presented in the form of data sheets, one for each of the major functions, with the system option for near-term, midterm, and far-term space projects applicable to each subcategory of functions to be fulfilled; (3) table relating initiatives and desired goals (public service and humanistic, materialistic, scientific and intellectual); and (4) data on size, weight and cost estimations. Y.J.A.

N76-30247*# Aerospace Corp., El Segundo, Calif. Advanced Orbital Systems Div.
ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980 - 2000). VOLUME 4: DETAILED DATA. PART 2: PROGRAM PLANS AND COMMON SUPPORT NEEDS (A STUDY OF THE COMMONALITY OF SPACE VEHICLE APPLICATIONS TO FUTURE NATIONAL NEEDS
I. Bekey, H. L. Mayer, and M. G. Wolfe Apr. 1976 266 p ref
(Contract NASw-2727)
(NASA-CR-148708; ATR-76(7365)-1-Vol-4-Pt-2) Avail: NTIS HC $9.00 CSCL 22A

The methodology of alternate world future scenarios is utilized for selecting a plausible, though not advocated, set of future scenarios each of which results in a program plan appropriate for the respective environment. Each such program plan gives rise to different building block and technology requirements, which are analyzed for common need between the NASA and the DoD for each of the alternate world scenarios. An essentially invariant set of system, building block, and technology development plans is presented at the conclusion, intended to allow protection of most of the options for system concepts regardless of what the actual future world environment turns out to be. Thus, building block and technology needs are derived which support: (1) each specific world scenario; (2) all the world scenarios identified in this study; or (3) generalized scenarios applicable to almost any future environment. The output included in this volume consists of the building blocks, i.e.: transportation vehicles, orbital support vehicles, and orbital support facilities; the technology required to support the program plans; identification of their features which could support the DoD and NASA in common; and a complete discussion of the planning methodology. Author

N77-24333*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
MICROWAVE PERFORMANCE CHARACTERIZATION OF LARGE SPACE ANTENNAS
D. A. Bathker, ed. 15 May 1977 79 p refs
(Contract NAS7-100)
(NASA-CR-153206; JPL-Publ-77-21) Avail: NTIS HC A05/MF A01 CSCL 20N

Performance capabilities of large microwave space antenna configurations with apertures generally from 100 wavelengths upwards are discussed. Types of antennas considered include: phased arrays, lenses, reflectors, and hybrid combinations of phased arrays with reflectors or lenses. The performance characteristics of these broad classes of antennas are examined and compared in terms of applications. Author

N77-31236*# Rockwell International Corp., Downey, Calif.
ADVANCED TECHNOLOGY LABORATORY EXPERIMENT SYSTEMS DEFINITION. VOLUME 2: MISSION ANALYSIS AND PLANNING. PART 1: FLIGHT PLAN, PAYLOAD 1 Final Report
May 1977 446 p
(Contract NAS1-14116)
(NASA-CR-145172-1; SD-76-SA-0093-2-1) Avail: NTIS HC A19/MF A01 CSCL 22A

The mission defined here reflects rigorous definitions of experiment operations and related resource utilizations and includes the added realism of key trajectory events, day-night overflight, and ground target viewing opportunities. It represents the first complete mission definition encompassing all of the important factors affecting mission design and, as such, provides a framework for future operational refinements and updates that will be required in subsequent efforts for development of the final mission plan. Author

N78-20149# Committee on Science and Technology (U. S. House).
SPACE INDUSTRIALIZATION
Washington GPO 1977 206 p refs Hearing before Subcomm. on Space Sci. and Application of the Comm. on Sci. and Technol., 95th Congr., 1st Sess., 29 Sep. 1977
(GPO-99-159) Avail: Subcomm. on Space Sci. and Applications

The advantages of using satellites for improved personal communications, educational television, and teleconferencing, as well as for continuous unattended tracking and location of vehicles, shipments, and nuclear materials were described. The capabilities of space shuttles and the technology requirements for constructing earth-orbiting factories to exploit zero gravity, constant solar power, and perfect vacuum conditions for space processing and manufacturing were explored. The mass-driver reaction engine concept was also discussed. A.R.H.

N78-20153*# McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.
INFORMATION SERVICES PLATFORMS AT GEOSYNCHRONOUS EARTH ORBIT: A REQUIREMENTS ANALYSIS
Feb. 1978 169 p
(Contract NAS1-12436)
(NASA-CR-156117; MDC-G7308) Avail: NTIS HC A08/MF A01 CSCL 22A

The potential user requirements for Information Services Platforms at geosynchronous orbits were investigated. A rationale for identifying the corollary system requirements and supporting research and technology needs was provided. Author

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02
INTERACTIVE ANALYSIS AND DESIGN

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

A69-12812
ELECTRICAL MEASUREMENTS OF AN ERECTABLE PARABOLA FOR SPACE MISSIONS
Dennis Holst (Martin Marietta Corp., Denver, Colo.).
IN: SPACE PROJECTIONS FROM THE ROCKY MOUNTAIN REGION; PROCEEDINGS OF THE SYMPOSIUM, DENVER, COLO., JULY 15, 16, 1968. VOLUME 1,
Symposium sponsored by the American Astronautical Society and the American Institute of Aeronautics and Astronautics. Tarzana, Calif., American Astronautical Society, 1968. 18 p.

Discussion of the desirability of establishing reliable design criteria for deployable antennas for space missions. A deployable antenna may be folded and stowed in a minimum volume aboard a launch vehicle and remotely erected after the space vehicle has achieved orbit. Parabolic reflectors provide a simple means of obtaining high gain. Two classes of erection techniques are outlined: mechanical erection and pressure erection. The configuration studied was an umbrella-type deployable parabola. It consists of a number of radial ribs between which a conducting mesh material is stretched. In this case, the unfolded antenna will not attain the ideal shape for perfect radiation. Another problem which appears is the design of the feed support assembly. Attention must also be given to the selection of a suitable conducting fabric to be used as the reflector surface. To answer the various questions arising in this connection, a specific tasting program is suggested. P. V. T.

A69-25500*#
MINIMIZING SPACECRAFT STRUCTURE/CONTROL-SYSTEM INTERACTION.
Richard B. Noll (Kaman Corp., Kaman AviDyne, Burlington, Mass.) and Curtis H. Spenny (NASA, Electronics Research Center, Cambridge, Mass.).
IN: AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, STRUCTURAL DYNAMICS AND AEROELASTICITY SPECIALIST CONFERENCE, NEW ORLEANS, LA., APRIL 16, 17, 1969, PROCEEDINGS.
New York, American Institute of Aeronautics and Astronautics, Inc., 1969, p. 58-65. 20 refs.
Contract No. NAS 12-613.

Spacecraft structure/control-system interaction problems and their minimization are reviewed. Interaction problems are identified with three basic structural configurations. Representative spacecraft examples in each category are discussed to illustrate various methods which have been used to minimize interactions. Examples include Explorer 3, ATS, Apollo CSM/LM, ISIS 1, OSO, 1963 49B, DODGE, and Radio Astronomy Explorer. Design improvements based on flight experience are emphasized. While interaction problems of manned spacecraft have required greater-in-depth studies, in-flight difficulties are shown to be most numerous on spacecraft equipped with extendible booms. The majority of these interactions are attributed to the susceptibility of the booms to the solar environment. Interaction effects on spacecraft which are spin stabilized about the principal axis of minimum moment of inertia are included. (Author)

A69-30679
BUCKLING OF FOLDED-PLATE STRUCTURES.
S. E. Swartz (Kansas State University of Agriculture and Applied Science, Manhattan, Kan.), M. L. Mikhail, and S. A. Guralnick (Illinois Institute of Technology, Chicago, Ill.).
(Society for Experimental Stress Analysis, Spring Meeting, Philadelphia, Pa., May 13-16, 1969.)
Experimental Mechanics, vol. 9, June 1969, p. 269-274. 9 refs.
NSF Grant No. GK-1280.

Experimental study of the buckling characteristics of 21 single-cell, simply supported, folded-plate structural models. Techniques for the fabrication and testing of the models are reported, together with a correlation of the measured and the predicted buckling load for each of the 21 models in which instability behavior was observed. (Author)

A69-41881 #
BENDING STIFFNESS OF AN INFLATED CYLINDRICAL CANTILEVER BEAM.
William J. Douglas (Keystone Computer Associates, Inc., Systems Analysis Dept., Fort Washington, Pa.).
AIAA Journal, vol. 7, July 1969, p. 1248-1253. 8 refs.

Determination of the effect of finite inflation on the subsequent response of a circular cylindrical cantilever to bending loads. The bending stiffness of the beam is used to measure the response to loading after inflation. Classical elasticity theory is incapable of detecting the changes in material properties and can only treat variation in geometry by approximation techniques for rather small strains. In the present work, the theory of small deformations superimposed on large ones allows both factors to be considered in a unified and clear manner, and small inflation is merely a special case. Using the Mooney-Rivlin constitutive assumption, explicit analytic results are obtained. Stiffness coefficients vary significantly with inflation, and this variation is seen to be appreciable even in the early stages of inflation. Experimental observations are related to the theoretical development. G.R.

A70-30762 # **Solar deflection of thin-walled cylindrical, extendible structures.** Robert J. Eby and Robert D. Karam (Fairchild Hiller Corp., Space Electronics Systems Div., Germantown, Md.). *Journal of Spacecraft and Rockets,* vol. 7, May 1970, p. 577-581. 8 refs.

An analytical expression is derived which describes the steady-state deflection of a long, thin, tubular structure with a locked overlapped cross section subjected to solar heating in a 0 g environment. By transforming the angular coordinate to correspond to the solar direction, it is possible to obtain a single expression which describes the circumferential temperature distribution. Thermal bending is found by closed form integration of the temperature-induced loading about the principal axes as dictated by overlap geometry. Maximum thermal bending is evaluated for various overlap angles as a function of dimensionless groups which include all thermal and geometric parameters. It is concluded that an optimum design is one which incorporates an overlap angle at 155 deg. The results are presented in graphical form suitable for engineering design, and a specific example is discussed. (Author)

A71-10941 # **Solar induced bending vibrations of a flexible member.** John D. Graham (Toronto, University, Toronto; Star Aerospace Products, Ltd., Malton, Ontario, Canada). *AIAA Journal,* vol. 8, Nov. 1970, p. 2031-2036. 18 refs. Defence Research Board of Canada Grant No. 5540/33.

The stability of in-plane bending of oscillations of long flexible members (STEMs) when subjected to solar heating is examined. The model accounts for the interdependence between the time varying STEM thermal curvature (caused by its changing temperature distribution) and the STEM bending motion. The linearized response of the STEM is determined in the Laplace transformed time domain and the ensuing stability criterion is found to be dependent upon, along with other parameters, the sun orientation, the material surface absorptivity and the extent of damping in the STEM, the latter being due mainly to the friction in the overlapped or interlocked part of the STEM element. In the case where the STEM is oriented towards the sun the motion is shown to be stable. The use of the best available values of absorptivity and damping shows stability to be marginal for silver-plated STEM in the case where the STEM is oriented away from the sun. More accurate test information on the mechanism and magnitude of damping is required to accurately determine stability or otherwise in the latter case. (Author)

A73-39545 **A refined finite element analysis of folded plate structures.** G. Attar-Hassan and S. S. F. Ng (Ottawa, University, Ottawa, Canada). In: Midwestern Mechanics Conference, 13th, Pittsburgh, Pa., August 13-15, 1973, Proceedings. Pittsburgh, University of Pittsburgh, 1973, p. 685-702. 10 refs. Research supported by the National Research Council of Canada.

A triangular finite element has been developed for solving folded plate structures. The element is formed by the combination of an in-plane and a plate bending high precision triangular element. The in-plane displacements are represented by a cubic polynomial, whereas the lateral displacement is represented by a quintic polynomial. Some difficulties arise when assembling inclined elements meeting along the ridge where the in-plane and the lateral displacements are coupled. This is due to the difference in order between the polynomials representing the in-plane and the lateral displacements, respectively. To overcome these difficulties, a new method of linking elements is presented. In this method, a new global rotation matrix is developed in which the corresponding terms to the second derivative of the in-plane displacements are set equal to zero. As a result, the second derivative of the lateral displacements, which is no longer controlled by the second derivative of the in-plane displacement, assumes very large values. To compensate for the removed control, a new load vector, called the 'reduced consistent load vector,' is developed. (Author)

A74-17602 **Librational dynamics of satellites with thermally flexed appendages.** V. J. Modi and K. Kumar (British Columbia, University, Vancouver, Canada). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Conference, Vail, Colo., July 16-18, 1973, AAS Paper 73-232.* 39 p. 50 refs. National Research Council of Canada Grant No. A-2181.

Numerical study of the librational dynamics of gravity oriented satellites having an arbitrary number of large flexible appendages that deform under differential solar heating. Equations of motion are obtained for satellites executing general spatial motion, and a thermal analysis of the appendages is conducted, giving a time history of the moments of inertia. The formulation for the system dynamics clearly identifies the rigid body and flexibility contributions. This is particularly useful in relating the complex flexibility equations to their degenerate form for the rigid case. Several typical configurations involving combinations of solar panels and booms are then considered, and their parametric response is obtained. The vast amount of information so generated is condensed in the form of system plots showing the librational amplitude and the average period. T.M.

A74-21398 # **Analysis of thickness tapered booms for space applications.** R. Kumar (Spar Aerospace Products, Ltd., Toronto, Canada) and S. Ahmed (Department of Communications, Communications Research Centre, Ottawa, Canada). *Journal of Spacecraft and Rockets,* vol. 11, Feb. 1974, p. 125-127.

It is shown that providing a taper on the wall thickness of a boom, used in space antenna applications, can effectively reduce maximum bending stress, tip deflection, and boom mass. For linear and parabolic thickness variations, maximum bending stresses occur at the root. M.V.E.

A75-13627 **Design of satellite flexibility experiments.** M. H. Kaplan and S. E. Hillard (Pennsylvania State University, University Park, Pa.). *International Astronautical Federation, International Astronautical Congress, 25th, Amsterdam, Netherlands, Sept. 30-Oct. 5, 1974, Paper 74-003.* 28 p. 10 refs.

Analysis of the interaction between flexibility of satellite appendages and satellite control is important for future vehicles. An approach to designing an orbital experiment on flexibility-control interaction is considered. The spacecraft model analyzed consists of a rigid central body with one continuous flexible solar array. Nonlinear equations of motion are treated. Out of plane bending and torsional bending of the array are considered. Important parameters are classified as mass dependent, mode shape dependent, geometry and modal damping dependent, and frequency dependent. The use of mechanical or piezoelectric accelerometers is recommended for in-flight measurements. The number, positioning, and data rate of the accelerometers and proposed experiment maneuvers are considered. Recommendations are made concerning further development of the experiment. A.T.S.

A75-18484 **Post buckling behaviour of thin-walled members.** A. Q. Khan (USS Consultants of Canada, Ltd., Montreal, Canada) and P. J. Harris (McGill University, Montreal, Canada). In: Computational methods in nonlinear mechanics; Proceedings of the International Conference, Austin, Tex., September 23-25, 1974. Austin, Texas Institute for Computational Mechanics, 1974, p. 799-808. 7 refs.

The elastic nonlinear behavior of thin walled nonplanar structures consisting of flat plates joined along their longitudinal edges is studied by means of a computer program based on a simple rectangular element. The complete load deflection response is studied from zero load to well into the post buckling range. The results are compared with experimental and theoretical solutions reported in the literature. (Author)

A76-26807 # **Discrete time attitude control of spacecraft containing low frequency lightly damped structural modes.** K. Folgate (General Electric Co., Philadelphia, Pa.). *American Institute of Aeronautics and Astronautics and Canadian Aeronautics and Space Institute, Communications Satellite Systems Conference, 6th, Montreal, Canada, Apr. 5-8, 1976, AIAA Paper 76-262.* 8 p.

A basic approach and design tools are developed to permit synthesis of attitude control systems for spacecraft with large lightweight deployed structures, such as solar arrays or antennas. Digital designs are used to implement a low bandwidth discrete time controller that employs a dual bandwidth state estimator. The choice of a dual bandwidth state estimator lead to a sampled data control system, i.e., one where the plant is a continuous system while the controller is a discrete time system. The method of selecting controller parameter values to achieve stability compensation is discussed, along with the results of linear analysis performed on the sampled data system. The flexibility of interchanging low frequency stabilization and higher frequency rolloff responsibilities between the estimator and torque loops is demonstrated. A novel approach is described that was used to build an all digital nonlinear simulation that runs extremely fast even in the presence of discontinuous inputs and lightly damped flexible structure modes. V.P.

A77-25760 * # **Continuum models for static and dynamic analysis of repetitive lattices.** A. K. Noor, W. H. Greene (NASA, Langley Research Center, Structures and Dynamics Div.; George Washington University, Hampton, Va.), and M. S. Anderson (NASA, Langley Research Center, Structures and Dynamics Div., Hampton, Va.). In: Structures, Structural Dynamics and Materials Conference, 18th, March 21-23, 1977, and Aircraft Composites: The Emerging Methodology for Structural Assurance, San Diego, Calif., March 24, 25, 1977, Technical Papers. Volume A. New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 299-310. 7 refs. (AIAA 77-414)

A simple, rational approach is presented for developing continuum models for large repetitive lattice structures subjected to static and dynamic loadings. The procedure involves introducing kinematic assumptions to reduce the dimensionality of the lattice, and equating the strain and kinetic energies of the continuum model to those of the original lattice structure. The proposed procedure is applied to obtain effective elastic and dynamic characteristics of continuum plate models for double-layered grids. Numerical results are presented of stress and free vibration problems for two double-layered grids. These problems demonstrate the high accuracy of the continuum plate models developed. Also, an assessment is made of different approximations to these models. (Author)

A77-42801 # **Evaluation of rotor-induced gyroscopic coupling on the natural modes of large flexible spacecraft.** J. R. Canavin (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.) and L. Meirovitch (Virginia Polytechnic Institute and State University, Blacksburg, Va.). In: Guidance and Control Conference, Hollywood, Fla., August 8-10, 1977, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 435-442. Contract No. F04701-76-C-0178. (AIAA 77-1096)

This paper studies vibration modes of inertially stabilized flexible spacecraft with momentum-exchange controllers. A method is developed for using existing nongyroscopic system modes, obtained by means of the classical modal analysis, to derive spacecraft modes for gyroscopic systems. In particular, a two-stage eigenvalue analysis is developed where the natural modes of the spacecraft with the rotors locked are used to determine the natural modes of the gyroscopic system. By varying the speed of the rotors from zero to any given value, one can study the effect of the gyroscopic coupling on the spacecraft modes. (Author)

A77-51491 **Static and dynamic analysis of space radiotelescope thin wall structure elements.** V. I. Usiukin and V. A. Teneshchenko (Academy of Sciences, Intercosmos Council, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-236.* 13 p. 6 refs.

A radiotelescope designed for use in space is modeled as large thin shells of revolution. The shells are considered to be momentum shells or nonmomentum shells and are prestressed as a result of inertia and surface forces. The geometry of the prestressed shells is known and corresponds to unperturbed state. The loads of solar wind, tide, control forces efforts and nonuniform structure heating are treated as perturbations. The sequence of determination of inner stresses and structural deformation due to the interaction of perturbed and unperturbed forces is given. Linearization of the generalized nonlinear differential equations is performed. The relationships obtained are reduced to a quasi-one-dimensional scheme using the functions division method. Matrix factorization permits development of a stable numerical algorithm for solving a stable problem. Computer solutions show the shell deforming at axisymmetric and nonaxisymmetric loading. The results of vibration modes and frequencies are also presented. (Author)

A78-12103 # **Equations of motion for a rotating flexible structure.** R. M. Laurenson and P. W. Heaton (McDonnell Douglas Astronautics Co., St. Louis, Mo.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Symposium, Blacksburg, Va., June 13-15, 1977. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1977, p. 341-350. 10 refs.

A formulation of the equations of motion for a rotating flexible structure is presented in matrix notation. These equations are general in that coupling terms between large overall spinning motion and response of elastic structure are retained, making the equations applicable to both time history simulation and modal analyses. Standard structural analysis procedures often result in nondiagonal mass matrices while the assumption of diagonal mass matrices is common to most spacecraft dynamics simulation programs. The presented equations of motion place no restriction on the diagonal nature of the structural mass matrix. Thus, the results are of interest to those developing general simulation programs employing the output of current structural analysis procedures. (Author)

A78-12108 # **Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control.** G. Margulies, J. N. Aubrun, D. Bushnell, and J. Y. L. Ho (Lockheed Research Laboratories, Palo Alto, Calif.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Symposium, Blacksburg, Va., June 13-15, 1977. Blacksburg, Va., Virginia Polytechnic Institute and State University, 1977, p. 437-456. 9 refs.

Large-scale computer programs for the analysis of shells of revolution, multibody attitude dynamics, and for linear systems simulation and analysis are employed to model the performance of a large erectable optical spacecraft. The rigid-body equipment of the craft is gimbaled to the flexible optical section to simulate the attitude maneuvering; mode shapes obtained from the structural analysis program are recomputed as three-dimensional vector fields over the undeformed structures before application of the multibody attitude dynamic program. Time-simulations of the spacecraft motions are presented, and the coefficient matrices of the corresponding linearized plant are generated. The linearized matrices are used in the linear analysis and simulation program, which is based on control theory and state-space representation. J.M.B.

A78-29781 # **A new optimality criterion method for large scale structures.** M. R. Khan, K. D. Willmert, and W. A. Thornton (Clarkson College of Technology, Potsdam, N.Y.). In: Structures, Structural Dynamics and Materials Conference, 19th, Bethesda, Md., April 3-5, 1978, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1978, p. 47-58. 14 refs. Contract No. N00014-76-C-0064. (AIAA 78-470)

An optimality criterion method, which exploits the concept of one most critical constraint, is reported. The method eliminates the need to calculate a large set of Lagrange multipliers for the active constraints, and also eliminates the need for a decision as to whether or not a particular constraint should be considered active. The method can treat multiple load conditions and stress and displacement constraints. Application of the method to a number of truss and frame structures demonstrates the efficiency and accuracy of the method. (Author)

A78-31888 # **Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control.** G. Margulies, J. N. Aubrun, D. Bushnell, and J. Y. L. Ho (Lockheed Research Laboratories, Palo Alto, Calif.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Jackson Hole, Wyo., Sept. 7-9, 1977, Paper.* 29 p. 9 refs.

A generic large optical space system is analyzed as an illustration of a methodology for integrating the different disciplines involved in the dynamics and control of large flexible spacecraft. Mode shapes obtained from a program for the analysis of shells of revolution were recomputed as three-dimensional vector fields over the undeformed structures, and certain tensor functions were integrated over the structures before being entered directly into a multibody attitude dynamic program. This program generates time-simulations of spacecraft motions and computes the coefficient matrices of the corresponding linearized plant. The linearized matrices are then processed by a linear analysis and simulation program based on modern control theory and state-space representation. The computer interconnections among the above three programs are described with attention to the analysis of flexible deformations during attitude maneuvers and to the determination of the transmission of onboard vibration sources. M.L.

A78-44376 # **The new generation of dynamic interaction problems.** P. Likins (Columbia University, New York, N.Y.). *American Astronautical Society, Annual Rocky Mountain Guidance and Control Conference, Keystone, Colo., Mar. 10-13, 1978, Paper 78-101.* 22 p. 28 refs.

First-generation dynamic-interaction problems are reviewed, including the wire whip antennas of the Explorer 1 spacecraft, the gravity-stabilized OV1-10 spacecraft, and the Orbiting Geophysical Observatory. Hybrid coordinate models describing spacecraft behavior are noted. Various second-generation dynamic-interaction problems are considered with reference to the influences of the extreme flexibility of an entire spacecraft. Attention is given to spacecraft computer constraints, estimators and optimal controllers, frequency-domain interpretation, dynamic system modeling, and the mathematical bases of modeling. S.C.S.

A78-44901 * # **Continuum modeling of three-dimensional truss-like space structures.** A. H. Nayfeh (Cincinnati, University, Cincinnati, Ohio) and M. S. Hefzy. *AIAA Journal,* vol. 16, Aug. 1978, p. 779-787. 12 refs. Grant No. NsG-1185.

A mathematical and computational analysis capability has been developed for calculating the effective mechanical properties of three-dimensional periodic truss-like structures. Two models are studied in detail. The first, called the octetruss model, is a three-dimensional extension of a two-dimensional model, and the second is a cubic model. Symmetry considerations are employed as a first step to show that the specific octetruss model has four independent constants and that the cubic model has two. The actual values of these constants are determined by averaging the contributions of each rod element to the overall structure stiffness. The individual rod member contribution to the overall stiffness is obtained by a three-dimensional coordinate transformation. The analysis shows that the effective three-dimensional elastic properties of both models are relatively close to each other. (Author)

A78-45669 # **Dynamical characteristics associated with deploying, orbiting, beam-type appendages.** K. W. Lips and V. J. Modi (British Columbia, University, Vancouver, Canada). *American Institute of Aeronautics and Astronautics and American Astronautical Society, Astrodynamics Conference, Palo Alto, Calif., Aug. 7-9, 1978, AIAA Paper 78-1399.* 9 p. 7 refs. National Research Council of Canada Grant No. A-2181.

Investigated are vibration characteristics associated with a beam-type spacecraft appendage which is not only deploying and rotating but, in addition, is moving along an arbitrary orbit. Linear equations governing in-plane and out-of-plane vibration are derived by following a Lagrangian procedure. The second order kinetic-potential used is discretized by expanding elastic displacements in terms of a suitable set of admissible functions. Axial foreshortening associated with transverse displacement is included in the analysis. Instantaneous eigenvalues and eigenfunctions are solved for over a large range of system parameters. As well, representative response data is presented based on direct numerical integration of the equations. Effects of deployment are isolated and illustrated together with the relatively strong stiffening influence of the spin parameter. Although deployment rate tends to introduce instability, it is the deployment-related Coriolis loading which can result in excessive displacements should deployment times be too long. Another result of interest is the fact that an orbiting beam can have higher characteristic frequencies associated with it than a beam spinning but not orbiting. Overall such information should be of particular value when considering interactions among the structural, control, and vehicle dynamics. (Author)

A78-45682 * # **Dynamics of a flexible body in orbit.** V. K. Kumar and P. M. Bainum (Howard University, Washington, D.C.). *American Institute of Aeronautics and Astronautics and American Astronautical Society, Astrodynamics Conference, Palo Alto, Calif., Aug. 7-9, 1978, AIAA Paper 78-1418.* 9 p. 7 refs. Grant No. NsG-1414.

The equations of motion of an arbitrary flexible body in orbit are derived. The model includes the effects of gravity with all its higher harmonics. As a specific example, the motion of a long, slender, uniform beam in circular orbit is modeled. The example considers the inplane motion of the beam in orbit. In the case of planar motion with only flexural vibrations, the pitch motion is not influenced by the elastic motion of the beam. For large values of the square of the ratio of the structural modal frequency to the orbital angular rate the elastic motion is decoupled from the pitch motion. However, for small values of this ratio and small amplitude pitch motion, the elastic motion is governed by a Hill's 3-term equation. Numerical simulation of this equation indicates the possibilities of instability for very low values of the square of the ratio of the modal frequency to the orbit angular rate. (Author)

A78-46513 * # **Computerized structural sizing at NASA Langley Research Center.** W. J. Stroud, J. Sobieszczanski-Sobieski, J. E. Waltz, and H. G. Bush (NASA, Langley Research Center, Hampton, Va.). *American Institute of Aeronautics and Astronautics, Conference on Air Transportation: Technical Perspectives and Forecasts, Los Angeles, Calif., Aug. 21-24, 1978, Paper 78-1550.* 15 p. 54 refs.

Programs at the NASA Langley Research Center associated with the development of computerized structural sizing technology are reviewed. Particular attention is given to (1) lightweight columns for space structure applications, (2) stiffened composite panels for aerospace structures, (3) thermal structures for high-speed aircraft and space vehicles, (4) structural sizing methodology for finite-element structural models, (5) the sizing of large complex structural systems in multidisciplinary environments. Improvements to computational efficiency are noted with reference to a reduced number of sizing variables, a reduced number of constraints, and improved sizing algorithms. S.C.S.

A78-51989 * # **Large space structures assembly simulation.** S. B. Hall (NASA, Marshall Space Flight Center, Huntsville, Ala.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1662.* 7 p.

Simulation requirements for the evaluation of Large Space Structure assembly techniques have been developed by analysis of a typical large space structure through its entire life cycle. Applications of neutral buoyancy, air bearing simulators, computer driven rendezvous and docking simulators, and other simulation modes were studied. Several demonstrations of assembly techniques in neutral buoyancy have been conducted at MSFC using large scale hardware. Experience from those demonstrations and subsequent simulations can be used to select viable approaches for orbital application in operational vehicles. Demonstration results are presented which illustrate techniques and hardware designs that can significantly simplify construction of early large space structures. (Author)

A78-51999 * # **Thermal control requirements for large space structures.** M. Manoff (Rockwell International Corp., Downey, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1675.* 7 p. Contract No. NAS1-14116.

Performance capabilities and weight requirements of large space structure systems will be significantly influenced by thermal response characteristics. Analyses have been performed to determine temperature levels and gradients for structural configurations and elemental concepts proposed for advanced system applications ranging from relatively small, low-power communication antennas to extremely large, high-power Satellite Power Systems (SPS). Results are presented for selected platform configurations, candidate strut elements, and potential mission environments. The analyses also incorporate material and surface optical property variation. The results illustrate many of the thermal problems which may be encountered in the development of three systems. (Author)

N69-15726*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena. Telecommunications Div.

LARGE SPACECRAFT ANTENNA STUDY, ANALYTICAL PATTERN SUBTASK

R. M. Dickinson 15 Jan. 1969 32 p refs
(Contract NAS7-100)
(NASA-CR-99137; JPL-TR-32-1352) Avail: CFSTI CSCL 09F

Results are presented of an analytic and experimental program to develop techniques for calculating the circularly polarized patterns of erectable spacecraft high-gain antennas. Surface equations for one class of radial rib erectable antenna are derived. Mathematical expressions are developed for calculating the far field circularly polarized patterns based upon the reflector surface equations and circularly polarized feed illumination patterns. Experimental measured patterns were obtained to compare with the computer calculated theoretical patterns. Sample computer programs used to obtain the best focus position and to calculate patterns are contained in the Appendix. Author

N70-43143* National Aeronautics and Space Administration, Washington, D.C.
THE NASTRAN PROGRAMMER'S MANUAL
Frank J. Douglas, ed. 1970 1514 p refs
(NASA-SP-223) Avail: COSMIC CSCL 09B

The NASTRAN computer program for the analysis of large complex structures is presented. The NASTRAN program has been designed according to two classes of criteria. The first class relates to functional requirements for the solution of an extremely wide range of large and complex problems in structural analysis with high accuracy and computational efficiency. These criteria are achieved by developing and incorporating the most advanced mathematical models and computational algorithms that have been proven in practice. The second class of criteria relates to the operational and organizational aspects of the program. These aspects are somewhat divorced from structural analysis itself, but are of equal importance in determining the usefulness and quality of the program. Author

N71-36256*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
NON-LINEAR CONSIDERATION OF GRAVITY IN A STIFFNESS TEST OF A WEAK STRUCTURE AT SMALL STRAINS
Ralph G. Barclay, Stuart L. Hanlein, John Sween, Jr., and Paul H. King *In its* NASTRAN: Users Experiences Sep. 1971 p17-26
Avail: NTIS HC $9.00/MF $0.95 CSCL 20K

The NASTRAN computer program was used to calculate lateral deflections of a very weak spacecraft antenna boom, essentially a vertically-hung cantilever beam, under laboratory loading. The non-linear effect of gravity was included. The purpose of the test was to determine the boom stiffness at extremely small strains thus simulating the strain conditions produced by dynamic lateral deflections in orbit. The calculated deflections indicate that the determination should be possible however, large hysteresis effects were found to be present and stiffness results have not yet been determined. Author

N71-37535*# Southern Illinois Univ., Carbondale. School of Technology.
ADVANCED STRUCTURAL GEOMETRY STUDIES. PART 1: POLYHEDRAL SUBDIVISION CONCEPTS FOR STRUCTURAL APPLICATIONS
Joseph D. Clinton Washington NASA Sep. 1971 206 p refs
(Grant NGR-14-008-002)
(NASA-CR-1734) Avail: NTIS CSCL 20K

A study leading to the formulation of computer-oriented mathematical models pertaining to methods of subdividing polyhedra into triangulated spherical space frames is presented. The models perform the truncations and transformations of the polyhedral forms and calculate the geometrical properties of the generated space frames (spheres, hemispheres, and domes). Author

N71-37537*# Southern Illinois Univ., Carbondale. School of Technology.
ADVANCED STRUCTURAL GEOMETRY STUDIES. PART 2: A GEOMETRIC TRANSFORMATION CONCEPT FOR EXPANDING RIGID STRUCTURES
Joseph D. Clinton Washington NASA Sep. 1971 147 p refs
(Grant NGR-14-008-002)
(NASA-CR-1735) Avail: NTIS CSCL 20K

A study concerned with a geometrical transformation concept for expanding Tessellation and Polyhedral forms applicable to expandable structures is presented. Structural systems capable of being packaged in a small compact area and later deployed into a final, larger structural system are described. Five basic concepts are considered: (1) telescoping concept, (2) folding concept, (3) fan concept, (4) umbrella concept, and (5) variable geometry concept. Author

N71-37803*# Mississippi State Univ., State College. Dept. of Electrical Engineering.
COMPENSATOR IMPROVEMENT WITH AN APPLICATION TO A LARGE SPACE VEHICLE
Jerrel R. Mitchell 30 Sep. 1971 32 p refs
(Contract NAS8-21377)
(NASA-CR-119959) Avail: NTIS CSCL 09C

The required specifications for a computerized compensator improvement program are submitted. Several definitions in regard to relative stability are presented along with some frequency response limitations and characteristics of a large space vehicle. A nonlinear programming algorithm for obtaining a solution for a strict constraint problem is developed and the necessary partial derivatives for applying the algorithm to compensator improvement are derived. Finally, for illustrating the effectiveness of the algorithm, two examples of improving the frequency response characteristics of a large space vehicle are presented along with helpful programming hints. Author

N72-12093*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
RADIAL RIB ANTENNA SURFACE DEVIATION ANALYSIS PROGRAM
John V. Coyner, Jr. 15 Dec. 1971 70 p refs
(Contract NAS7-100)
(NASA-CR-124570; JPL-TM-33-518) Avail: NTIS CSCL 09A

A digital computer program was developed which analyzes any radial rib antenna with ribs radiating from a central hub. The program has the capability for calculating the antenna surface contour (reversed pillowing effect), the optimum rib shape for minimizing the rms surface error, and the actual rms surface error. Rib deflection due to mesh tension and catenary cable tension can also be compensated for, and the pattern from which the mesh gores are cut can be determined. Author

N72-16871*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
WAGGING TAIL VIBRATION ABSORBER
R. G. Barclay and P. W. Humphrey *In* Shock and Vibration Inform. Center The Shock and Vibration Bull. no. 40, pt. 5 Dec. 1969 p 147-155 refs
(NASA-TM-X-67585) Avail: NTIS; Director, Navy Publ. and Printing Serv. Office, Naval District of Washington, Bldg. 157-2, Washington Navy Yard, Washington, D. C. 20390; $15.00/set CSCL 20K

A 750-foot cantilever length of extendible-tape boom (very low stiffness) was considered as the main system to be damped. A number of tail lengths were tried from 20 feet to 80 feet after which 40 feet was investigated further as a desirable compromise between performance and practical lengths. A 40-foot damping tail produced a damping effect on the main boom for the first mode equivalent in decay rate to 3.1 percent of critical damping. In this case the spring-hinge and tail were tuned to the main boom first mode frequency and the hinge damping was set at 30 percent of critical based on the tail properties. With this same setting, damping of the second mode was .4 percent and the third mode .1 percent. Author

N72-25789*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
EXPERIMENTAL THERMAL MECHANICS OF DEPLOYABLE BOOM STRUCTURES
Roamer Predmore *In its* Significant Accomplishments in Technol., GSFC, 1970 1972 p 140-144
Avail: NTIS HC $3.00 CSCL 20M

An apparatus was developed for thermal distortion measurements on deployable boom structures. The calibration procedure and thermal static bending plus twist measurements are considered. The thermal mechanics test facility is described. A table is presented for several examples of spacecraft applications of thermal static distortion measurements on 3-m deployable booms. K.P.D.

N72-26850*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
INTEGRATED DYNAMIC ANALYSIS OF A SPACE STATION WITH CONTROLLABLE SOLAR ARRAYS
Joseph A. Heinrichs (Fairchild Ind., Inc., Germantown, Md.), Alan L. Weinberger (Fairchild Ind., Inc., Germantown, Md.), and Marvin D. Rhodes *In* Shock and Vibration Inform. Center The

Shock and Vibration Bull., No. 42, Pt. 2 Jan. 1972 p 137-152 refs
(NASA-TM-X-68469) Avail: NTIS; Shock and Vibration Information Center, Naval Research Labs., Washington, D. C.: HC $40.00 per set CSCL 20K

An integrated dynamic analysis and corresponding digital computer simulation for application to a space station with controllable solar arrays are presented. The analysis and simulation have been developed for the primary purpose of evaluating dynamic load interactions between the solar arrays and the space station which can result from orbital perturbations of the combined system. Integrated into the analytical formulation are the dynamics associated with the space station, the solar array flexibilities and their respective control systems. Application of the simulation is made utilizing present concepts of a space station with large area arrays and of typical control systems. A structural analysis of the flexible solar arrays is initially required to provide modal data for the simulation; and analytical results for an array concept are given. A verification of the structural dynamic methods used in the simulation is presented. This verification is accomplished by the application of the simulation to a problem of known solution, a uniform beam subjected to a unit step load applied at mid-span. Author

N72-32849*# Fairchild Industries, Inc., Germantown, Md.
INTEGRATED DYNAMIC ANALYSIS SIMULATION OF SPACE STATIONS WITH CONTROLLABLE SOLAR ARRAYS (SUPPLEMENTAL DATA AND ANALYSES) Final Report
Joseph A. Heinrichs and Joseph J. Fee (Wolf Res. and Develop. Corp.) Sep. 1972 464 p refs
(Contract NAS1-10155)
(NASA-CR-112145) Avail: NTIS HC $25.25 CSCL 22B

Space station and solar array data and the analyses which were performed in support of the integrated dynamic analysis study. The analysis methods and the formulated digital simulation were developed. Control systems for space station altitude control and solar array orientation control include generic type control systems. These systems have been digitally coded and included in the simulation. Author

N73-33003*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
RUSAP: A COMPUTER PROGRAM FOR THE CALCULATION OF ROLL-UP SOLAR ARRAY PERFORMANCE CHARACTERISTICS
R. G. Ross, Jr. and J. V. Coyner, Jr. 1 Oct. 1973 54 p refs
(Contract NAS7-100)
(NASA-CR-135898; JPL-TM-33-634) Avail: NTIS HC $4.75 CSCL 10A

RUSAP is a FORTRAN 4 computer program designed to determine the performance characteristics (power-to-weight ratio, blanket tension, structural member section dimensions, and resonant frequencies) of large-area, roll-up solar arrays of the single-boom, tensioned-substrate design. The program includes the determination of the size and weight of the base structure supporting the boom and blanket and the determination of the blanket tension and deployable boom stiffness needed to achieve the minimum-weight design for a specified frequency for the first mode of vibration. A complete listing of the program, a description of the theoretical background, and all information necessary to use the program are provided. Author

N74-17622# Spar Aerospace Products, Ltd., Toronto (Ontario).
THE CONTINUUM MECHANICS DYNAMIC STUDY OF A SATELLITE WITH FLEXIBLE SOLAR PANELS Final Report
D. B. Cherchas and R. Kumar Jul. 1973 174 p
(Contract ESTEC-1723/72)
(SPAR-R-554; ESTEC-CR(P)-294) Avail: NTIS HC $11.75

A continuum mechanics dynamics analysis was performed to determine the natural modes of vibration of a communications satellite with large flexible solar arrays. Assuming a symmetric satellite model, all translational and rotational modes of vibration were studied and the first three modes of each type were calculated to give natural frequencies and mode shapes. The effects of array boom root flexibility, array boom torsional stiffness, array solar cell blanket stiffness and body mass on the natural modes were established. The rotational natural modes were utilized to determine the response of the spacecraft to attitude control system inputs: (1) constant pitch, (2) roll and (3) yaw torques of short duration. The spacecraft response was found by superposing the rigid spacecraft motions with the 'flexible' spacecraft motions described by the natural modes. The array boom tip motions, body angles and angular rates and torques experienced by the body due to flexible oscillations of the arrays were calculated. The response was found using one, two and three natural modes of the appropriate type to evaluate the effect of the higher frequency modes. Author (ESRO)

N74-26394# National Aerospace Lab., Amsterdam (Netherlands). Space Div.
HANDBOOK FOR THE THERMAL MODELLING OF SPACE MECHANISMS BY THE NODAL NETWORK METHOD Final Report
J. P. B. Vreeburg, A. A. M. Delil, and J. F. Heemskerk Paris ESRO Feb. 1974 195 p refs
(Contract ESTEC-1679/72)
(ESRO-CR-219) Avail: NTIS HC $12.75

A literature survey, theory, step-by-step procedure, data and examples relating to the thermal modelling of spacecraft bearing mechanisms are given. Various standard forms and formats were defined. An appropriate nodal network for the mechanism was constructed. The temperatures and heat fluxes in the nodal network were obtained with the aid of standard computer programs. The procedure is illustrated by means of sample calculations for space mechanisms that were chosen so that various classes of mechanism under various thermal loading conditions are covered. The theory underlying the thermal modelling procedure is discussed. The procedure can be adapted to heat transfer by radiation and conduction in any type of structure, because the theory is not restricted to any particular application. Tables of thermal properties of materials are included. Author (ESRO)

N75-22539 Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
A SEMI-AUTOMATIC MODAL-SURVEY TEST TECHNIQUE FOR COMPLEX AIRCRAFT AND SPACECRAFT STRUCTURES
E. Breitbach *In* ESRO Large Struct. for Manned Spacecraft Mar. 1974 p 519-528 refs

An improved test technique for determining the normal modes, normal frequencies, generalized masses, and generalized damping coefficients of complex structures are dealt with. It is shown how the normal modes can be isolated using a semi-automatic computer-controlled multipoint harmonic excitation. New procedures for measuring the coupled generalized damping matrix and the generalized masses by means of electronically simulated additional masses or stiffnesses are described. A control method for checking the orthogonality of the measured normal modes is presented. Author (ESRO)

N75-33698* Martin Marietta Corp., Denver, Colo.
SIMULATION OF MAN-MACHINE INTERACTION ON SHUTTLE PAYLOAD MANIPULATOR
R. O. Hookway and R. S. Jackson *In* NASA. Ames Res. Center 11th Ann. Conf. on Manual Control May 1975 p 356-376 refs
CSCL 05H

The main objective of this simulation was to evaluate the feasibility of a simplified control system for a remote manipulator for space shuttle payloads. The motion commanded by the operator through the control system to the six degree of freedom manipulator approximates that of a backhoe. Compatibility of low arm damping, heavy payloads, small clearances in the shuttle cargo bay and stringent mission timelines were evaluated. The effects of various devices to enhance visual cues were evaluated. Phase I of the simulation was capture of a payload flying free in space relative to the shuttle. Phase II was simulation of cargo stowage into a mockup of the space shuttle cargo bay. A shuttle remote manipulator control station mockup including TV monitors and hand controllers is used in the simulation. Results evaluating various parameters of the control system and the task, including arm flexibility, are presented. Author

N76-28306 Societe Nationale Industrielle Aerospatiale, Cannes (France).
FINITE ELEMENT DYNAMIC ANALYSIS OF LARGE DIMENSIONAL FLEXIBLE SOLAR ARRAYS: NECESSITY OF MODAL TRUNCATION FOR THE SIMULATION OF SPACECRAFT CONTROL MANOEUVRES
G. LeGuilly and J. G. Ferrante (ESTEC) *In* ESA Dyn. and Control of Non-rigid Space Vehicles 1976 12 P refs

As the power requirements for future generation of communication satellites continue to increase, new designs of large solar arrays must be investigated. For this purpose flexible roll-out/fold-out structures represent a very interesting solution. The finite element idealization of such structures and the calculation of fixed base eigen modes by means of a special purpose computer program called DAFSA (Dynamic Analysis of Solar Arrays) are dealt with. The interpretation of these modes is given and the utilization of the convergence property of their associated participation gains is discussed. Special emphasis is put on local and global modes, and also on the representativity of flexible effect when modal truncation is unavoidable. Author (ESA)

N77-10280*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
A RAYLEIGH-RITZ APPROACH TO THE SYNTHESIS OF LARGE STRUCTURES WITH ROTATING FLEXIBLE COMPONENTS
L. Meirovitch and A. L. Hale *In* NASA. Langley Res. Center Advan. in Eng. Sci., Vol. 2 1976 p 531-542 refs

(Grant NsG-1114)
Avail: NTIS HC A20/MF A01

The equations of motion for large structures with rotating flexible components are derived by regarding the structure as an assemblage of substructures. Based on a stationarity principle for rotating structures, it is shown that each continuous or discrete substructure can be simulated by a suitable set of admissible functions or admissible vectors. This substructure synthesis approach provides a rational basis for truncating the number of degrees of freedom both of each substructure and of the assembled structure. Author

N77-12119*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
A COMPARISON OF SPACECRAFT PENETRATION HAZARDS DUE TO METEOROIDS AND MANMADE EARTH-ORBITING OBJECTS
David R. Brooks Nov. 1976 27 p refs
(NASA-TM-X-73978) Avail: NTIS HC A03/MF A01 CSCL 22B

The ability of a typical double-walled spacecraft structure to protect against penetration by high-velocity incident objects is reviewed. The hazards presented by meteoroids are compared to the current and potential hazards due to manmade orbiting objects. It is shown that the nature of the meteoroid number-mass relationship makes adequate protection for large space facilities a conceptually straightforward structural problem. The present level of manmade orbiting objects (an estimated 10,000 in early 1975) does not pose an unacceptable risk to manned space operations proposed for the near future, but it does produce penetration probabilities in the range of 1-10 percent for a 100-m diameter sphere in orbit for 1,000 days. The number-size distribution of manmade objects is such that adequate protection is difficult to achieve for large permanent space facilities, to the extent that future restrictions on such facilities may result if the growth of orbiting objects continues at its historical rate. Author

N77-19487*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
STRUCTURAL STIFFNESS, STRENGTH AND DYNAMIC CHARACTERISTICS OF LARGE TETRAHEDRAL SPACE TRUSS STRUCTURES
Martin M. Mikulas, Jr., Harold G. Bush, and Michael F. Card Mar. 1977 50 p refs
(NASA-TM-X-74001) Avail: NTIS HC A03/MF A01 CSCL 13M

Physical characteristics of large skeletal frameworks for space applications are investigated by analyzing one concept: the tetrahedral truss, which is idealized as a sandwich plate with isotropic faces. Appropriate analytical relations are presented in terms of the truss column element properties which for calculations were taken as slender graphite/epoxy tubes. Column loads, resulting from gravity gradient control and orbital transfer, are found to be small for the class structure investigated. Fundamental frequencies of large truss structures are shown to be an order of magnitude lower than large earth based structures. Permissible loads are shown to result in small lateral deflections of the truss due to low-strain at Euler buckling of the slender graphite/epoxy truss column elements. Lateral thermal deflections are found to be a fraction of the truss depth using graphite/epoxy columns. Author

N77-20501*# Grumman Aerospace Corp., Bethpage, N.Y.
APPLICATION OF NASTRAN TO LARGE SPACE STRUCTURES
T. Balderes, J. Zalesak, V. DyReyes, and E. Lee *In* NASA. Ames Res. Center NASTRAN: User's Experiences Oct. 1976 p 295-330 refs
Avail: NTIS HC A24/MF A01 CSCL 13M

The application of NASTRAN to design studies of two very large-area lightweight structures is described. The first is the Satellite Solar Power Station, while the second is a deployable three hundred meter diameter antenna. A brief discussion of the operation of the SSPS is given, followed by a description of the structure. The use of the NASTRAN program for static, vibration and thermal analysis is illustrated and some results are given. Next, the deployable antenna is discussed and the use of NASTRAN for static analysis, buckling analysis and vibration analysis is detailed. Author

N77-23188# British Aircraft Corp. (Operating) Ltd., Bristol (England). Electronics and Space Systems Group.
MATHEMATICAL METHODS IN FLEXIBLE SPACECRAFT DYNAMICS, VOLUME 1 Final Report
C. J. H. Williams, E. B. Crellin, and S. A. Gotts Dec. 1976 196 p refs 2 Vol.
(Contract ESTEC-2405/75-AK)
(ESS/SS-766-Vol-1; ESA-CR(P)-915-Vol-1) Avail: NTIS HC A09/MF A01

The present state of knowledge in the field of dynamics of flexible spacecraft is summarized. The word dynamics include deployment dynamics, stability of spin, response to attitude control torques, response to external disturbances, etc. The mathematical tools, analytical and numerical, which have been used to treat these problems are presented in detail and are critically compared with respect to their practical advantages and disadvantages. Author (ESA)

N77-23189# British Aircraft Corp. (Operating) Ltd., Bristol (England). Electronics and Space Systems Group.
MATHEMATICAL METHODS IN FLEXIBLE SPACECRAFT DYNAMICS, VOLUME 2 Final Report
C. J. H. Williams, E. B. Crellin, and S. A. Gotts Dec. 1976 286 p refs 2 Vol.
(Contract ESTEC-2405/75-AK)
(ESS/SS-766-Vol-2; ESA-CR(P)-915-Vol-2) Avail: NTIS HC A13/MF A01

For abstract, see N77-23188.

N77-23753*# Lockheed Electronics Co., Houston, Tex. Systems and Services Div.
KINEMATIC CAPABILITY IN THE SVDS
H. Flanders Mar. 1977 51 p refs
(Contract NAS9-15200)
(NASA-CR-151360; LEC-10246; JSC-12606) Avail: NTIS HC A04/MF A01 CSCL 05H

The details of the Remote Manipulator System kinematic model implemented into the Space Vehicle Dynamics Simulation are given. Detailed engineering flow diagrams and definitions of terms are included. Author

N78-13105*# Boeing Aerospace Co., Huntsville, Ala.
SIMPLIFIED THERMAL ESTIMATION TECHNIQUES FOR LARGE SPACE STRUCTURES

E. W. Brogren, D. L. Barclay, and J. W. Straayer Oct. 1977 119 p refs
(Contract NAS1-13967)
(NASA-CR-145253; D180-19334-2) Avail: NTIS HC A06/MF A01 CSCL 22B

A tool for making rapid estimates of the response of space structures to thermal environments encountered in earth orbits is provided for the designer of these structures. Charts giving heating rates and temperatures for certain typical large spacecraft structural elements are provided. Background information for spacecraft thermal design considerations is presented. Environments, requirements, thermal control techniques, design guidelines, and approaches available for more detailed thermal response analysis are discussed. Author

N78-14214# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Abt. Thermoelastik.

THERMAL TECHNOLOGY. PART 1: THERMAL PROBLEMS OF SATELLITE ANTENNAS

Oct. 1975 186 p refs In GERMAN; ENGLISH summary Proc. of 4th DGLR Colloq., Cologne, 23 Oct. 1975
(DLR-IB-152-76/08) Avail: NTIS HC A09/MF A01

Papers are presented in the field of satellite antenna thermal control. The following subjects are discussed: thermally induced vibrations of satellite antenna booms, effects of thermal errors on antenna accuracy and consequences on antenna design, effect of types of thermal insulation on the thermal design of large antennas, thermal control of a satellite truss antenna, thermoelastic behavior of a satellite antenna noting contact-free deformation measurement, and thermal insulating effect of spherical contact surfaces in high vacuum applied to ball bearings.

N78-18117*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.

OPTIMIZATION OF THE DESIGN PARAMETERS FOR A WIDE-BAND RADIOMETRIC SYSTEM

Pradeep K. Agrawal (Joint Inst. for Advan. of Flight Sci., Hampton, Va.) Jan. 1978 25 p refs
(NASA-TM-78662) Avail: NTIS HC A02/MF A01 CSCL 14C

The optimun design parameters for a swept frequency wide-band radiometric antenna system for spacecraft applications are studied. Wide band antenna systems are needed to observe layered surfaces which are frequency sensitive and require multiple measurements for interpretation. The lowest frequency band of interest is between 1.4 to 2.8 Ghz. Starting with a given size reflector fed in the offset mode by a corrugated horn located at the focus of the parabola, the primary performance indexes; e.g., half power beamwidth, cross polarization level, and overall beam efficiency were calculated over a wide frequency range (two to one) for different physical horn dimensions and for different values of f/D ratio. These data are used to find the best design under given restriction of reflector size and blockage. Author

N78-23140*# Howard Univ., Washington, D. C. Dept. of Mechanical Engineering.

THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES. PART B: DEVELOPMENT OF CONTINUUM MODEL AND COMPUTER SIMULATION Final Report

Peter M. Bainum, V. K. Kumar, and Paul K. James May 1978 116 p refs
(Grant NsG-1414)
(NASA-CR-156976) Avail: NTIS HC A06/MF A01 CSCL 22B

The equations of motion of an arbitrary flexible body in orbit were derived. The model includes the effects of gravity with all its higher harmonics. As a specific example, the motion of a long, slender, uniform beam in circular orbit was modelled. The example considers both the inplane and three dimensional motion of the beam in orbit. In the case of planar motion with only flexible vibrations, the pitch motion is not influenced by the elastic motion of the beam. For large values of the square of the ratio of the structural modal frequency to the orbital angular rate the elastic motion was decoupled from the pitch motion. However, for small values of the ratio and small amplitude pitch motion, the elastic motion was governed by a Hill's 3 term equation. Numerical simulation of the equation indicates the possibilities of instability for very low values of the square of the ratio of the modal frequency to the orbit angular rate. Also numerical simulations of the first order nonlinear equations of motion for a long flexible beam in orbit were performed. The effect of varying the initial conditions and the number of modes was demonstrated. Author

N78-24273# Engins Matra, Velizy (France).

THERMAL DESIGN VERIFICATION, QUALIFICATION AND ACCEPTANCE TESTING CONCEPT FOR FUTURE LARGE SPACE OBJECTS

J. F. Arnoult and P. Rollier Paris ESA 15 Dec. 1977 95 p refs
(Contract ESTEC-3255/NL/77-HP(SC))
(N-44/85/PR/ChH; ESA-CR(P)-1039) Avail: NTIS HC A05/MF A01

Thermal testing of large space vehicles is discussed. The causes of mathematical thermal model errors and the means to determine, estimate, and reduce them, as well as how to perform thermal tests in order to achieve the qualification and acceptance test goals, were analyzed. A test philosophy for the Ariane Large Satellite (ALS) is described and discussed. The opportunity is taken to specify the testing capacity limitation of the SIMLES, which is the largest thermal test facility existing in Europe. Recommendations concerning design philosophies for large satellites which will be undertaken between 1980 and 1990 are given, bearing in mind that, if possible, building of new European test facilities must be avoided. In addition some comments are given concerning temperature limits and temperature margin definitions. Author (ESA)

N78-24688# Aerospace Engineering Office, Zurich (Switzerland).

STUDY OF TEST METHODS FOR LARGE FLEXIBLE SOLAR ARRAYS (VELSA) Final Report

C. R. Vincent, K. J. Zimmermann, and H. R. Luessi Paris ESA Jul 1977 276 p refs Prepared jointly with Pilatus Aircraft Ltd.
(Contract ESTEC 2990/76 NL HP(SC))
(ESA-CR(P) 1016) Avail: NTIS HC A13/MF A01

Methods and means to predict and verify the dynamic on-orbit characteristics of large flexible solar arrays are discussed. The actual status is given by surveys of available computer programs, recent correlation work, test facilities, and test methods. Required verification tests are listed and, in the outline of particular tests, the gravity effects are checked. Analytical methods investigated for the prediction of the dynamic characteristics take into account material and geometrical nonlinearities as well as thermal transient loads. Algorithms for the correlation of the mathematical model to test results are discussed. Based on cost estimates, feasibility of tests and analytical aspects, suitable verification programs are elaborated for both stowed and deployed configurations. Considering test priorities, a reduced cost program is set up in parallel. The accuracy in the prediction of the solar array dynamic characteristics is mainly improved by a logic sequence of tests starting at component level and following various assembly stages as well as by the correlation of the mathematical model. Author (ESA)

N78-25123*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.

A DIGITAL COMPUTER PROGRAM FOR THE DYNAMIC INTERACTION SIMULATION OF CONTROLS AND STRUCTURE (DISCOS), VOLUME 1

Carl S. Bodley (Martin Marietta Corp., Denver), A. Darrell Devers (Martin Marietta Corp., Denver), A. Colton Park (Martin Marietta Corp, Denver), and Harold P. Frisch May 1978 169 p refs
(NASA-TP-1219-Vol-1; G7702-F26-Vol-1) Avail: NTIS HC A08/MF A01 CSCL 22B

A theoretical development and associated digital computer program system for the dynamic simulation and stability analysis of passive and actively controlled spacecraft are presented. The dynamic system (spacecraft) is modeled as an assembly of rigid and/or flexible bodies not necessarily in a topological tree configuration. The computer program system is used to investigate total system dynamic characteristics, including interaction effects between rigid and/or flexible bodies, control systems, and a wide range of environmental loadings. In addition, the program system is used for designing attitude control systems and for evaluating total dynamic system performance, including time domain response and frequency domain stability analyses.

Author

N78-31464*# Wiggins (J. H.) Co., Redondo Beach, Calif.
MODEL VERIFICATION OF LARGE STRUCTURAL SYSTEMS
Final Report, 13 Apr. 1976 - 15 Jul. 1978
L. T. Lee and T. K. Hasselman Jul. 1978 241 p refs
(Contract NAS8-31950)
(NASA-CR-150811; TR-78-1300) Avail: NTIS
HC A11/MF A01 CSCL 20K

A computer program for the application of parameter identification on the structural dynamic models of space shuttle and other large models with hundreds of degrees of freedom is described. Finite element, dynamic, analytic, and modal models are used to represent the structural system. The interface with math models is such that output from any structural analysis program applied to any structural configuration can be used directly. Processed data from either sine-sweep tests or resonant dwell tests are directly usable. The program uses measured modal data to condition the prior analytic model so as to improve the frequency match between model and test. A Bayesian estimator generates an improved analytical model and a linear estimator is used in an iterative fashion on highly nonlinear equations. Mass and stiffness scaling parameters are generated for an improved finite element model, and the optimum set of parameters is obtained in one step.

A.R.H.

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03
STRUCTURAL CONCEPTS

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

A68-18019#

A FOLDABLE TUBULAR CONNECTING ELEMENT AND ITS APPLICATION TO AN EXTENSIBLE RETICULAR COLUMN [UN ELEMENTO DE CONEXION TUBULAR PLEGABLE Y SU APLICACION A UNA COLUMNA RETICULAR EXTENDIBLE].

Julio Fernandez Sintes (Instituto Nacional de Tecnica Aeroespacial, Madrid, Spain).

(Astronautical International Federation, Congress, 18th, Belgrade, Yugoslavia, Sept. 1967.)

Ingenieria Aeronautica y Astronautica, vol. 19, Sept.-Oct. 1967, p. 23-33. 6 refs. In Spanish.

Discussion of the possible application of foldable tubes to space structures. The pure bending of foldable tubes is discussed, together with the distribution of stresses in a foldable tube, and the continuity of certain operating and structural characteristics in the coupling of a foldable tube with a circular tube. An example of the application of foldable tubular connections to an extensible reticular structure is considered. M.M.

A68-24311#

A FAMILY OF RIGID SHELL STRUCTURES, SELF-DEPLOYABLE FROM FOLDED CONFIGURATIONS OF SMALL INITIAL VOLUME.

A. P. Coppa (General Electric Co., King of Prussia, Pa.).

American Institute of Aeronautics and Astronautics, and American Society of Mechanical Engineers, Structures, Structural Dynamics and Materials Conference, 9th, Palm Springs, Calif., Apr. 1-3, 1968, AIAA Paper 68-359. 16 p.

Members, $1.00; nonmembers, $1.50.

Description of a new family of folded-plate shell structures, called Coppacones, derived from foldable transformations of conical shell frusta. The structures consist of arrays of planar elements mutually joined along their lines of intersection. Their geometry is specified by five independent parameters and defined by formulas. A number of useful properties are exhibited, including low-volume packageability, self-deployability into relatively large size, high structural efficiency, designable combinations of axial and radial rigidities, and variability of shape and size. A wide variety of mean surface shapes can be produced, including cylinders, cones, cylindrical and conical tori, spheres, ellipsoids, and more general doubly curved shell forms. Applications such as erectable solar arrays, space station and planetary base structures, and antenna structures are briefly discussed. (Author)

A68-25464*#

RELATIVE RATING OF 9' - 16' DEPLOYED DIAMETER SPACEBORNE ANTENNA ERECTING TECHNIQUES.

E. W. Radany (Neotec Corp., Rockville, Md.).

American Institute of Aeronautics and Astronautics, Communications Satellite Systems Conference, 2nd, San Francisco, Calif., Apr. 8-10, 1968, Paper 68-436. 9 p.

Members, $1.00; nonmembers, $1.50.

NASA-sponsored research.

Discussion of a parametric study of six techniques for erecting 9 to 16-in. -deployed-diameter spaceborne paraboloidal antennas. The antenna-erecting techniques have applicability to near-earth or interplanetary missions. Optimum weight distribution curves are presented for each erecting technique as a function of the antenna geometric variables. These weights were determined for constraints placed on: (1) the packaging ratio, (2) thermal deflection, (3) 1-"g" loading deflection, (4) stowed and deployed configuration structural natural frequency, (5) ascent loading stress levels, and (6) maneuvering load-stress levels. The six techniques were assigned a relative rating, based on the consideration of optimum weight, deployed configuration deviation from parabolic contour, deployment reliability, degraded mode capability, technical risk, and cost. Weighting factors quantifying the quality and importance of each of the foregoing items were employed in establishing the relative ratings. M.M.

A68-42162

FLEXURAL INSTABILITY OF ELASTIC RECOVERY FOLDABLE TUBES.

J. Fernandez-Sintes (Instituto Nacional de Tecnica Aerospacial, Madrid, Spain).

(International Astronautical Federation, International Astronautical Congress, 17th, Madrid, Spain, Oct. 9-15, 1966, Paper.)

IN: SPACECRAFT SYSTEMS; INTERNATIONAL ASTRONAUTICAL FEDERATION, INTERNATIONAL ASTRONAUTICAL CONGRESS, 17TH, MADRID, SPAIN, OCTOBER 9-15, 1966, PROCEEDINGS. VOLUME 1.

Edited by Michal Lunc.

Paris, Dunod Editeur; New York, Gordon and Breach, Science Publishers, Inc.; Warsaw, PWN-Polish Scientific Publishers, 1967, p. 327-333.

Consideration of foldable tubes now under development for use as structural elements, piping of fluids, antennas, and masts. A foldable tube is a cylindrical shell with a closed transverse section the shape and proportions of which are such that the tube can be flattened laterally and folded or coiled without exceeding its elastic limit. When the activating mechanism is released, the tube regains its free form elastically. The structural behavior of this type of tube is examined. A direct method of variational calculus, analogous to that of Rayleigh and Ritz is applied to the bending phenomena. F.R.L.

A68-42789*#

EXPANDABLE AND MODULAR STRUCTURES TECHNOLOGY FOR SUPPORT OF MANNED MISSIONS.

F. W. Forbes (USAF, Systems Command, Research and Technology Div., Aero Propulsion Laboratory, Wright-Patterson AFB, Ohio) and M. I. Yarymovych (NASA, Office of Manned Space Flight, Washington, D. C.).

(International Astronautical Federation, International Astronautical Congress, 17th, Madrid, Spain, Oct. 9-15, 1966, Paper.)

IN: LIFE IN SPACECRAFT; INTERNATIONAL ASTRONAUTICAL FEDERATION, INTERNATIONAL ASTRONAUTICAL CONGRESS, 17TH, MADRID, SPAIN, OCTOBER 9-15, 1966, PROCEEDINGS. VOLUME 5.

Edited by Mical Lunc.

Paris, Dunod Editeur; New York, Gordon and Breach, Science Publishers, Inc.; Warsaw, PWN-Polish Scientific Publishers, 1967, p. 147-158.

Summary of the present state of technology of expandable and modular structures, with direct emphasis on its immediate and future applications to manned space missions. The various types of structures are reviewed: inflatable structures, chemically-rigidizable structures (gas-catalyzed urethane systems, radiation-cured polyester systems, foamed-in-place rigidization systems), unfurlable structures, and elastic recovery structures. Airlocks, crew tunnels, and hangars constructed by such processes are reviewed, and the problems connected with space stations and lunar shelters are briefly considered. The feasibility of manned space assembly of modular structures is mentioned. A brief examination of the human factor and human engineering requirements is included. S.Z.

A68-44253*

LARGE SPACE ERECTABLE COMMUNICATION ANTENNAS.

J. A. Fager (General Dynamics Corp., Convair Div., San Diego, Calif.).

International Astronautical Federation, Congress, 19th, New York, N. Y., Oct. 13-19, 1968, Paper SD 9. 11 p.

New York, American Institute of Aeronautics and Astronautics, $1.00.

Contracts No. NASw-1438; No. NAS 8-18118; No. NAS 8-21460.

Large antennas are required to provide optimum use of the shrinking frequency spectrum. At constant frequency, increased antenna size reduces beamwidth and increases gain. The paper discusses an erectable truss antenna concept capable of deploying a rigid (1.5 cps), lightweight (0.10 lb/ft2 of aperture), paraboloid from 5 to 300 ft in diam. A three-dimensional spring-loaded truss retracts into three potential packaging configurations such that, typically, a 100-ft-diam antenna could be packaged into a 10-ft envelope. Depth of the truss reduces solar induced thermal distortions enabling tolerance-to-diameter ratios of 10-4 to be achieved over the reflector surface. While deployment is completely automatic, all functions could be uniquely supported by an astronaut. Radio frequency tests have been successfully performed on a 6-ft working model at 15 GHz with a peak gain frequency projected at 30 GHz.

A69-17608
FOLDABLE TUBULAR CONNECTION AND ITS APPLICATION TO AN EXPANDABLE LATTICE COLUMN.
J. Fernandez-Sintes (Instituto Nacional de Tecnica Aeroespacial, Madrid, Spain).
IN: INTERNATIONAL ASTRONAUTICAL FEDERATION, INTERNATIONAL ASTRONAUTICAL CONGRESS, 18TH, BELGRADE, YUGOSLAVIA, SEPTEMBER 24-30, 1967, PROCEEDINGS. VOLUME 2 - SPACECRAFT SYSTEMS, EDUCATION.

Edited by Michal Lunc.
Oxford, Pergamon Press, Ltd. ; Warsaw, Panstwowe Wydawnictwo Naukowe, 1968, p. 219-227. 5 refs.
Analysis of the lengthwise variation of the cross-sectional distortions of foldable tubular connections. Using the Rayleigh-Ritz method, a general expression for the total potential is given, from which the changes of the transverse and longitudinal curvature can be deduced. An example of the application of foldable tubular connections to an expandable lattice structure is presented. Z. W.

A69-18350*#
WIRE SCREEN BOOMS FOR GRAVITY GRADIENT AND ANTENNA APPLICATION.
H. R. Wiant (General Dynamics Corp., Convair Div., Materials and Process Dept., San Diego, Calif.).
U.S. Air Force Systems Command and Aerospace Corp., Symposium on Gravity Gradient Attitude Stabilization, El Segundo, Calif., Dec. 3-5, 1968, Paper. 7 p.
Contracts No. NAS 5-9597; No. NAS 5-10376.
The wire-screen deployable boom was developed as one solution to the problem of thermal bending of slender tubes in space. Problem analysis, material development, fabrication, and testing of wire-screen booms and their deployment mechanism is presented. A simple gravity-gradient or antenna boom exhibiting acceptable strength and superior straightness was developed, using a combination of mechanical and thermal analysis and materials and processing technology for the solution of a specific problem. (Author)

A69-25532#
FREQUENCIES AND MODE SHAPES OF A 100-FOOT SPACE ERECTABLE PARABOLIC ANTENNA.
R. K. Gieseke (General Dynamics Corp., Convair Div., San Diego, Calif.).
IN: AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, STRUCTURES, STRUCTURAL DYNAMICS, AND MATERIALS CONFERENCE, 10TH, NEW ORLEANS, LA., APRIL 14-16, 1969, PROCEEDINGS.
New York, American Institute of Aeronautics and Astronautics, Inc., 1969, p. 383-396. 8 refs.
Because of the increased influence of structrual feedback on the control system requirements of large, flexible satellites, accurate evaluation of multidimensional mode shapes and frequencies has become even more vital to a successful system design. This work describes an evaluation of the modal properties of a 100-ft space erectable antenna through the use of a digital computer program developed to perform modal determinations on structures of arbitrary geometry in three dimensions. The antenna is modeled by defining the stiffness matrices of several substructures and then merging the substructure matrices on the basis of common coordinates. The eigen-values resulting from the analytical model exhibit a regular multiplicity of values, reflecting the symmetries of the antenna. (Author)

A69-35544
ERECTABLE STRUCTURES AND MESHES FOR SPACE APPLICATIONS.
Harry J. Sheetz, III (Radio Corporation of America, Astro-Electronics Div., Princeton, N.J.).
IN: MATERIALS AND PROCESSES FOR THE 70'S; SOCIETY OF AEROSPACE MATERIAL AND PROCESS ENGINEERS, NATIONAL SYMPOSIUM AND EXHIBITION, 15TH, LOS ANGELES, CALIF., APRIL 29-MAY 1, 1969, PROCEEDINGS. North Hollywood, Western Periodicals Co.; Azusa, Calif., Society of Aerospace Material and Process Engineers (Science of Advanced Materials and Process Engineering Proceedings. Volume 15), 1969, p. 509-519. 13 refs.
Spacecraft antennas, gravity-gradient booms, and radiant-energy reflectors for spacecraft which are folded or telescoped for the launch phase require new concepts of construction and deployment as their size requirements increase. The paper describes some new techniques in fabricating, stowing, and deploying metal booms and meshes. Formulas to permit analysis and design of adequate structures are given, and techniques for the mounting and deployment of these structures are described. A bibliography for further reference is included. (Author)

A69-35595 #
GENERAL AVIATION–THE AIRPORT PROBLEM.
Neal R. Montanus (Port of New York Authority, New York, N.Y.).
American Institute of Aeronautics and Astronautics, Aircraft Design and Operations Meeting, Los Angeles, Calif., July 14-16, 1969, Paper 69-820. 6 p.
Members, $1.00; nonmembers, $1.50.
Discussion of proposals to relieve congestion at major airports during peak traffic hours. These proposals include the development of alternate facilities, the institution of restrictive flight schedules for peak hours, and the introduction of a fee schedule to encourage use of alternate facilities by general aircraft. B.H.

A69-42827 * #
DEPLOYMENT LATCHUP DYNAMICS OF AN ERECTABLE TRUSS ANTENNA.
McLane Downing and Hayden A. Mitchell (General Dynamics Corp., Convair Div., San Diego, Calif.).
American Astronautical Society and Operations Research Society of America, Joint National Meeting, Denver, Colo., June 17-20, 1969, AAS Paper 69-336. 31 p. 10 refs.
Contract No. NAS 8-21460.
Description of two techniques for analyzing the dynamics of zero-g deployment of erectable truss parabolic antennas with diameters from 5 to 300 ft. These techniques are applicable to (1) erectable truss designs for other antenna types and for different space structures, and (2) other deployable space structure designs. Large space structures must be packaged to fit within launch vehicles and subsequently be deployed. Dynamic analysis must ensure that deployment is reliable, complete, and free from structural damage. Deployment latchup loads are obtained as a function of antenna reflector mechanical energy. Reflector deployment time history simulation computes component velocities, accelerations, loads, energy relationships, and reflector kinetic energy at latchup. (Author)

A69-42877 * #
LARGE SPACE ERECTABLE STRUCTURES.
Desmond H. Vaughan (General Dynamics Corp., Convair Div., San Diego, Calif.).
American Astronautical Society and Operations Research Society of America, Joint National Meeting, Denver, Colo., June 17-20, 1969, AAS Paper 69-152. 32 p. 7 refs.
Contracts No. NAS 3-1438; No. NAS 8-18118; No. NAS 8-21460.
Description of an expanding structure concept which enables the deployment, in space, of large space frames. Rigidity, dynamic stiffness, thermal shape stability, structural efficiency and integrity are all inherent characteristics of the basic concept. Such structures are applicable for space antennas, solar concentrators, solar panel arrays, space stations, lunar shelters, and any project where a rigid, light-weight, packageable structure is required. During the past four years, application to space erectable antennas has been studied in depth. Various configurations are presented, including a 78-ft helical antenna and a 100-ft diameter paraboloidal antenna. The expandable truss concept promises to meet a broad range of space structure requirements projected through the '70s. (Author)

A70-11931

AEROSPACE STRUCTURES DESIGN CONFERENCE, SEATTLE, WASH., AUGUST 4, 5, 1969, PROCEEDINGS.

Conference sponsored by the Seattle Professional Engineering Employees Association, the American Institute of Aeronautics and Astronautics, the Boeing Co., the University of Washington, and the Pacific Science Center.

Seattle, Wash., Seattle Professional Engineering Employees Association, 1969. 324 p.

S15.

CONTENTS:

A70-11932 * #

DEPLOYMENT TECHNIQUES DEVELOPED FOR LARGE AREA ROLL-OUT SOLAR ARRAYS.

W. A. Hasbach (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.).

IN: AEROSPACE STRUCTURES DESIGN CONFERENCE, SEATTLE, WASH., AUGUST 4, 5, 1969, PROCEEDINGS.

Conference sponsored by the Seattle Professional Engineering Employees Association, the American Institute of Aeronautics and Astronautics, the Boeing Co., the University of Washington, and the Pacific Science Center.

Seattle, Wash., Seattle Professional Engineering Employees Association, 1969, p. 1-1 to 1-12.

Description of a feasibility study which has been performed to determine deployment systems which could extend large-area, lightweight, flexible solar arrays in space. The estimated weight for each design concept, including the estimated power-to-weight ratio, is tabulated. In the stowed configuration, the array must occupy a minimum of area within the shroud envelope and, upon command, extend at a uniform rate into the deployed position. The manufacturing technology is limited to modest extensions of the existing state of development. M.M.

A70-14725 #

DEPLOYABLE BOOMS FOR GRAVITY GRADIENT STABILIZATION—A PROGRESS REPORT.

J. D. MacNaughton and E. R. Grimshaw (Spar Aerospace Products, Ltd., Toronto International Airport, Toronto, Canada).

Canadian Aeronautics and Space Journal, vol. 15, Nov. 1969, p. 371-374. 8 refs.

Demonstration of the evolution of the configuration of STEM (storable tubular extendible member) booms and mechanisms to meet the changing requirements of aerospace gravity gradient stabilization systems. It is noted that the invention of the BI-STEM was in fact the first major change in STEM philosophy in this period, and that the interlocked BI-STEM is perhaps the most significant advance since the STEM concept was introduced as an aerospace mechanism. M.M.

A70-14898 * #

ANALYSIS OF PERFORMANCE CHARACTERISTICS AND WEIGHT VARIATIONS OF LARGE-AREA ROLL-UP SOLAR ARRAYS.

John V. Coyner, Jr. and Ronald G. Ross, Jr. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *American Society of Mechanical Engineers, Winter Annual Meeting, Los Angeles, Calif., Nov. 16-20, 1969, Paper 69-WA/Ener-11.* 6 p. Members, $1.00; nonmembers, $2.00.

An analysis capability to determine the relationships between performance characteristics of large-area roll-up solar arrays of the single-boom, tensioned substrate design, includes the determination of the size and weight of the base structure supporting the boom and blanket and the optimum blanket tension and deployable boom stiffness needed to achieve a specified frequency for the first mode of vibration. Size and weight equations relate change in length and width of the array to change in support structure size and weight. Root finding subroutines, used to determine the blanket tension and boom stiffness necessary to obtain a minimum frequency of the deployed array equal to a desired value, employ a modified double false position method to obtain the desired root. The frequencies are determined from a finite element model of the deployed solar array. (Author)

A70-34137 # **Spacecraft booms - Present and future.** G. G. Herzl (Lockheed Missiles and Space Co., Palo Alto, Calif.). In: Aerospace mechanisms. Part A General applications. Edited by G. G. Herzl. San Francisco, J. W. Stacey, Inc. (Aerospace Mechanisms Series. Volume 1), 1970, p. 339-356. 9 refs.

Review of the state of the art and future trends in the design of spacecraft booms. The present performance of booms is summarized, and some current applications of booms on spacecraft are illustrated by a series of photographs of Russian spacecraft using booms in various ways. Future trends considered include better performance, better manufacturing techniques, longer active operational lifetimes, and the need for very long spacecraft booms. O.H.

A70-34138 * # **State-of-the-art materials and design for spacecraft booms.** Charles Staugaitis (NASA, Goddard Space Flight Center, Greenbelt, Md.). In: Aerospace mechanisms. Part A - General applications. Edited by G. G. Herzl. San Francisco, J. W. Stacey, Inc. (Aerospace Mechanisms Series. Volume 1), 1970, p. 357-359.

Description of five spacecraft boom concepts developed in response to a comprehensive investigation of spacecraft materials and design conducted by the Goddard Space Flight Center. These boom designs represent all the basic concepts either currently in production or in the latter stages of development. The primary purpose of the study was to investigate the thermal and mechanical properties of these promising boom configurations. The boom designs and the materials used for each are discussed and evaluated. O.H.

A70-34141 # **The BI-STEM - A new technique in unfurlable structures.** J. D. MacNaughton, H. N. Weyman, and E. Groskopfs (de Havilland Aircraft of Canada, Ltd., Malton, Ontario, Canada). In: Aerospace mechanisms. Part A - General applications. Edited by G. G. Herzl. San Francisco, J. W. Stacey, Inc. (Aerospace Mechanisms Series. Volume 1), 1970, p. 369-375.

Description of the BI-STEM, a new development of the Storable Tubular Extendible Member (STEM), which is used for erecting unfurlable structures in space. Two diametrically opposed 'underlapped' elements are employed in a front-to-front configuration. These BI-STEM elements may be stored on single or multiple drums in much the same fashion as STEM elements. Some of the significant advantages over the more conventional STEM for certain applications are highlighted. F.R.L.

A70-34142 # **New closed tubular extendible boom.** Bruce B. Rennie (Boeing Co., Kent, Wash.). In: Aerospace mechanisms. Part A - General applications. Edited by G. G. Herzl. San Francisco, J. W. Stacey, Inc. (Aerospace Mechanisms Series. Volume 1), 1970, p. 377-383. 5 refs.

Outline of a new concept which has been added to the family of extendible booms. The Boeing-developed MAST (Multiple Applications Storable Tube) is a closed, collapsible tube that may be used to transport fluid and transmit torque in addition to the other functions performed by currently used extendible booms. Data are presented to serve as a design guide, and the development work is described. F.R.L.

A70-34143 * # **Torsionally rigid and thermally stable boom.** F. C. Rushing, A. B. Simon, and C. I. Denton (Westinghouse Defense and Space Center, Baltimore, Md.). In: Aerospace mechanisms. Part A - General applications. Edited by G. G. Herzl. San Francisco, J. W. Stacey, Inc. (Aerospace Mechanisms Series. Volume 1), 1970, p. 385-389. Contracts No. NAS 5-9598; No. NAS 5-10130.

Description of the Torsionally Rigid and Thermally Stable Boom, which uses a unique pattern of windows or perforations in combination with selected thermal coatings on both inside and outside surfaces to produce equal distortions on opposite sides of the boom in sunlight, and thus eliminate thermal bending. A typical boom is made of 0.002-in.-thick beryllium copper and is ½-in. in diameter. An interlocked seam maximizes torsional and bending rigidities, and makes them more predictable. A special deployer which has been developed for the boom is described. F.R.L.

A70-44603 # **The crossed H interferometer - A large space structure for orbital astronomy.** G. E. Taylor, Jr. (General Dynamics Corp., Convair Div., San Diego, Calif.). *International Astronautical Federation, International Astronautical Congress, 21st, Konstanz, West Germany, Oct. 4-10, 1970, Paper.* 16 p.

This paper presents the preliminary structural and systems design, including dynamics and thermodynamics analysis, of a large radio astronomy antenna. The deployment, operation and maintenance of the gravity gradient stabilized structure in synchronous orbit, using man as a deployment monitor and malfunction correction media, is also discussed. Desired performance parameters were derived through meetings with members of the scientific community during early phases of configuration design. These parameters established the requirement for a large adjustable structure to operate in .5 MHz to 10.0 MHz range, and provided a basis for structural and systems design of the facility. Structure and on-board systems required for a two-year mission were designed for man's participation in maintenance and updating of the facility, thus improving the probability of mission success. The facility consists of two satellites which are separated by a 10,000 meter adjustable length tether. Attitude control is effected through sun sensors and auto pilot commanded pulsing of the cold gas nitrogen reaction control system duplicated within each satellite. (Author)

A71-12324 * **A new geometry for unfurlable antennas.** Arthur C. Ludwig (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *MicroWaves,* vol. 9, Nov. 1970, p. 41, 42.

Description of the mechanical design features and electrical characteristics of unfurlable spacecraft antennas using a Gregorian geometry with a singly curved conical main-reflector surface. The sub-reflector contour is a segment of a parabola revolved about the antenna's center-line axis. All surfaces are figures of revolution, and the main attraction of the design is that the singly curved main reflector may be folded without stretching or compressing the surface. Therefore, it is possible to make the main reflector surface from light sheet material rather than a compliant mesh material. Recent testing in the range from 2295 to 8448 MHz yielded an efficiency of 58%. T.M.

A71-25272 # **Strength and efficiency of deployable booms for space applications.** R. F. Crawford (Astro Research Corp., Santa Barbara, Calif.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Variable Geometry and*

Expandable Structures Conference, Anaheim, Calif., Apr. 21-23, 1971, AIAA Paper 71-396. 14 p. 8 refs. Members, $1.50; non-members, $2.00.

Design data are derived for three categories of automatically deployable booms to meet several different types of space requirements. Boom categories are reelable cylindrical shells, coilable lattice structures, and articulated lattice structures. Boom requirements considered involve their bending stiffness and strength, compressive strength, and one category where they are self-loading. Results show articulated booms are lightest in all but the self-loading category where coilable lattice booms are lightest. Cylindrical booms occupy the least stowage volume for all requirements. However, deployment canister requirements, boom materials, and thermal distortions should also be considered since they affect selection and design of booms. (Author)

A71-25273 # **Construction and evaluation of a lightweight parabolic antenna model.** D. L. Pope, W. H. Hewitt, Jr., and J. G. Tetz (Bell Telephone Laboratories, Inc., Whippany, N.J.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Variable Geometry and Expandable Structures Conference, Anaheim, Calif., Apr. 21-23, 1971, AIAA Paper 71-397.* 9 p. 14 refs. Members, $1.50; nonmembers, $2.00.

The antenna model is 10 feet in diameter and weighs only 1.7 pounds. The basic structure consists of two compression members, a torus and a central mast comprised of inflated Mylar tubes, interconnected by tension wire systems. This structure supports a pattern of expanded metal mesh triangular facets approximating a paraboloid with an effective diameter of 8.4 feet. The details and construction of the model are described and the results of electrical performance tests are given. The antenna gain at 9 GHz is 39 dB. An ideal reflector of the same diameter has a gain of 46 dB at this frequency. The 7 dB loss can be attributed to the porosity and surface tolerance of the reflecting mesh. Trade-offs to improve the electrical performance are discussed. The present model, however, provides an impressive capability per unit weight without further modification. (Author)

A71-25276 # **A zero backlash deployment mechanism for large space structures.** Paul E. Hawkes and Gerald I. Goldberg (Fairchild Hiller Corp., Space and Electronics Systems Div., Germantown, Md.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Variable Geometry and Expandable Structures Conference, Anaheim, Calif., Apr. 21-23, 1971, AIAA Paper 71-400.* 9 p. Members, $1.50; nonmembers, $2.00.

The study guidelines, mechanical and structural design, dynamic analysis, and test results of the dynamically scaled deployment mechanism are presented. The predicted test responses of the scaled model are compared to the predicted dynamic characteristics of the actual full scale model to verify the accuracy of the scaling. The test results are then compared to the original predictions and the difficulties encountered in performing the tests are discussed. (Author)

A71-41981 **Present and future applications of expandable structures for spacecraft and space experiments.** Karl O. Brauer. *International Astronautical Federation, International Astronautical Congress, 22nd, Brussels, Belgium, Sept. 20-25, 1971, Paper.* 12 p.

Detailed description of major types of stowable expandable structures suitable for spacecraft and space experiment applications. The structures discussed include inflatable structures, rigidized cloth structures, and mechanically deployable structures. Applications of inflatable structures as flotation bags used for sea recovery of spacecraft and as spacecraft recovery devices such as flexible wings, ballutes, and inflated cones are described. In considering rigidized cloth structures, the advantages of a honeycomb structure are cited, and the use of amino acid gelatin as a rigidizing material for expandable structures is considered. The mechanically deployable structures described include unfolding systems, telescoping systems, and prestressed tubular extendible systems. A.B.K.

A73-13045 **Advanced antenna meshes for spacecraft unfurlable reflectors.** D. J. Levy and W. R. Momyer (Lockheed Research Laboratories, Palo Alto, Calif.). In: Non-metallic materials selection, processing and environmental behavior; Proceedings of the Fourth National Technical Conference and Exhibition, Palo Alto, Calif., October 17-19, 1972. Azusa, Calif., Society of Aerospace Material and Process Engineers, 1972, p. 525-532.

Metallized fiberglas antenna mesh was prepared and evaluated in comparison with metallized polyester and fibrous metal antenna meshes. The paper includes a discussion of physical property requirements, mesh reflector theory, yarn material properties, mesh constructions, metallization materials and methods, mesh degradation modes, apparatus for flex and crush testing, and comparative properties of antenna meshes. Metallized fiberglas mesh is attractive with respect to mass/area, wrinkle recovery, cost, and long-term stability in the space environment. (Author)

A73-18905 **Deployable structures (Les structures déployables).** G. Barkats (Société Nationale Industrielle Aérospatiale, Paris, France). In: French space technology. Volume 1.
Paris, Information Propagande Françaises, Editeur; Centre National d'Etudes Spatiales, 1971, p. 49-58. In English and French.

The various design principles of deployable structures are reviewed and are demonstrated for such applications as solar cell panels and flexible booms employed in gravity gradient stabilization. The vehicular and environmental constraints placed on deployable structures, and their influence of system design are examined. Properties and applications of rigid-component structures, flexible structures, inflatable structures, and rigid inflatable structures are outlined. V.P.

A73-33620 **Reliability estimate of a Space Deployable Antenna.** F. J. Moreno (Harris-Intertype Corp., Radiation Div., Melbourne, Fla.). In: Annual Reliability and Maintainability Symposium, Philadelphia, Pa., January 23-25, 1973, Proceedings. New York, Institute of Electrical and Electronics Engineers, Inc., 1973, p. 182-185.

A reliability estimate of a Space Deployable Antenna (SDA) is calculated based on engineering design values and results of development testing. The main problem is one of estimating the reliability of a 'one-shot' device which is primarily a mechanical system. The SDA is segmented in two main subsystems - an Upper Restraint Subsystem and a Mechanical Deployment Subsystem - which were modeled separately then combined to arrive at an estimate of successful deployment probability. Problem formulation and the modeling approach are heavily influenced by the design and development process associated with the system. As a consequence, the estimation techniques are constrained to utilize data that are made available at various stages of the process. (Author)

A74-17204 # **Technological problems with large-area solar cell arrays (Technologische Probleme bei grossflächigen Solargeneratoren).** N. Römisch (Gesellschaft für Weltraumforschung mbH, Porz-Wahn, West Germany). *Österreichische Gesellschaft für Weltraumforschung und Flugkörpertechnik and Deutsche Gesellschaft für Luft- und Raumfahrt, Gemeinsame Jahrestagung, 6th, Innsbruck, Austria, Sept. 24-28, 1973, DGLR Paper 73-107.* 26 p. 11 refs. In German.

Comparative study of two proposed solar cell array concepts with respect to their design, testing, launching, and operation. The two concepts considered are, respectively, a collapsible semirigid array and a flexible rollout array. A detailed study is made of launch vehicle constraints on weight and storage volume in the two concepts, the effects of reaction forces resulting from extension of the solar array on orbital and attitude control of the satellite are assessed, and an analysis is made of the heat-transfer and power-generating capabilities of the two concepts. A.B.K.

03 STRUCTURAL CONCEPTS

A74-24919 **Some choices for design of deployable solar arrays.** R. Kumar and S. Ahmed (Spar Aerospace Products, Ltd., Toronto, Canada). In: Photovoltaic power and its applications in space and on earth; International Congress on the Sun in the Service of Man, Paris, France, July 2-6, 1973, Proceedings. Brétigny-sur-Orge, Essonne, France, Centre National d'Etudes Spatiales, 1973, p. 217-226. 6 refs.

Deployable solar arrays are required to meet the rising demands of electrical energy for space missions. The existing schemes for deployable solar arrays are briefly presented. One of the critical components of a deployable solar array system is the actuator boom. It provides extension and retraction capabilities to the system and acts as the prime structural member of the system. The characteristics of actuator booms have been identified in order to enable designers to make a judicious choice for their systems. Initial steps for preliminary design are outlined. (Author)

A74-34918 * **Developments of a unique graphite/epoxy antenna subreflector.** E. Y. Robinson, R. A. Stonier (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.), and C. L. Lofgren (Boeing Co., Aerospace Group, Seattle, Wash.). In: Composite materials: Testing and design; Proceedings of the Third Conference, Williamsburg, Va., March 21, 22, 1973. Philadelphia, Pa., American Society for Testing and Materials, 1974, p. 632-650. 8 refs. Contract No. NAS7-100.

Advanced concepts for large, furlable space antennas have led to an extensive development program at the Jet Propulsion Laboratory (JPL) with configurations utilizing conical main reflectors. The antenna subreflectors for these conical configurations have unusual geometries and new structural requirements. Structural efficiency of the conical antennas is improved through the use of fiber composites. A subreflector was designed and fabricated with graphite/epoxy material. The subreflector is a cylindrical paraboloid with demanding criteria for contour surface precision, high thermal stability, and sufficient structural capacity for inertial launch loads in axial and transverse directions. The paper describes the design, analysis, and fabrication of the subreflector. (Author)

A75-11108 * # **Spoked wheels to deploy large surfaces in space.** R. F. Crawford, J. M. Hedgepeth, and P. R. Preiswerk (Astro Research Corp., Santa Barbara, Calif.). *Canadian Aeronautics and Space Institute and American Institute of Aeronautics and Astronautics, Joint Meeting, Toronto, Canada, Oct. 30, 31, 1974, AIAA Paper 74-1267.* 9 p. 9 refs. Contract No. NAS2-6731.

A mechanism for deploying large-surface space payloads has been developed and is characterized. It has potential applicability for deploying surfaces for communications, shielding, earth sensing, and solar-cell arrays. When deployed, the mechanism resembles a spoked wheel, and it retracts into a compact volume by virtue of its hinged rim and reelable spokes. Payload surfaces can be stowed on, deployed from, and supported by its spokes, hub, or rim. The capability of the mechanism to act as an efficient and stable structure is exemplified by parametric data on its application for deploying solar-cell arrays. (Author)

A75-13717 # **Advanced lightweight rigid solar arrays based on carbon fibre technology.** D. E. Koelle (Messerschmitt-Bölkow-Blohm GmbH, Ottobrunn, West Germany). *International Astronautical Federation, International Astronautical Congress, 25th, Amsterdam, Netherlands, Sept. 30-Oct. 5, 1974, Paper 74-085.* 12 p. 6 refs.

The status of development of solar arrays is considered, giving attention to certain disadvantages in conventional structures. It is pointed out that the carbon-fiber composite structure with its inherent stiffness and low weight provides an approach to overcome these disadvantages. Details regarding the general design of carbon-fiber composite structures for solar panels are discussed along with some specific solar panel designs for satellite applications. G.R.

A75-23020 **Some boom choices for design of deployable solar arrays.** R. Kumar (Spar Aerospace Products, Ltd., Toronto, Canada) and S. Ahmed (Department of Communications, Communications Research Centre, Ottawa, Canada). *Solar Energy,* vol. 16, Dec. 1974, p. 159-163. 7 refs.

Considerations involved in the design of deployable solar arrays for spacecraft are discussed. The two main generic categories of flexible arrays now being developed are the roll-up type, which is stowed on a drum, and the flat-pack type, which is folded when stowed. Two types of extendible booms, the BI-STEM and the Astromast, are described. The relative advantages of schemes using one or two booms with a deployable solar array are analyzed. A.T.S.

A76-42352 # **Large deployable antennas and solar generators with ultralightweight design characteristics (Grosse Entfaltantennen und Solargeneratoren in extremer Leichtbauweise).** W. Schäfer (Messerschmitt-Bölkow-Blohm GmbH, Ottobrunn, West Germany). *American Astronautical Society and Deutsche Gesellschaft für Luft- und Raumfahrt, International Meeting on Utilization of Space Shuttle and Spacelab, Bonn, West Germany, June 2-4, 1976, DGLR Paper 76-112.* 15 p. In German.

A 12-GHz deployable antenna with a diameter of 3.5 m for a Spacelab experiment is considered, taking into account the antenna configuration, the study of its mechanical and thermal behavior in a space environment, and the demonstration of the operational antenna characteristics under space conditions. The design of a deployable 9-kW solar generator based on an employment of solar cells is also discussed. It is pointed out that the design concepts to be tested show great promise for a use in space applications of the future. G.R.

A76-46081 # **Expandable structures for spacecraft.** K. O. Brauer (South African Council for Scientific and Industrial Research, Pretoria, Republic of South Africa). *International Astronautical Federation, International Astronautical Congress, 27th, Anaheim, Calif., Oct. 10-16, 1976, Paper 76-201.* 10 p. 24 refs.

Advantageous features of expandable structures and progress in their space application are reviewed. Typical uses of expandable structures in passive communication satellites, antennas, stabilization booms, solar arrays, spacecraft landing struts, manipulating arms, airlocks, as well as in recovery, landing, and flotation systems are described and recommendations are given for optimum utilization of various special types of expandable structures in future space missions. The discussion covers mechanically deployable and inflatable structures, chemically-rigidized, stiffened and unstiffened cloth structures. Particular attention is given to such mechanically deployable structures as storable tubular extendible shaft systems, spring-loaded, telescoping, and unfolding systems, and their performance data. S.N.

A77-12825 * **SEP solar array technology development.** R. V. Elms, Jr. (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.) and L. E. Young (NASA, Marshall Space Flight Center, Huntsville, Ala.). In: Intersociety Energy Conversion Engineering Conference, 11th, State Line, Nev., September 12-17, 1976, Proceedings. Volume 2. New York, American Institute of Chemical Engineers, 1976, p. 1372-1378. Contract No. NAS8-31352.

A technology development program is in progress to define a detail design of a lightweight 25 KW solar array for Solar Electric Propulsion (SEP) and to demonstrate technology readiness for fabrication, testing and flight of the large area solar array system. The requirements and baseline design for the 66 W/kg are discussed. The requirement for operation at 0.3 to 6.0 AU heliocentric distance presents a wide range of temperature environments as well as severe combined thermal/vacuum/UV radiation environments. The specific technology deficient areas are defined and the technology development program is presented. The program includes design and design evaluation testing on a component level followed by the fabrication and test of a developmental full-scale solar array wing. The results of the design studies and test program underway are presented. The test program covers the areas of fabrication testing, design support evaluation testing, zero-gravity array fold-up testing, full-scale array wing testing, and NDT development testing. (Author)

A77-25747 * # **Some design considerations for large space structures.** H. G. Bush, M. M. Mikulas, Jr., and W. L. Heard, Jr. (NASA, Langley Research Center, Hampton, Va.). In: Structures, Structural Dynamics and Materials Conference, 18th, March 21-23, 1977, and Aircraft Composites: The Emerging Methodology for Structural Assurance, San Diego, Calif., March 24, 25, 1977, Technical Papers. Volume A. New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 186-196. 8 refs. (AIAA 77-395)

Physical characteristics of large skeletal frameworks for space applications are investigated by analyzing one concept: the tetrahedral truss, which is idealized as a sandwich plate with isotropic faces. Appropriate analytical relations are presented in terms of the truss column-element properties, which for calculations were taken as slender graphite/epoxy tubes. Column loads, resulting from gravity-gradient control and orbital transfer, are found to be small for the class structure investigated. Fundamental frequencies of large truss structures are shown to be an order of magnitude lower than large earth-based structures. Permissible loads are shown to result in small lateral deflections of the truss due to low strain at Euler buckling of the slender graphite/epoxy truss column elements. Lateral thermal deflections are found to be a fraction of the truss depth using graphite/epoxy columns. (Author)

A77-32065 # **Fabrication and assembly of large composite structures in space.** F. F. W. Krohn and D. L. Browning (General Dynamics Corp., Convair Div., San Diego, Calif.). *American Institute of Aeronautics and Astronautics and Princeton University, Conference on Space Manufacturing Facilities, 3rd, Princeton, N.J., May 9-12, 1977, AIAA Paper 77-543.* 9 p.

Future space programs will require structural systems two to three orders of magnitude larger than present systems. A method is presented for on-orbit fabrication of space structures from continuous graphite/thermoplastic composite strip. The material is preconsolidated in the desired lamination orientation/thickness and compactly stored on reels for boost. On-orbit it is heated, formed into useful structural cross sections, and cooled, in a continuous process called 'rolltrusion'. This process is integrated with element assembly/joining operations in a beam fabricator capable of building up to 28 kilometers of uninterrupted beam from Shuttle-compatible material reels. A conceptual approach to construction of a photovoltaic solar-power satellite is also presented, and the status of current technology development is reviewed. (Author)

A77-32598 # **Fabrication methods for large space structures.** R. L. Kline (Grumman Aerospace Corp., Bethpage, N.Y.). *American Institute of Aeronautics and Astronautics and Princeton University, Conference on Space Manufacturing Facilities, 3rd, Princeton, N.J., May 9-12, 1977, AIAA Paper 77-544.* 12 p. 10 refs.

Space fabrication has a major impact on the development of ultra large space structures. The structural design and materials selection are significantly affected by automatic space fabrication, assembly and orbital transfer of major structural elements as well as by the mission operations in orbit. Development of an automatic facility used to fabricate a structural building block element is reviewed and its application in the construction of larger assemblies examined. Problems related to the construction and operation of large space structures are presented. Structural verification and quality assurance techniques are some of the many technology issues which require further definition; these are explored for possible solutions. The long service life requirement expected for large structures makes their maintenance and refurbishment a key economic issue; methods of repair and replacement of components are reviewed. (Author)

A77-42802 * # **Specifying spacecraft flexible appendage rigidity.** S. M. Seltzer and H. L. Shelton (NASA, Marshall Space Flight Center, Systems Dynamics Laboratory, Huntsville, Ala.). In: Guidance and Control Conference, Hollywood, Fla., August 8-10, 1977, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 443-452. (AIAA 77-1098)

As a method for specifying the required degree of rigidity of spacecraft flexible appendages, an analytical technique is proposed for establishing values for the frequency, damping ratio, and modal gain (deflection) of the first several bending modes. The shortcomings of the technique result from the limitations associated with the order of the equations that can be handled practically. An iterative method is prescribed for handling a system whose structural flexibility is described by more than one normal mode. The analytical technique is applied to specifying solar panel rigidity constraints for the NASA Space Telescope. The traditional nonanalytic procedure for specifying the required degree of rigidity of spacecraft flexible appendages has been to set a lower limit below which bending mode frequencies may not lie. M.L.

A77-51402 **Design considerations for multi-beam communication satellite's antennas.** B. I. Chirkov, A. A. Snesarev (Ministry of Communication Industry, Moscow, USSR), G. K. Galimov, and M. B. Vysotskaia (High Electrotechnical School of Communication, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-41.* 22 p. 15 refs.

Four uses of multibeam antenna systems are considered. These uses are to increase the energy potential of the radio line in separate spaced areas, to increase the energy potential of the radio line within a wide service area, to increase the energy potential as in the first case with provision for reuse of the frequency spectrum in different areas, and to increase the energy potential as in the second case with provisions for reuse of the frequency spectrum in separate beams. Design characteristics which correspond to these uses are described, and design features are analyzed. The advantages of a double-reflector antenna are explained, and it is concluded that double-reflector antennas are most suitable for use on geostationary communication satellites. M.L.

A77-51414 **Transforming welded shells for space systems.** B. E. Paton, V. M. Balitskii, and V. N. Samilov (Akademiia Nauk Ukrainskoi SSR, Institut Elekrosvarki, Kiev, Ukrainian SSR). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-60.* 11 p.

Regular isometric transformation of welded thin metal shells is studied, with the aim of facilitating the construction of metal assemblies in space. Laws for isometric surface transformation, based on the differential Codazzi-Gauss equations, are discussed, and processes involving a series of regular isometric folds to create an overall transformation with no shell deformation are considered. Examples of the processes, including the construction of multicone shells from planar disks or the transformation of a toroidal shell into a compact roll, are given. J.M.B.

A77-51415 * **Space power stations - Space construction, transportation, and pre-development, space project requirements.** R. Piland (NASA, Johnson Space Center, Houston, Tex.). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-64.* 45 p. 9 refs.

Several features of solar energy space power stations are discussed. An end-to-end analysis of a system using silicon solar cells is reviewed, and the merits of construction in low earth orbit and in geosynchronous orbit are compared. A suggested space construction procedure, described in detail, would use a 'beam builder', an automated machine, to fabricate the first sublevel truss structural members from strip stock material that is stored on reels. An assembly jig would then be used to position a number of beam builders in the proper location and to support the beams as they are produced to facilitate joining them to form the final space power station structure. Space projects for evaluating the construction concept are proposed, and a possible space construction sequence is considered. Space transportation that would be required in conjunction with the space power station is described. M.L.

A77-51417 **Infinitely built-up space radio telescope.** V. I. Buiakas, A. S. Gvamichava, and L. A. Gorshkov (Academy of Sciences, Intercosmos Council, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-67.* 40 p. 26 refs.

Possible space radio telescope configurations which make use of an assembled spherical reflector to provide multibeam operation are analyzed. An extendable reflector, capable of operating at any intermediate stage, is assembled from 200 m modules which consist of a spatial rod framework on which flat hexagon subreflectors are mounted. The reflector geometry can be modified by automatic adjustment of subreflector positions relative to the framework and also by adjustment of connections between modules. Proposed space radio telescope projects are discussed with attention to the detection of extraterrestrial civilizations, the detection of stars and planets, and holography of the universe. M.L.

A78-27020 **Large communication-satellite antenna.** J. Schultz (Grumman Aerospace Corp., Bethpage, N.Y.). In: International Conference on Communications, Chicago, Ill., June 12-15, 1977, Conference Record. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1977, p. 340-343.

Antennas planned for future space satellites will be too large to be carried aloft in an assembled configuration. They will therefore have to be deployable. A design concept for such antennas, usable at UHF-to-microwave frequencies, is discussed with reference to communications system parameters, and structural analysis. Various possibilities for the electrical configuration of a flat-faced phased-array are presented, including space fed-, bootlace-, active-, multibeam-, and beam steering arrays. Deployment sequence and control system parameters are described in terms of the structural configuration projected for the antenna. D.M.W.

A78-32883 # **Advanced lightweight solar array technology.** L. G. Chidester (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). In: Communications Satellite Systems Conference, 7th, San Diego, Calif., April 24-27, 1978, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1978, p. 55-60. 5 refs. (AIAA 78-533)

The paper discusses large-area, lightweight, flexible-substrate solar-array technologies applicable to future communication satellites and considers advances expected in the field. Intelsat V will introduce a new generation of communication satellites that incorporate three-axis body stabilization and sun-oriented solar arrays. The new technology would increase solar array specific power from 20 W/kg to 50-60 W/kg. When applied to the Space Transportation System, the large-area, lightweight arrays promise improvements in stowage volume, weight, cost, and resistance to environmental degradation during the satellite lifetime. B.J.

A78-32929 # **Large space erectable antenna stiffness requirements.** J. A. Fager (General Dynamics Corp., Convair Div., San Diego, Calif.). In: Communications Satellite Systems Conference, 7th, San Diego, Calif., April 24-27, 1978, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1978, p. 415-422. (AIAA 78-590)

Major initial questions regarding the design of large space antennas at higher frequencies are related to stiffness requirements and the effect of size and weight constraints. The typical pointing accuracy requirements as a function of size and RF operating frequency are shown in a graph. The design must take into account criteria concerning contour control, thermal distortion, ground test capability, and, most critical, pointing capability. Without ample isotropic stiffness the thermal distortion becomes excessive and antenna performance deteriorates. In concepts for large space antennas, it was found to be the major problem to attain a reasonable stiffness which could be matched into a control system. One of the space erectable or assembly concepts which has the promise of supplying the isotropic stiffness needed for large systems is the geodetic truss. The dynamic behavior of such design concepts is discussed along with problems of ground testing. G.R.

A78-36703 * **Automated space fabrication of structural elements.** E. E. Engler (NASA, Marshall Space Flight Center, Structural Development Branch, Huntsville, Ala.) and W. K. Muench (NASA, Bethpage, N.Y.). In: The industrialization of space; Proceedings of the Twenty-third Annual Meeting, San Francisco, Calif., October 18-20, 1977. Part 1. San Diego, Calif., American Astronautical Society; Univelt, Inc., 1978, p. 27-56. (AAS 77-201)

A description is presented of an automated space fabrication technique for basic structural elements, taking into account as representative the design loads and requirements of the solar power satellite structure. Roll forming for continuous cap and brace members is applicable for all proposed metallic materials. Spot-welding, electron beam welding, ultrasonic welding, laser welding, cold welding, and various mechanical fastening techniques are applicable for the automated fabrication process. Termination of the formed cap and brace members can be accomplished by sawing, shearing, punching, and laser cutting. The most cost effective materials were found to be the aluminum alloys. Selected for further study were AL20224T3 and AL2219-T62. In the area of fiber composites, thermoplastic matrix materials with graphite fibers were selected for future studies. G.R.

A78-36706 * **Structural and assembly concepts for large erectable space systems.** E. Katz (Rockwell International Corp., Space Div., Downey, Calif.), E. T. Kruszewski, and E. C. Naumann (NASA, Langley Research Center, Structures and Dynamics Div., Hampton, Va.). In: The industrialization of space; Proceedings of the Twenty-third Annual Meeting, San Francisco, Calif., October 18-20, 1977. Part 1. San Diego, Calif., American Astronautical Society; Univelt, Inc., 1978, p. 101-113. (AAS 77-205)

This paper presents a summary of studies performed by the Space Division of Rockwell under contract to the Langley Research Center of the NASA. The studies specifically addressed requirements and concepts for erectable structures ranging in size from 100 to 300 meters - using the Shuttle Orbiter as the operation/assembly base. This paper discusses various types of structural configurations and building block elements and the criteria which influence their designs. A brief review is given concerning the subject of flight control. An assembly concept is presented - showing how the Orbiter may be equipped and operated to build large area structures. Estimates are also given for cargo bay stowage and mission timelines. (Author)

A78-37274 * # **Thermal control of a solar sail.** L. D. Stimpson, M. L. Greenfield, W. Jaworski (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.), and F. Wolf. *American Institute of Aeronautics and Astronautics and American Society of Mechanical Engineers, Thermophysics and Heat Transfer Conference, 2nd, Palo Alto, Calif., May 24-26, 1978, AIAA Paper 78-885.* 10 p. Contract No. NAS7-100.

Thermal control concepts for the square and the heliogyro solar sail designs under consideration for a Halley's Comet rendezvous mission are presented. The mission, involving a 1982 launch, navigation to a 0.25-AU cranking orbit about the sun in order to develop a retrograde orbit, and rendezvous with the comet in 1986, would subject surfaces of the sail vehicle to solar constant values ranging from 16 to 0.1. A highly reflective coating to produce propulsive force is needed for one surface of the sail, while the other surface requires a highly emittive coating. The problem of maintaining the sail wrinkle-free is discussed. J.M.B.

A78-45869 # **The booms and mechanisms of Geos.** G. Schmidt (Dornier System GmbH, Friedrichshafen, West Germany), M. Newns (British Aircraft Corp., Bristol, England), and B. Henson (ESA, Geos Div., Noordwijk, Netherlands). *ESA Bulletin,* no. 9, May 1977, p. 22-27.

The sensors of the four particle and three field experiments on the Geos satellite must be mounted on booms in order to avoid the effects of satellite-generated electrostatic, electromagnetic, and magnetostatic interference. Three boom configurations are reviewed: short- and long-radial, and axial. Design parameters of the booms are discussed, and a description of the provisions made for stowage of the booms on the satellite is presented. Attention is given to the ground testing of the booms (and the 1 m waveguide blade of the UHF antenna), especially in terms of mechanical deployment using pulleys and cables. D.M.W.

A78-47263 **An institutional plan for multipurpose space platforms.** D. D. Smith. *Satellite Communications,* vol. 2, Aug. 1978, p. 24, 25, 28-31. 6 refs.

In their experimental stage, space platforms for communications, earth sensing, and meteorology will be owned, operated, and coordinated by NASA. In the later, fully operational stages, these functions could be shared by a number of agencies, under NASA licensing. The agencies could assume many forms, e.g., a U.S. governmental agency, a monopoly corporation, a consortium of private sector entities, or a regional organization. In addition, the ownership of the various platform components could be spread among several agencies. Hypothetical examples of such variegated ownership are presented, i.e., PLATCO, which would own the platform; AMCOM, which would provide for regional (Western Hemisphere) integration of communications services; AMET, which would manage meteorological data, etc. D.M.W.

A78-49546 **A statistical evaluation of a space stable optical support structure.** D. D. Smith and R. E. Jones (Boeing Aerospace Co., Seattle, Wash.). *(Society for the Advancement of Material and Process Engineering, National Symposium and Exhibition, 23rd, Anaheim, Calif., May 3, 1978.) SAMPE Journal,* vol. 14, Sept.-Oct. 1978, p. 4-12.

A probabilistic approach to the design of a thermally stable optical support structure is presented. The design is a truss structure which would provide a space stable support system for the secondary mirror of an optical telescope system. To meet the expected thermal performance criteria, graphite/epoxy has been utilized as the basic material system. A thermal stability sensitivity study revealed the effect of each structural component and their relationship to other components of the support structure. From the sensitivity study, tolerance ranges were estimated for each type of structural component and, with appropriate probability density functions, a statistical simulation study of the optical support structure thermal stability was performed. The stability criteria, structural design and test/accept techniques are also presented. (Author)

A78-51981 * # **Design concept of geostationary platform.** E. C. Hamilton and W. T. Carey, Jr. (NASA, Marshall Space Flight Center, Huntsville, Ala.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1642.* 8 p.

The payload efficiency of communication satellites has typically averaged 25 to 30% while meteorology and earth observation satellites range from 30 to 35%. Improvement in solar cell efficiency, batteries, electric propulsion for stationkeeping, and solid-state circuitry will increase this efficiency in the future, but it will still be advantageous in the Shuttle era to reduce the expenditure for support systems. A platform that provides all the support functions could reduce the initial cost due to economics of scale and also reduce transportation cost. Three alternate configurations of a platform for geosynchronous orbit communications and meteorology missions are presented. (Author)

A78-51983 # **Joints and implications on space construction.** R. S. Totah (Rockwell International Corp., Satellite Systems Div., Seal Beach, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1653.* 6 p.

Joints for space construction activities must satisfy a myriad of operational and structural requirements and, at the same time, be easily mated by either remote manipulators or manually by astronauts in an EVA mode. Fundamental requirements for large space platform joints are discussed, including interface, performance, physical, and most importantly, assembly requirements. Basic approaches to the design of joints are explored, including the physical arrangement of the joints, the attachment method employed, and the degree of flexibility of the joints during assembly and after assembly. One particular concept, a ball socket joint, is described along with the assembly process which influenced the design. The assembly process was based on a Shuttle-tended construction mode and identified the orbiter's remote manipulator system (RMS) as a major tool for making the joints. This important feature was subjected to a demonstration test utilizing the Manipulator Development Facility (MDF) at Johnson Space Center of the NASA. The test is described and the results presented which, essentially, show that the ball socket joint can be mated in less than one minute. (Author)

A78-51984 * # **Space Spider - A concept for fabrication of large structures.** W. R. Britton (Martin Marietta Aerospace, Denver, Colo.) and J. D. Johnston (NASA, Marshall Space Flight Center, Huntsville, Ala.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1655.* 9 p.

The Space Spider concept for the automated fabrication of large space structures involves a specialized machine which roll-forms thin gauge material such as aluminum and develops continuous spiral structures with radial struts to sizes of 600-1,000 feet in diameter by 15 feet deep. This concept allows the machine and raw material to be integrated using the Orbiter capabilities, then boosting the rigid system to geosynchronous equatorial orbit (GEO) without high sensitivity to acceleration forces. As a teleoperator controlled device having repetitive operations, the fabrication process can be monitored and verified from a ground-based station without astronaut involvement in GEO. The resultant structure will be useful as an intermediate size platform or as a structural element to be used with other elements such as the space-fabricated beams or composite nested tubes. (Author)

A78-51986 * # **Orbital servicing of space platforms.** J. R. Turner (NASA, Marshall Space Flight Center, Huntsville, Ala.) and W. L. DeRocher, Jr. (Martin Marietta Aerospace, Denver, Colo.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1659.* 11 p. 8 refs. Contract No. NAS8-30820.

NASA-MSFC is planning systems for the orbital servicing and maintenance of large geosynchronous platforms. The goal is to devise methods to maintain, update, and/or replace the basic spacecraft housekeeping equipment as well as the onboard mission equipment. The planning has passed through the feasibility demonstration level. A hard engineering test unit of such an on-orbit servicing system, complete with control system, is being tested and evaluated by MSFC. B.J.

A78-51990 * # **Manned maneuvering unit - A space platform support system.** C. E. Whitsett, Jr. (NASA, Johnson Space Center, Houston, Tex.), J. A. Lenda, and J. T. Josephson (Martin Marietta

Aerospace, Denver, Colo.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1663.* 9 p. 5 refs.

The assembly and evaluation of large space platforms in low earth orbit will become practical in the Shuttle era. Extravehicular crewmembers, equipped with manned maneuvering units (MMUs), will play a vital role in the construction and checkout of these platforms. The MMU is a propulsive backpack with mobility extending the crew's visual, mental, and manipulative capabilities beyond the cabin to on-the-spot assembly and maintenance operations. Previous MMU experience is reviewed, Shuttle MMU design features related to space platform support are described, and the use of the MMU for specific construction and assembly tasks is illustrated. (Author)

A78-51992 # **A crane for construction in space.** R. J. Gunkel, R. E. Holmen, and J. M. Tschirgi (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1666.* 11 p.

An investigation of the techniques and the hardware required for the construction of space stations showed the feasibility of an implementation of the considered space station designs on the basis of the current state of the art of construction technology. A crane in space fulfills the same basic function as a crane on the ground. It is used to move large masses in a controlled fashion and to provide support for various assembly functions. The configuration of a crane system designed to operate in space depends not only on the construction tasks planned, but also on the configuration of the facility into which it will be integrated and the operations it will serve. A study was conducted of what might be required of such a crane system. Attention is given to concept options, manipulator arm configurations, turret configuration, work platforms, motion mechanics, visual monitoring, and control response and damping. G.R.

A78-52742 # **Automatic fabrication of large space structures - The next step.** W. K. Muench (Grumman Aerospace Corp., Bethpage, N.Y.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1651.* 8 p.

An outline is presented of a plan which will lead to the establishment of an operational five giga watt solar power satellite in space. A detailed description is presented of the first stage of this plan. This stage is concerned with the development of a machine that is to be employed to produce the basic building block beams in space, which are used in the assembly of the large space structures required. A ground demonstration version of this machine has already been completed. After the feasibility of automatically producing beams has been successfully demonstrated, questions arise concerning the next step which has to be taken. One possible answer to this question is discussed, taking into account the development of a special end effector for the Space Shuttle's remote manipulator system. G.R.

A78-52743 # **On-orbit fabrication and assembly of composite structures.** D. L. Browning (General Dynamics Corp., Convair Div., San Diego, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1654.* 8 p.

An investigation is conducted regarding the merits and the feasibility of on-orbit fabrication of composites for space applications. It is found that for reasons of economics, reliability, and structural efficiency, on-orbit beam fabrication with composite materials will be the principal mode of basic-member construction for the very large space systems of the future. The most significant current issue, then, is not so much why on-orbit fabrication as when. Clearly the system-functional technologies of future large space systems must first be developed and demonstrated, perhaps, in orbit, then integrated into larger spacecraft serving as prototypes to provide proof-of-concept for the yet larger operational systems. Similarly, cost-effective construction technology must be available when needed and the very high reliability required for mass production must exist. G.R.

N68-12276# Contraves Corp., Zurich (Switzerland).
PASSIVE TEMPERATURE CONTROL FOR LARGE SPACE SHIPS [PASSIVE TEMPERATUR-KONTROLLE BEI GROSSEN RAUMFAHRZEUGEN]
Hans Eder [1967] 36 p In GERMAN Presented at WGLR/DGRR Ann. Meeting, Karlsruhe, West Germany, 1967
CFSTI: $3.00

A mathematical model is formulated for an orbiting satellite structure with passive temperature control. Absorption and emission properties of the satellite's surface and an energy exchange mechanism in the satellite's interior insure a regulated temperature distribution. This proposed basic satellite structure consists of 5 cells, each of which represents a thermal control unit, clustered around a thick walled hollow magnesium core. The outer walls of the configuration act as isolation barriers and control the heat exchange with the surrounding atmosphere, and the walls of the magnesium core act as heat conductors in a hot environment, and as heaters in a cold environment. Transl. by G.G.

N68-15239*# Data Dynamics, Inc., Los Angeles, Calif.
INFLATABLE STRUCTURES IN SPACE
A. Kozorezov and A. Glukharev [1967] 6 p Transl. into ENGLISH from Aviats. i Kosmonavt. (Moscow), no. 10, 1966 p 71–73 Prepared for JPL
(Contract NAS7-100)
(NASA-CR-92596) CFSTI: HC $3.00/MF $0.65 CSCL 22B

Material composition, weight, size, and method of unfolding of inflatable structures for manned and unmanned space stations are reviewed. The design of a particular inflatable space station/laboratory for a prolonged flight in orbit with a crew of astronauts on board is described. A simpler inflatable spacecraft is also described. Other types of structures currently being developed (such as wire meshes, inflatable wing-parachutes) are also commented upon. L.S.

N68-20267*# General Dynamics/Convair, San Diego, Calif.
FEASIBILITY STUDY OF LARGE SPACE ERECTABLE ANTENNAS. VOLUME 4: STUDY, PARABOLIC EXPANDABLE TRUSS ANTENNA EXPERIMENT
23 Feb. 1968 557 p refs
(Contract NASw-1438)
(NASA-CR-93837; GD/C-DCL-67-002, V. 4) CFSTI: HC $3.00/MF $0.65 CSCL 09F

A detail analysis of the 100 ft parabolic antenna experiment is presented. During the deployment, adjustment, and test phase, the Apollo is docked to the feed. The antenna has an independent transmitter, receiver, telemetry, station keeping, attitude control, and power system. Specific potential problem areas were evaluated in greater detail to determine solutions. Elements of the antenna were fabricated and tested. A 6.1 ft. diameter scale model of the antenna was tested on the RF range and demonstrated predicted beamwidth and gain up to the maximum test frequency of 15 GHz. Astronaut support in erection, adjust, and test conduction was developed in an operational plan. Fabrication and test sequency plan is outlined and a preliminary program cost of $27.3 million is indicated for a 100 ft. dia. antenna experiment that could be launched 34 months from go-ahead. Author

N68-20304*# General Dynamics/Convair, San Diego, Calif.
FEASIBILITY STUDY OF LARGE SPACE ERECTABLE ANTENNAS. VOLUME 3: SUMMARY. PARABOLIC EXPANDABLE TRUSS ANTENNA EXPERIMENT

22 Jan. 1968 32 p
(Contract NASw-1438)
(NASA-CR-93833; GD/C-DCL-67-002, V. 3) CFSTI: HC $3.00/MF $0.65 CSCL 09F

A Saturn-launched experiment is proposed in which a large 100-ft parabolic expandable truss antenna would be deployed, preferably in synchronous orbit. A 740-sq ft omnidirectional solar cell system is to provide power for the tests performed in the 100 MHz to 6 GHz range, with an expulsion and momentum exchange system to be used for stationkeeping and attitude control. Peripherally-mounted telemetry antennas are to provide continuous data relay to earth. Anticipated support by the Apollo crew is discussed in terms of decision-making, evaluation, and malfunction correction. Primary operating sequence of the experiment is depicted; boost to synchronous equatorial orbit is estimated at approximately 7-1/2 hours. Summary details are given on the packaging, subsystems, radiation pattern measurement, fabrication, and the equipment required by the astronaut to perform the EVA tasks. Weight data are summarized, and primary development tasks are listed. M.G.J.

N68-27929*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
FEASIBILITY DEVELOPMENT OF A SELF-DEPLOYING ELECTROMAGNETIC ENERGY FOCUSING REFLECTOR FOR SPACE OR TRANSPORTABLE GROUND BASED APPLICATIONS
William Korvin, Hossein Bahiman, and John Gates *In* AFSC Expandable and Modular Struct. Conf. May 1967 p 237–253

Materials and systems design concepts for a large aperture, lightweight, high gain, easily packaged and deployed parabolic antenna system having application in space and transportable tactical ground communications systems; are reported. The materials technique used is classified under the subheading of materials of the memory technique. This material consists of a fiber glass grid core covered with a thin flexible resin system plated by a metallic vacuum deposit which can be preformed in the desired shape, deformed into a packaged condition, and when released, because of its stored elastic strain energy, resumes its original fabricated contour. To implement this high modulus memory material approach for a practical design, a review of candidate material properties for the reflector design was carried out. Effort was started on the design and fabrication of a single piece, flexible, preformed mesh reflector. A mesh material configuration was chosen for its ability to form complex curves and to alleviate self-shrouding of the structure with solar radiation as well as reducing wind loads in possible ground use. Since the flexibility of a simple parabolic dish for packaging without degradation is not in keeping with the stiffness necessary (e.g. deployed configuration stability in a one g field), radial ribs of the same material were added. The parabolic dish was designed with marginal ability to maintain its preformed configuration without support as were the ribs; however, when assembled the composite structure became self-supporting. Included are data on radio frequency characteristics (primary and secondary pattern) of the system and a review of areas of possible material and design improvement. S.C.W.

N68-27933# Schjeldahl (G. T.) Co., Northfield, Minn.
UNFURLABLE ANTENNAS
A. J. Wendt and L. D. Surber *In* AFSC Expandable and Modular Struct. Conf. May 1967 p 317–343 refs

Design and electrical test results for an inflatable cigar antenna, and an inflatable parabolic antenna are presented. The cigar antenna is basically a surface wave structure which uses circular disk elements to control the phase velocity of the radiated wave. In this respect, it closely resembles the Yagi–Uda antenna. Electrical and mechanical characteristics of the antenna are given. Electrical tests indicated that the gain of the cigar antenna was reasonably close to the theoretical value. Satisfactory radiation patterns were measured from 134 MHz to 225 MHz, a 1.68.1 bandwidth. Mechanical loading and deflection tests indicated that under zero internal pressure, the antenna structure can withstand a 0.02-g side load with a safety factor greater than two. It is concluded that the inflatable cigar antenna concept provides a very practical design approach to a medium gain VHF communications antenna for space application. Two 10-ft diameter inflatable parabolas were constructed having an f/D ratio of 0.833 and 0.42. The rms surface error on the shorter focal length model was 0.133, and approximately 1,000 on the longer focal length model. Radiation measurements were performed only on the shorter focal length model. Based on results obtained from electrical tests, it is concluded that: (1) the inflatable parabolic reflector is a very efficient antenna; (2) in a space application, the parabolic surface could be strain rigidized by pressurizing the antenna until the metal foil passes its yield point, and the same technique could be used to rigidize the feed support system; and (3) the rms surface error can be drastically reduced if a machined mandrel is used to form the parabolic surface. S.C.W.

N68-31404*# Boeing Co., Seattle, Wash. Space Div.
LARGE AREA SOLAR ARRAY Quarterly Report—Phase 2, 1 Mar.–31 May 1968
R. C. Weikel, F. W. McAfee, J. L. Apperson, and Dwight A. Norsen
Jun. 1968 252 p refs Prepared for JPL
(Contracts NAS7-100; JPL-951934)
(NASA-CR-95999; D2-113355-6, Pt. U; QR-3) CFSTI: HC $3.00/MF $0.65 CSCL 13H

Following a summary of engineering, technology, and manufacturing activities relating to the development of a large area solar array, details are presented of the various aspects of the development program. Design and requirements are stated, and the effect of boost environment on design is detailed. The latter includes the dynamic and internal loads for stowed configurations, vibration and stress-deformation analyses, the prestress conditions, and temperature distribution and temperature control aspects. Both ground and space release and deployment are covered, and electrical power source design and performance analysis are reviewed. Attention is also given to process development and material properties, quality assurance and reliability, and weight status; and critical safety margins are summarized. M.W.R.

N69-13234*# Boeing Co., Seattle, Wash. Space Div.
LARGE AREA SOLAR ARRAY, PHASE 2 Final Report
J. L. Apperson, F. W. McAfee, D. A. Norsen, and R. C. Weikel
Oct. 1968 271 p refs Prepared for JPL
(Contracts NAS7-100; JPL-951934)
(NASA-CR-97868; D2-113355-7) Avail: CFSTI CSCL 10B

This is the large area solar array, Phase 2, final report. Phase 2 is the second step in the large area solar array program and further develops fabrication procedures and design of a 1,250-square-foot section of the large area solar array. The results of this effort include: (1) the activity and results of the development testing of mechanism components for tiedown, release, and deployment of the array; (2) the fabrication methods and test activity and results for the 8- by 13-foot main subpanel; (3) the development, test and analyses of the simulated zero g deployment fixture, and the deployment testing with full-scale dummy subpanel and prototype deployment mechanisms; (4) the preliminary design for Phase 3 GSE; (5) the production and usage of transportation handling and test equipment; (6) the development of deployment demonstration equipment; and (7) the electrical degradation and vibration tests and analyses of a 4-foot-square sample panel. Author

N69-26234*# Astro Research Corp., Santa Barbara, Calif.
INVESTIGATION OF A COILABLE LATTICE COLUMN
R. F. Crawford Washington NASA May 1969 31 p ref
(Contract NAS7-427)
(NASA-CR-1301; ARC-R-310) Avail: CFSTI

A lattice column consisting of six longerons interconnected by crossed helical braces was fabricated and tested to determine the feasibility of its concept and to verify analysis of its structural performance. Its helical braces from a cross-sectional shape which can be elastically flattened. This flattened column can then be coiled longitudinally into a relatively small cylindrical volume. The test segment of the column was fabricated of 0.035 inch diameter steel wires joined together with coins into which the intersection of the wires was soldered. Tests were performed on the segment to determine its torsional stiffness, axial buckling strength, and its capability to be flattened and coiled. Author

N69-29417*# Southern Illinois Univ., Carbondale. School of Technology.
STRUCTURAL DESIGN CONCEPTS FOR FUTURE SPACE MISSIONS
Julian H. Lauchner, R. Buckminster Fuller, Joseph D. Clinton, Mark B. Mabee, Richard M. Moeller et al 1 Nov. 1968 63 p
(Grant NGR-14-008-002)
(NASA-CR-101577) Avail: CFSTI CSCL 12A

This report explains one method of subdividing a polyhedron into triangular facets and exploding it into the surface of a sphere. A mathematical model is included which explains the geometry used in subdividing and transforming the icosahedron into the structural sphere. Also included are a computer program and a plot routine used in the computations. Author

N69-38781*# Astro Research Corp., Santa Barbara, Calif.
AXISYMMETRIC AND CYLINDRICAL ISOSTABILOIDS
Peter R. Preiswerk, John M. Hedgepeth, and Hans U. Schuerch Washington NASA Oct. 1969 50 p refs
(Contract NAS 7-427)
(NASA-CR-1444; ARC-R-299) Avail: CFSTI CSCL 20K

The differential equations for the geometric layout of compression-loaded axisymmetric and cylindrical two-family filamentary structures are established. The analytical formulation is based upon the requirement that failure due to local instability occurs simultaneously in the whole structure. Solutions are obtained for the particular case where the body force due to the structure's own weight is the only load. For this special case, the shapes of the meridian and the cross section, respectively, have been determined, as well as the pattern of the filaments. In addition, the weight per area covered by the structure is formulated and discussed. Minimum-weight configurations are defined. Examples for large earth-based and moon-based structures are presented. Author

N70-25762*# General Dynamics/Convair, San Diego, Calif.
LARGE ERECTABLE ANTENNA FOR SPACE APPLICATION Final Report
E. C. Hamilton (NASA. Marshall Space Flight Center) and John A. Fager 30 Sep. 1969 333 p refs
(Contract NAS8-21460)
(NASA-CR-102522; GDC-DCL69-003) Avail: CFSTI CSCL 09E

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N70-27128*# Astro Research Corp., Santa Barbara, Calif.
AXISYMMETRIC FILAMENTARY STRUCTURES
A. F. Fraser, P. R. Preiswerk, M. D. Benton, and O. R. Burggraf Washington NASA Apr. 1970 113 p refs
(Contract NAS7-427)
(NASA-CR-1518; ARC-R-274) Avail: CFSTI CSCL 20K

The theory of filamentary axisymmetric structures is broadened to include surface loads other than normal pressure. Structures with two sets of symmetrically disposed fiber are considered in detail, and force transfer between filaments is accounted for in the theory. The governing equations are derived, and isotensoid surface shapes are determined and classified for a wide range of load conditions. The governing equations are also applied to problems where the surface shape and loading are prescribed and the filament geometry and load variation in the surface are to be determined. The general nature of filamentary structures is discussed in depth, and useful qualitative results are obtained for multiple layer nets. A non-axisymmetric isotensoid (or isocompressoid) is obtained as a special limiting case. Author

N70-33180* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
FOLDING APPARATUS Patent
Wade E. Lanford, inventor (to NASA) Issued 28 Nov. 1961 (Filed 11 Feb. 1960) 4 p Cl. 93-1
(NASA-Case-XLA-00137; US-Patent-3,010,372; US-Patent-Appl-SN-8203) Avail: US Patent Office CSCL 13I

A folding apparatus and method for folding thin flexible sheets helically and vertically simultaneously to form a compact packaged configuration are described. The application of this technique is found in packaging of artificial satellites in a configuration which will permit extension or expansion by centrifugal force on being ejected into the upper atmosphere. P.N.F.

N70-39609*# Spar Aerospace Products, Ltd., Toronto (Ontario).
USE OF EXTENDIBLE BOOM DEVICES FOR SPACE SHUTTLE AND EVA OPERATIONS
H. Robert Warren *In* NASA. Lewis Res. Center Space Transportation System Technol. Symp., Vol. 5 Jul. 1970 p 103–126
Avail: NTIS CSCL 22B

Given is a state-of-the-art review on a particular device that could have wide application in orbital maintenance and safety activities on the space shuttle. This is the extendible boom device for which we use the general term of STEM. Illustrations are given of STEM units that have already been developed and have either flown, or been qualified for flight. Reviewed are current and future developments which have more direct relevance to the space shuttle program; provided is also a brief summary of design characteristics that are available to the designer for future space shuttle applications. Author

N71-16102* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
SELF-ERECTING REFLECTOR Patent
Hossein Bahiman, John D. Gates, and William Korvin, inventors (to NASA) Issued 21 Jul. 1970 (Filed 16 Jun. 1967) 6 p Cl.

343-915; Int. Cl. H01q15/20
(NASA-Case-XGS-09190; US-Patent-3,521,290;
US-Patent-Appl-SN-647298) Avail: US Patent Office CSCL 22B

A collapsible antenna structure having a reflector of a continuous high modulus mesh with a plurality of radially extending mesh ribs integrally attached to the convex side is described. The self-erectable antenna elements are designed to be packaged as low volume units to be deployed to an expanded operational shape. Official Gazette of U.S. Patent Office

N71-19214* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
SPACE MANUFACTURING MACHINE Patent
Hans F. Wuenscher, inventor (to NASA) Issued 20 Oct. 1970 (Filed 28 Apr. 1969) 8 p Cl. 244-1; Int. Cl. B64g1/00
(NASA-Case-MFS-20410; US-Patent-3,534,926;
US-Patent-Appl-SN-819599) Avail: US Patent Office CSCL 13I

An apparatus is described for various manufacturing operations in the low and zero gravity environment of orbital space flight. The machine includes a cylindrical tank-like capsule in which manufacturing operations are carried out. An environmental control system is provided for controlling the atmosphere and pressure within the capsule. High and low frequency coils along with electrostatic field coils are mounted in the capsule for positioning, spinning transporting, and agitating materials being processed in the capsule. Heating devices are included for melting materials and various probes are provided for adding liquid or gaseous materials to the workpieces being processed. A mixing apparatus is included for preparing and placing mixtures of materials in the capsule for processing. Official Gazette of the U.S. Patent Office

N71-20658* Radio Corporation of America, Princeton, N.J.
COLLAPSIBLE REFLECTOR Patent
Robert J. Mason, Patrick T. Scully, and Franklin S. Wezner, inventors (to NASA) Issued 26 Dec. 1967 (Filed 13 Jan. 1965) 7 p Cl. 343-915 Sponsored by NASA
(NASA-Case-XMS-03454; US-Patent-3,360,798;
US-Patent-Appl-SN-425363) Avail: US Patent Office CSCL 09E

An automatically erecting parabolic reflector is described which utilizes leaf springs for erection from an original packaged condition. A flexible reflective sheet is stretched across articulated ribs, each of which is foldable at a leaf spring joint near its mid-point and at an end junction where it is joined by leaf spring members at the vertex of the paraboloid to an axial elongate member. The resilient leaf springs bias the ribs to a normally unfolded condition. In its packaged condition, the ribs are folded and held against the axial member by latching tabs, one on each rib near its mid-point, which are releasably engaged with a holding ring affixed to the axial member. The free ends of the ribs are held adjacent the axial member by an encompassing retainer band. By removing the retainer band, the leaf spring connections urge the ribs to unfold whereby the latching tab of each rib is unlatched from the axial member and the reflector assumes its operational configuration. Official Gazette of the U.S. Patent Office

N71-22561*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena. Guidance and Control Div.
DESIGN AND DEVELOPMENT OF A 66-W/kg 23-m SQUARE ROLL UP SOLAR ARRAY
W. A. Hasbach *In its* JPL Quarterly Tech. Rev., Vol. 1, No. 1 Apr. 1971 p 68-77 ref
Copyright. Avail: NTIS HC$6.00/MF$0.95 CSCL 10A

Future space missions require greater power output, lighter weight, and decreased stowed volume for solar arrays. A program was initiated to develop the technology for a roll-up solar array by preparing a detailed design, performing the associated analyses, fabricating an engineering development model, and subjecting the engineering model to a comprehensive test program consisting of both environmental and developmental tests. The design and testing of the 66-W/kg (30-W/lb), 23-sq m (250 sq ft) roll-up solar array developed is described. Author

N72-25454* National Aeronautics and Space Administration. Manned Spacecraft Center, Houston, Tex.
FOLDABLE CONSTRUCTION BLOCK Patent
William C. Huber, inventor (to NASA) Issued 30 May 1972 6 p Filed 18 Sep. 1970 Supersedes N72-15470 (10 - 06, p 778)
(NASA-Case-MSC-12233-1; US-Patent-3,665,669;
US-Patent-Appl-SN-73422; US-Patent-Class-52-594;
US-Patent-Class-52-169; US-Patent-Class-52-173) Avail: US Patent Office CSCL 13C

Apparatus and method of construction using foldable building blocks are reported. The apparatus includes an open top construction block foldable from a flat sheet of material to form a container having downwardly extending interlock tabs, with struts being provided between opposite vertical walls and diagonally opposed vertical joints to control horizontal expansion of the block when a solid material is placed therein. Also described is a closed top block foldable from a single sheet of material with interlock tabs extending downwardly from one side wall of the block and interlock tab receiving slots provided in the top of the block. Official Gazette of the U.S. Patent Office

N71-21045* National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
INFLATABLE SUPPORT STRUCTURE Patent
James E. Pleasants, inventor (to NASA) Issued 23 Jan. 1968 (Filed 13 Jan. 1965) 4 p Cl. 52-2
(NASA-Case-XLA-01731; US-Patent-3,364,631;
US-Patent-Appl-SN-425365) Avail: US Patent Office CSCL 13M

A constant strength pneumatic cantilever beam is described along with a platform utilizing a number of the beams for support of inflatable structural panels. The circular cross section beam has a linear edge and an opposite edge conforming to the moment curve of the loads to be supported. The beam is preferably formed from a plastics material which may be sealed to a support and thus provide a completely inflatable, lightweight structure for use in low vacuum environments. D.L.G.

N72-32070*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
THE DEVELOPMENT, DESIGN AND TEST OF A 66 W/kg (30-W/lb) ROLL-UP SOLAR ARRAY
W. A. Hasbach and R. G. Ross, Jr. 15 Sep. 1972 38 p refs
(Contract NAS7-100)
(NASA-CR-128196; JPL-TR-32-1562) Avail: NTIS HC $4.00 CSCL 10A

A program to develop a 250 square foot roll-up solar array with a power-to-weight ratio exceeding 30 watts per pound is described. The system design and fabrication of a full scale engineering development model are discussed. The system and development test program results are presented. Special test equipment and test procedures are included, together with comparisons of experimental and analytical results. Author

N73-18870* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
A FOLDABLE 4.27 METER (14 FOOT) SPACECRAFT ANTENNA
Donald J. Starkey *In* NASA. Lyndon B. Johnson Space Center The 7th Aerospace Mech. Symp. Nov. 1972 p 37-46

CSCL 09E

The problems and solutions associated with the design, fabrication, and testing of a large, lightweight, radial-rib, folding, spacecraft antenna reflector are discussed. The antenna reflector was designed as a highly efficient communications system for outer-planet missions extending as far as approximately 59.839 x 10 to the 11th power meters (40 astronomical units) from the sun. The methods used to obtain a lightweight precision rib surface, the evaluation and fabrication of the metallic reflector mesh surface, and the surface-evaluation techniques used on the assembled antenna reflector are included. Author

N73-32749* National Aeronautics and Space Administration. Pasadena Office, Calif.
EXPANDABLE SPACE FRAMES Patent
Alan H. Schoen, inventor (to NASA) Issued 11 Sep. 1973 9 p Filed 17 Dec. 1970 Supersedes N71-28948 (09 - 16, p 2683)
(NASA-Case-ERC-10365-1; US-Patent-3,757,476; US-Patent-Appl-SN-99198; US-Patent-Class-52-646; US-Patent-Class-52-64; US-Patent-Class-52-80; US-Patent-Class-52-109; US-Patent-Class-287-92) Avail: US Patent Office CSCL 22B

Expandable space frames having essentially infinite periodicity limited only by practical considerations, are described. Each expandable space frame comprises a plurality of hinge joint assemblies having arms that extend outwardly in predetermined symmetrically related directions from a central or vertex point. The outer ends of the arms form one part of a hinge point. The outer expandable space frame also comprises a plurality of struts. The outer ends of the struts from the other part of the hinged joint. The struts interconnect the plurality of hinge point in sychronism, the spaceframes can be expanded or collapsed. Three-dimensional as well as two-dimensional spaceframes of this general nature are described.
Official Gazette of the U.S. Patent Office

N74-16154# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain).
FOLDABLE BOOM SYSTEMS STUDY. FIRST PHASE: INITIAL STUDIES Final Report
M. A. OrtegaPerez, A. RodriguezVilla, J. DelaTorrePineiroa, T. ElicesConcha, J. L. EspinoGranado, J. FernandezSintes, M. MartinezLlaneza, A. PenasAbella, V. TorroglosaPonce, A. MartiMoral et al Paris ESRO May 1973 185 p refs
(Contract ESTEC-1130/70)
(ESRO-CR-164) Avail: NTIS HC $11.25

An evaluation was made of various types of foldable rod and girder boom systems in an effort to select the type best suited dynamically and structurally for spacecraft applications. Feasibility, reliability, and availability are also considered. Attention was given to configuration and mode of deployment. Hinges and locking devices, actuators, fastening, and release, mechanisms are all dealt with. Various control systems are idealized and their mathematical models defined. Author (ESRO)

N74-33741*# Harris Corp., Melbourne, Fla.
DEPLOYABLE REFLECTOR DESIGN FOR Ku-BAND OPERATION
B. C. Tankersley Sep. 1974 391 p refs
(Contract NAS1-11444)
(NASA-CR-132526) Avail: NTIS HC $22.75 CSCL 09C

A project was conducted to extend the deployable antenna technology state-of-the art through the design, analysis, construction, and testing of a lightweight, high surface tolerance, 12.5 foot diameter reflector for Ku-band operation. The applicability of the reflector design to the Tracking and Data Relay Satellite (TDRS) program was one requirement to be met. A documentary of the total program is presented. The performance requirements used to guide and constrain the design are discussed. The radio frequency, structural/dynamic, and thermal performance results are reported. Appendices are used to provide test data and detailed fabrication drawings of the reflector. Author

N75-14831*# Astro Research Corp., Santa Barbara, Calif.
SPOKED WHEELS TO DEPLOY LARGE SURFACES IN SPACE-WEIGHT ESTIMATES FOR SOLAR ARRAYS Final Report
R. F. Crawford, J. M. Hedgepeth, and P. R. Preiswerk Washington NASA Jan. 1975 60 p refs
(Contract NAS2-6731)
(NASA-CR-2347; ARC-R-1004) Avail: NTIS HC $4.25 CSCL 22B

Extensible booms were used to deploy and support solar cell arrays of varying areas. Solar cell array systems were built with one or two booms to deploy and tension a blanket with attached cells and bussing. A segmented and hinged rim supported by spokes joined to a common hub is described. This structure can be compactly packaged and deployed. Author

N75-15728# Applied Physics Lab., Johns Hopkins Univ., Silver Spring, Md.
EXTENDIBLE SPACE STRUCTURES
R. A. Mattey Jun. 1974 48 p refs
(Contract N00017-72-C-4401)
(AD-787512; APL-TG-1244) Avail: NTIS CSCL 22/2

A list is given of all extendible and inflatable structures in space, along with the launching nation. Configurations of the coilable beryllium copper booms are illustrated, as well as associated engineering problems and solutions. Some unique extendible structures such as the Triad boom and coilable extendible structures are described. Author (GRA)

N75-20461# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain).
FOLDABLE BOOM SYSTEMS STUDY. SECOND PHASE: DEFINITION AND DEVELOPMENT Final Report
A. RodriguezVilla, M. A. Ortega Perez, J. DelaTorrePineiroa, T. ElicesConcha, J. L. EspinoGranado, M. MartinezLlaneza, A. MartiMoral, P. GomezFernandeez, E. FuenteTremps, J. L. MalloSalagre et al Paris ESRO Sep. 1974 160 p refs
(Contract ESTEC-1130/70)
(ESRO-CR-211) Avail: NTIS HC $6.25

Three representative boom systems were defined and designed. Drawings for all units and components and testing methods were examined. The boom types include: a rod boom for a spinning satellite; a rod boom for a nonspinning satellite; and a girder boom for both spinning and nonspinning satellites. Author (ESRO)

N76-11421*# Itek Corp., Lexington, Mass.
FEASIBILITY OF A 30-METER SPACE BASED LASER TRANSMITTER Final Report
R. R. Berggren and G. E. Lenertz Oct. 1975 111 p refs
(Contract NAS3-19400)
(NASA-CR-134903; Rept-8254-1) Avail: NTIS HC $5.50 CSCL 20E

A study was made of the application of large expandable mirror structures in future space missions to establish the feasibility and define the potential of high power laser systems for such applications as propulsion and power transmission. Application of these concepts requires a 30-meter diameter, diffraction limited mirror for transmission of the laser energy. Three concepts for the transmitter are presented. These concepts include consideration of continuous as well as segmented mirror surfaces and the major stow-deployment categories of inflatable, variable geometry and assembled-in-space structures. The mirror surface for each concept would be actively monitored and controlled to maintain diffraction limited performance at 10.6 microns during operation. The proposed mirror configurations are based on existing aerospace state-of-the-art technology. The assembled-in-space concept appears to be the most feasible, at this time. Author

N76-12233# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Space Div.
STUDY OF DEPLOYABLE ANTENNAS FOR SATELLITES Final Report
Mar. 1975 431 p refs Prepared jointly with Centro de Invest. Fis. 3 Vol.
(Contract ESTEC-2070/73-HP)
(MBB-URV-80-75; ESA-CR(P)-645-A) Avail: NTIS HC $11.75

Deployable antenna design alternatives were studied and most essential antenna concepts investigated leading to the selection of the optimum configuration (framework antenna). Dynamic behavior of the optimum structural concept was calculated for the folded and deployed antenna, and the antenna temperatures determined for the most critical cases. The RF computer program was extended and adapted to antennas with mesh reflectors and the antenna pattern characteristics investigated for different mechanical errors. Antenna characteristics of the calculated thermal distortions were determined and the RF characteristics of large antennas studied. A lightweight deployable 12 GHz antenna development program was established. Drawings of deployable and foldable antennas are attached in two annexes.

N76-12240 Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany). Space Div.
DEVELOPMENT PLANNING FOR A LIGHTWEIGHT DEPLOYABLE 12 GHz ANTENNA
W. Schaefer *In its* Study of Deployable Antennas for Satellites Mar. 1975 13 p refs

A development program for a lightweight deployable 12 GHz antenna was established based on the main study activities literature search and optimum antenna concept selection; detailed design of the selected concept; RF, mechanical, and thermal analysis of the selected concept; investigation of antenna measurement possibilities; and on comparable investigations conducted at MBB within the national German space program. Cost estimates are included. ESA

N76-19177* TRW Systems Group, Redondo Beach, Calif.
A STRUT WITH INFINITELY ADJUSTABLE THERMAL EXPANSIVITY AND LENGTH
Paul T. Nelson *In* NASA. Kennedy Space Center 9th Aerospace Mech. Symp. Aug. 1975 p 59-67

CSCL 20K

A tubular strut with an integral mechanism for adjusting its thermal expansivity and length was developed to fulfill the stringent thermal stability requirements anticipated for the metering truss in the Large Space Telescope. Its features may be advantageously applied to a general variety of structures and precision mechanisms where dimensional control of component elements in a dynamic thermal environment is required. Detail, design, fabrication, and test of a developmental strut are discussed. Author

N76-24635# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain).
ANALYTICAL STUDIES ON FOLDABLE TUBES Final Report
J. Fernandez-Sintes Mar. 1974 87 p refs
(Contract ESTEC-729/69-AA)
(ESA-CR(P)-793) Avail: NTIS HC $5.00

Theoretical analyses and derived design criteria were developed to take into account the effect of prestressing in foldable tubes for satellite hinges. An analysis is made of the stress distribution which develops in a prestressed tube folded in the stowage configuration. This analysis leads to design criteria relating minimum length and parameter range for elastic design. The flexural behavior of a prestressed tube is analyzed and results in the form of dimensionless parameters are given to determine an estimate of the flexural collapse load. The analyses are applied to INTA TEP foldable prestressed tubes. Author (ESA)

N76-28651*# General Electric Co., Philadelphia, Pa. Space Div.
CONCEPTUAL APPROACH STUDY OF A 200 WATT PER KILOGRAM SOLAR ARRAY Quarterly Report
R. W. Stanhouse, D. Fox, and W. Wilson 15 Jul. 1976 102 p refs Prepared for JPL
(Contracts NAS7-100; JPL-954393)
(NASA-CR-148505; Doc-76SDS4242; QR-2) Avail: NTIS HC $5.50 CSCL 10A

Solar array candidate configurations (flexible rollup, flexible flat-pact, semi-rigid panel, semi-rigid flat-pack) were analyzed with particular attention to the specific power (W/kg) requirement. Two of these configurations (flexible rollup and flexible flat-pack) are capable of delivering specific powers equal to or exceeding the baseline requirement of 200 W/kg. Only the flexible rollup is capable of in-flight retraction and subsequent redeployment. The wrap-around contact photovoltaic cell configuration has been chosen over the conventional cell. The demand for ultra high specific power forces the selection of ultra-thin cells and cover material. Based on density and mass range considerations, it was concluded that 13 micrometers of FEP Teflon is sufficient to protect the cell from a total proton fluency of 2(10 to the 12th power) particles/sq cm over a three-year interplanetary mission. The V-stiffened, lattice boom deployed, flexible substrate rollup array holds the greatest promise of meeting the baseline requirements set for this study. Author

N76-29358*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
A NESTABLE TAPERED COLUMN CONCEPT FOR LARGE SPACE STRUCTURES
Harold G. Bush and Martin M. Mikulas, Jr. Jul. 1976 18 p refs
(NASA-TM-X-73927) Avail: NTIS HC $3.50 CSCL 22B

A structural element concept is described which permits achievement of weight critical payloads for space shuttle. These columns are highly efficient structural members which could be the basic building elements for very large, space truss structures. Parametric results are presented which show that untapered cylindrical columns result in volume limited payloads on the space shuttle and that nestable, tapered columns easily eliminate this problem. It is recognized that the tapered column concept belongs to a class of structures which must be assembled in orbit. However, analytical results are presented which indicate that the gain in the amount of structure placed in orbit per launch, is great enough that such a concept should be considered in future systems studies of very large space structures. Author

N76-33714# Applied Physics Lab., Johns Hopkins Univ., Laurel, Md.
SAS-C SOLAR ARRAY DEVELOPMENT DYNAMICS
C. E. Williams Aug. 1975 65 p refs
(Contract N00017-72-C-4401)
(AD-A022713; APL-JHU-TG-1281) Avail: NTIS CSCL 10/1

SAS-C has four segmented solar arrays, each consisting of three contiguous, spring-connected solar panels. Array deployment involves unfolding from an inverted 'N' configuration to an extended planar configuration. The deployment dynamics of this type of mechanical system are such that the possibility of damage to any one of the four solar arrays, because of undesirable deployment dynamics, is quite significant. Minimizing this possibility has been the objective of an analytical and experimental investigation. In the analytical investigation, digital computer simulations were used to examine many aspects of the deployment dynamics. The simulations resulted in a set of array spring and mass parameters that minimize deployment damage potential. Experimental investigations consisted of spacecraft despin an array deployment in a vacuum chamber. The report presents analytic and experimental results. Acceptable agreement was obtained between the vacuum test data and the digital simulation. All of the results indicate that the expected deployment dynamics are acceptable for flight. GRA

N77-10276*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
RESPONSE OF LONG, FLEXIBLE CANTILEVER BEAMS APPLIED ROOT MOTIONS
Robert W. Fralich *In its* Advan. in Eng. Sci., Vol. 2 1976 p 491-499 ref
Avail: NTIS HC A20/MF A01 CSCL 13M

Results are presented for an analysis of the response of long, flexible cantilever beams to applied root rotational accelerations. Maximum values of deformation, slope, bending moment, and shear are found as a function of magnitude and duration of acceleration input. Effects of tip mass and its eccentricity and rotatory inertia on the response are also investigated. It is shown that flexible beams can withstand large root accelerations provided the period of applied acceleration can be kept small relative to the beam fundamental period. Author

N77-13915*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICAL AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 6: STRUCTURES AND DYNAMICS PANEL Final Report
Aug. 1975 93 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73966) Avail: NTIS HC A05/MF A01 CSCL 13M

Structural requirements for future space missions were defined in relation to technology needs and payloads. Specific areas examined include: large area space structures (antennas, solar array structures, and platforms); a long, slender structure or boom used to support large objects from the shuttle or hold two bodies apart in space; and advanced composite structures for cost effective weight reductions. Other topics discussed include: minimum gage concepts, high temperature components, load and response determination and control, and reliability and life prediction. J.M.S.

N77-17126# Massachusetts Inst. of Tech., Cambridge. Center for Space Research.
PRELIMINARY DESIGN OF A COMPOSITE STRUCTURE FOR AN AIR FORCE SPACE APPLICATION Final Report, Jul. 1975 - Jan. 1976
John F. McCarthy, Jr. and Oscar Orringer May 1976 100 p refs
(Contract F33615-75-C-5265)
(AD-A029014; CSR-TR-76-1; AFFDL-TR-76-53) Avail: NTIS HC A05/MF A01 CSCL 22/2

Results of a preliminary design investigation of nineteen concepts for a communication satellite truss, based on construction with advanced fiber composite materials, are presented. Of the nineteen candidate concepts, two emerge as designs which appear to be structurally sound and capable of fabrication with state-of-the-art methods at reasonable cost. These structures are shown to be capable of meeting the very stringent thermal deformational stability requirements of the satellite, requirements which cannot be met by equivalent metallic structure. Additional benefits of reduced radar cross section, reduced signal interference, and weight savings, and structural reliability are also indicated for the composite designs. Author (GRA)

N77-23136*# Grumman Aerospace Corp., Bethpage, N.Y.
ORBITAL CONSTRUCTION DEMONSTRATION STUDY Final Report
1 Dec. 1976 78 p
(Contract NAS9-14916)
(NASA-CR-151352; NSS-OC-RP-008) Avail: NTIS HC A05/MF A01 CSCL 22A

A conceptual design and program plan for an Orbital Construction Demonstration Article (OCDA) was developed that can be used for evaluating and establishing practical large structural assembly operations. A flight plan for initial placement and continued utility is presented as a basic for an entirely new shuttle payload line-item having great future potential benefit for space applications. The OCDA is a three-axis stabilized platform in low-earth orbit with many structural nodals for mounting large construction and fabrication equipments. This equipment would be used to explore methods for constructing the large structures for future missions. The OCDA would be supported at regular intervals by the shuttle. Construction experiments and consumables resupply are performed during shuttle visit periods. A 250 kw solar array provides sufficient power to support the shuttle while attached to the OCDA and to run construction experiments at the same time. Wide band communications with a Telemetry and Data Relay Satellite compatible high gain antenna can be used between shuttle revisits to perform remote controlled, TV assisted construction experiments. Author

N77-27156*# Boeing Aerospace Co., Seattle, Wash.
LARGE SPACE ERECTABLE STRUCTURES - BUILDING BLOCK STRUCTURES STUDY Final Report
W. H. Armstrong, D. E. Skoumal, and J. W. Straayer Apr. 1977 119 p refs
(Contract NAS9-14914)
(NASA-CR-151449; D-180-20607-2) Avail: NTIS HC A06/MF A01 CSCL 22A

A modular planar truss structure and a long slender boom concept identified as building block approaches to construction of large spacecraft configurations are described. The concepts are compatible in weight and volume goals with the Space Transportation System, use standard structural units, and represent high on-orbit productivity in terms of structural area or beam length. Results of structural trade studies involving static and dynamic analyses of a single module and rigid body deployment analyses to assess kinetics and kinematics of automatic deployment of the building block modules are presented. J.M.S.

N77-27432*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
LIGHTWEIGHT STRUCTURAL COLUMNS Patent Application
Harold G. Bush, inventor (to NASA) Filed 29 Jun. 1977 17 p
(NASA-Case-LAR-12095-1; US-Patent-Appl-SN-811401) Avail: NTIS HC A02/MF A01 CSCL 13M

Lightweight half-lengths of columns for truss structures were designed that are adapted for nestable storage and transport to facilitate fabrication of large area truss structures at a remote site. The design would be particularly adaptable for space applications. NASA

N77-33260*# Harris Corp., Melbourne, Fla.
AAFE LARGE DEPLOYABLE ANTENNA DEVELOPMENT PROGRAM: EXECUTIVE SUMMARY Final Report
NASA Washington Oct. 1977 45 p
(Contract NAS1-13943)
(NASA-CR-2894) Avail: NTIS HC A03/MF A01 CSCL 09C

The large deployable antenna development program sponsored by the Advanced Applications Flight Experiments of the Langley Research Center is summarized. Projected user requirements for large diameter deployable reflector antennas were reviewed. Trade-off studies for the selection of a design concept for 10-meter diameter reflectors were made. A hoop/column concept was selected as the baseline concept. Parametric data are presented for 15-meter, 30-meter, and 100-meter diameters. A 1.82-meter diameter engineering model which demonstrated the feasiblity of the concept is described. Author

N78-17124*# AEC-ABLE Engineering Co., Inc., Goleta, Calif.
CONCEPTUAL ANALYSES OF EXTENSIBLE BOOMS TO SUPPORT A SOLAR SAIL Final Report
R. F. Crawford and M. D. Benton 20 Oct. 1977 82 p
(Contracts NAS7-100; JPL-954700)
(NASA-CR-155615; AECR-7715/1064) Avail: NTIS HC A04/MF A01 CSCL 22B

Extensible booms which could function as the diagonal spars and central mast of an 800 meter square, non-rotating Solar Sailing Vehicle were conceptually designed and analyzed. The boom design concept that was investigated is an extensible lattice boom which is stowed and deployed by elastically coiling and uncoiling its continuous longerons. The seven different free-span lengths in each spar which would minimize the total weights of the spars and mast were determined. Boom weights were calculated by using a semi-empirical formulation which related the overall weight of a boom to the weight of its longerons. Author

N78-21333*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
LARGE ACTIVE RETRODIRECTIVE ARRAYS FOR SPACE APPLICATIONS
R. C. Chernoff 15 Jan. 1978 59 p refs
(Contract NAS7-100)
(NASA-CR-156163; JPL-Pub-78-20) Avail: NTIS HC A04/MF A01 CSCL 20N

An active retrodirective array (ARA) electronically points a microwave beam back at the apparent source of an incident pilot signal. Retrodirectivity is the result of phase conjugation of the pilot signal received by each element of the array. The problem of supplying the correct phase reference to the phase conjugation circuit (PCC) associated with each element of the array is solved by central phasing. By eliminating the need for structural rigidity, central phasing confers a decisive advantage on ARA's as large spaceborne antennas. A new form of central phasing suitable for very large arrays is described. ARA's may easily be modified to serve both as transmitting and receiving arrays simultaneously. Two new kinds of exact, frequency translating PCC's are described. Such PCC's provide the ARA with input-output isolation and freedom from squint. The pointing errors caused by the radial and transverse components of the ARA's velocity, by the propagation medium, and by multipath are discussed. A two element ARA breadboard was built and tested at JPL. Its performance is limited primarily by multipath induced errors. Author

N78-22146*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
STRUCTURAL MEMBERS, METHOD AND APPARATUS Patent Application
Jack A. Kinzler, inventor (to NASA) Filed 4 Apr. 1978 50 p
(NASA-Case-MSC-16217-1; US-Patent-Appl-SN-893383) Avail: NTIS HC A03/MF A01 CSCL 22A

A lightweight structural member suitable as trusses to be used in the assembly of large structures in space (e.g., solar power satellite) is described, together with a compact, fully automated machine for manufacturing such members in a space environment from compactly stowed sheet material. The rigid, triangular truss is formed of initially flexible, relatively thin rolled sheet material, and includes three parallel tubular columns formed from a strip of sheet material closed upon itself by helical winding. The structural member takes advantage of the space environment, such as low gravitational forces, to utilize construction materials, such as flexible sheet material; and solves the problems of the constraints of manufacturing large space structures such as limited capability for transportation of materials, and stowage of greatest amount of raw material in the most compact form, etc. NASA

N78-33446*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TELESCOPING COLUMNS Patent Application
John T. Mazur, inventor (to NASA) (Harris Corp., Melbourne, Fla.) Filed 29 Sep. 1978 16 p Sponsored by NASA
(Contract NAS1-13943)
(NASA-Case-LAR-12195-1; US-Patent-Appl-SN-946991) Avail: NTIS HC A02/MF A01 CSCL 13I

A power operated telescoping column is described for the deployment and retraction of a large parabolic antenna for space applications. The column consists of several axially elongated rigid structural sections nested within one another. The outermost and each intermediate section includes several rotatable screws extended longitudinally. Sprockets, rigidly attached to the screws and interconnected by a chain, provide simultaneous rotation of the screws of a single section. Threaded legs are attached at the base end of the section and are oriented to engage the screws of the next outer section. The column is extended and retracted by selectively rotating the screws of the sections with a motor and engagement mechanism. As the screws of one section are rotated, the next inner section is extended or retracted. NASA

N78-33480*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
STRUCTURAL EFFICIENCY OF LONG LIGHTLY LOADED TRUSS AND ISOGRID COLUMNS FOR SPACE APPLICATIONS
Martin M. Mikulas, Jr. Jul. 1978 54 p refs
(NASA-TM-78687) Avail: NTIS HC A04/MF A01 CSCL 20K

The general mass characteristics of long lightly loaded columns for space applications are investigated by studying four column concepts. The first is a simple tubular column, the second is a three longeron truss column constructed of tubular members, the third is a three longeron truss column constructed of solid rod members, and the fourth is an open grid work isogrid wall tubular column. Design procedures, which include an initial imperfection in the straightness of the column, are developed for the different concepts and demonstrated numerically. A new set of structural efficiency parameters are developed for lightly loaded columns and are used to show a comparison of the masses of the four column concepts investigated. Author

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04
CONTROL SYSTEMS

Includes new attitude and control techniques, improved surface accuracy measurement and control techniques.

A68-35236#
ANALYSIS AND CONTROL OF FLEXIBLE STRUCTURES.
N. N. Puri and D. Tabak (General Electric Co., Valley Forge, Pa.).
IN: ANNUAL PRINCETON CONFERENCE ON INFORMATION SCIENCES AND SYSTEMS, 2ND, PRINCETON UNIVERSITY, PRINCETON, N.J., MARCH 25, 26, 1968, PROCEEDINGS.

Conference sponsored by Princeton University and the Circuit Theory Group of the Institute of Electrical and Electronics Engineers. Princeton, N.J., Princeton University, 1968, p. 237-241. 12 refs.

Discussion of two basic mathematical models for the analysis and optimal control of flexible structures and evaluation of their applicability. The two models considered are normal-modes modeling and the discrete-points representation of flexible subsystems. Particular problems of controllability, stability analysis, and time-optimal control are considered. An analytic example illustrates the discrete-points method. R.A.F.

A70-19481 #
AUTOMATIC ASSEMBLY IN SPACE (AVTOMATICHESKAIA SBORKA V KOSMOSE).
V. P. Legostaev and B. V. Raushenbakh.
(International Astronautical Federation, Congress, 19th, New York, N.Y., Oct. 13-19, 1968.)
Kosmicheskie Issledovaniia, vol. 7, Nov.-Dec. 1969, p. 803-813. In Russian.

Discussion of the automatically controlled rendezvous and docking maneuvers required for orbital assembly of large space vehicles (as a means of reducing booster size and launching costs). The equations of motion of the centers of mass of the vehicle components during a rendezvous maneuver are derived, together with the equations of motion of the components relative to their centers of mass. The control laws for rendezvous maneuvers are derived, and the operation of the control system is described. V.P.

A70-32726 **Automatic assembly in space.** V. P. Legostaev and B. V. Raushenbach. (*Kosmicheskie Issledovaniia,* vol. 7, Nov.-Dec. 1969, p. 803-813.) *Cosmic Research,* vol. 7, Nov.-Dec. 1969, p. 723-731. Translation..

Discussion of the automatically controlled rendezvous and docking maneuvers required for orbital assembly of large space vehicles (as a means of reducing booster size and launching costs). The equations of motion of the centers of mass of the vehicle components during a rendezvous maneuver are derived, together with the equations of motion of the components relative to their centers of mass. The control laws for rendezvous maneuvers are derived, and the operation of the control system is described. V.P.

A72-32587 # **Attitude control of flexible space vehicles.** G. Porcelli (Fairchild Industries, Inc., Fairchild Space and Electronics Div., Germantown, Md.). *AIAA Journal,* vol. 10, June 1972, p. 807-812. 14 refs.

Objectives of this paper are to enhance the concept of multiple control in attitude control systems for large flexible space vehicles and to discuss some questions of stability and structure-control system interaction. The approach to the design of a multiple control system is illustrated with a typical example for which the control system configuration includes a main loop providing control for the main portion of the structure and auxiliary loops providing active damping for the flexible appendages. Criteria for the first cut design of each auxiliary loop are given. The performance of the multiloop control system described, versus that of the corresponding single-loop, is illustrated by the results of analog simulation. Qualitative results of analysis and stability limitations of different classes of attitude control system configurations for large flexible space vehicles are also discussed. The normal mode approach particularly suitable for the use of transfer functions is considered in modeling the structure dynamics. (Author)

A74-21394 * # **Attitude stability of a flexible solar electric spacecraft - A parametric study.** E. L. Marsh (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Journal of Spacecraft and Rockets,* vol. 11, Feb. 1974, p. 89-96. 6 refs. Contract No. NAS7-100.

The influence of large area solar array flexibility on the attitude control of a solar electric spacecraft is analyzed. The spacecraft consists of a rigid central body, two flexible roll-out solar arrays, and a cluster of three electric propulsion engines. Each engine has gimballing or translational capacity, or both, for attitude control purposes. A parametric stability study of various spacecraft configurations was made, using hybrid coordinate techniques in an eigenvalue analysis. Parameters varied were solar array aspect ratio, solar array first natural frequency, solar array rotation angle about the yaw axis, and sensor gain factors. Only the first six modes of solar array vibration were included in the study. The attitude response characteristics of the various spacecraft configurations were obtained by means of a digital computer simulation program of the system's equations of motion. The feasibility of using the thrusters for attitude control of electric propulsion spacecraft is demonstrated. It is also shown that although the dynamics effects of large-area flexible solar arrays can be harmful, changes in the control system parameters can insure stable attitude control. (Author)

A74-33345 * **Attitude control of a spinning flexible spacecraft.** S. M. Seltzer (NASA, Marshall Space Flight Center, Astrionics Laboratory, Huntsville, Ala.), J. S. Patel (U.S. Navy, Naval Underwater Systems Center, New London, Conn.), and G. Schweitzer (München, Technische Universität, Munich, West Germany). *Computer and Electrical Engineering,* vol. 1, Dec. 1973, p. 323-339. 11 refs. Research supported by the National Research Council.

The dynamics of rotational motion of a spinning orbiting spacecraft consisting of two rigid bodies connected by a flexible joint and arbitrary number of flexible appendages (two of which are flexible massless booms having masses on their tips) is analyzed. Active attitude control is provided by momentum exchange devices (e.g. control moment gyroscopes) or a mass expulsion system. The linearized equations of motion describing the vehicle are presented, and a large scale digital simulation that has been developed at the Marshall Space Flight Center is presented. A simplified model of the geometrically complex vehicle is selected to make it analytically tractable. The simplified model consists of a single rigid core body with two attached flexible massless booms having tip masses. The states of the vehicle are defined as small perturbations about its steady-state spin. An analysis is performed to determine the domain of stability. (Author)

A74-36663 # **Holographic structural control for large space reflectors and radio telescopes.** T. A. Heppenheimer (Rockwell International Corp., Space Div., Downey, Calif.). *Journal of Spacecraft and Rockets,* vol. 11, July 1974, p. 536-538. 13 refs.

An active control system based on existing holographic technology is proposed for maintaining the precision contours of large space reflectors whose elements are translated by actuators. A hologram of the surface contour is superimposed on a reference hologram, and the deviations from the nominal of any point on the surface are obtained by computer counting of the interference fringes. This surface information is then fed to the individual actuators. Either microwave holography or the two-frequency method in optical holography may be used. Some applications of the proposed method to radio telescopy are also discussed. J.K.K.

A74-42416 **Thermal stabilization of gravity gradient boom rods.** F. J. Campbell, J. A. Eisele, and W. L. Warnick (U.S. Navy, Naval Research Laboratory, Washington, D.C.). In: International

Symposium on Space Technology and Science, 10th, Tokyo, Japan, September 3-8, 1973, Proceedings. Tokyo, AGNE Publishing, Inc., 1973, p. 611-615. Navy-supported research.

Thermal bending can be reduced appreciably if a suitable thermal control surface is utilized on the gravity gradient boom rod material. The rod is presently formed from beryllium-copper alloy ribbon tempered to form a hollow cylinder when the ribbon is unrolled from the storage spool. The outer surface is conventionally plated with silver which has a solar absorptance to emittance ratio of approximately 5. Solar radiation normal to the rod produces a surface temperature of several hundred degrees Celsius and a front-to-back expansion differential which bends the rod. The bonding of FEP-teflon sheet with a silvered film acting as a second surface mirror to the beryllium-copper ribbon results in a calculated equilibrium temperature of the boom rod of -82 C in the sun and of -113 C in the earth's shadow at a satellite altitude of 600 n mi. The thermal differential shock experienced by the boom as it emerges from the earth's shadow is thereby greatly reduced. (Author)

A75-11105 # **Dynamical equations of spacecraft with controlled flexible appendages using finite element approach.** G.-T. Tseng (RCA, Astro-Electronics Div., Princeton, N.J.). *Canadian Aeronautics and Space Institute and American Institute of Aeronautics and Astronautics, Joint Meeting, Toronto, Canada, Oct. 30, 31, 1974, AIAA Paper 74-1261.* 11 p. 15 refs.

This paper describes the derivation of the nonlinear dynamical equations of a class of flexible spacecraft using a set of appendage modal coordinates as a subset of the generalized coordinates for the entire system. The spacecraft system consists of a rigid central body to which an arbitrary number of rotors and an arbitrary number of controlled flexible appendages are attached. The appendages are idealized as systems of beam and triangular plate elements interconnected at nodes. The formulation includes the influence of significant internal stresses arising either from spacecraft spin or structural/mechanical preloads. The final form of the equations is presented and their applications are discussed through appendage modal-coordinate truncation in system simulation and attitude-control analysis. (Author)

A75-12572 # **Multi-loop analysis of a precision pointing spacecraft with controlled flexible appendages.** J. S. Pistiner, G. T. Tseng, and L. Muhlfelder (RCA, Astro-Electronics Div., Princeton, N.J.). *Canadian Aeronautics and Space Institute and American Institute of Aeronautics and Astronautics, Joint Meeting, Toronto, Canada, Oct. 30, 31, 1974, AIAA Paper 74-1262.* 8 p. Contract No. F04701-72-C-0221.

This paper describes the development and application of a multi-loop frequency response analysis method to determine the stability and response to disturbances of a precision pointing earth-oriented satellite with a controlled flexible appendage. Since the spacecraft control axes are not principal axes and the driven solar array represents a flexible appendage, single-loop rigid body analysis will not yield valid stability predictions. A four-loop (roll, pitch, yaw, array) frequency-domain computer program was developed, which permits the servo designer to verify open and closed loop stability of the strongly coupled servos in the presence of multiple low-frequency flexible body modes. Although the approach presented here was applied to a scientific satellite application, its methodology can readily be adapted to other spacecraft configurations with controlled flexible appendages. (Author)

A75-15191 # **Vibrations of space booms under centrifugal force field.** R. Kumar (Spar Aerospace Products, Ltd., Toronto, Canada). *CASI Transactions,* vol. 7, Mar. 1974, p. 1-5. 12 refs.

In plane and out of plane free vibrations of rotating space booms have been studied using the Myklestad method. A modified stiffness matrix relating to state vectors of consecutive stations has been derived. Relations accounting for root radius, tip mass, and spin rate have been obtained for rapid prediction of the first natural frequencies. The difference in centrifugal stiffening for in plane and out of plane vibrations is maximum for the first mode and becomes insignificant for higher modes. For high spin rates and zero root radius, the in plane fundamental frequency is directly proportional to the square root of the spin rate, whereas the out of plane fundamental frequency tends to become equal to the angular speed of rotation irrespective of the tip mass. Natural frequencies of higher modes decrease as the tip mass is increased but after a certain value, they start increasing. (Author)

A75-22946 * **Three-axis attitude control for solar-powered electric propulsion spacecraft.** H. K. Bouvier (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Society of Automotive Engineers, National Aerospace Engineering and Manufacturing Meeting, San Diego, Calif., Oct. 1-3, 1974, Paper 740874.* 14 p. 15 refs. Members, $1.75; nonmembers, $2.75.

Spacecraft utilizing solar electric propulsion (SEP) for certain long-term interplanetary missions will depend on large, flexible solar arrays. The resulting spacecraft configurations present some complex flight control problems. Questions regarding a general design approach are discussed along with options for three-axis control forces, tradeoffs for three-axis control forces, controllers for SEP attitude control, sensors for SEP attitude control, aspects of nonrigid vehicle interaction with attitude control, thrust vector control SEP dynamics, and mass expulsion control SEP dynamics. It is found that the state-of-the-art of control system design is mature enough to support an SEP project. G.R.

A76-16783 # **Influence of stored angular momentum on the modal characteristics of spacecraft with flexible appendages.** P. C. Hughes and H. N. Sharpe (Toronto, University, Downsview, Ontario, Canada). *(American Society of Mechanical Engineers, Paper 75-APM-Y,* 1975.) *ASME, Transactions, Series E - Journal of Applied Mechanics,* vol. 42, Dec. 1975, p. 785-788. 13 refs. Department of Communications Contract No. DSS-36100-3-0323.

The attitude dynamics and control of flexible spacecraft are more clearly understood if the natural frequencies of oscillation are known for these spacecraft. The influence of stored angular momentum (for example, dual-spin vehicles, or vehicles with a momentum wheel) on these natural frequencies is determined in terms of the appendage characteristics, the inertia distribution, and stored angular momentum. Primary emphasis is placed on general qualitative results. The discussion is illustrated with an example. (Author)

A76-28880 **Selection and adaptation of a control law for a Double Gimballed Momentum Wheel system on a large solar array satellite.** J. Broquet (Engins MATRA, S.A., Vélizy-Villacoublay, Yvelines, France). In: International Federation of Automatic Control, Triennial World Congress, 6th, Boston and Cambridge, Mass., August 24-30, 1975, Proceedings. Part 4. Pittsburgh, Pa., Instrument Society of America, 1975, p. 14.4 1-14.4 6.

From literature on the control of geostationary satellite using a DGMW as actuator and only a roll and pitch earth sensor as detector, a comparison of the various types of roll/yaw control laws is performed on the basis of realistic hardware characteristics. The natural limitations of any law concerning the satellite pointing accuracy when large disturbing torques are applied, impose a torque identification and a compensation at satellite attitude level. Simple methods for a board identification of major solar thruster disturbing torques are proposed in a preliminary baseline, and result of normal mode control simulation is shown. (Author)

A76-46286 **The dynamics of flexible bodies.** B. Fraeijs de Veubeke (Liège, Université, Liège, Belgium). *International Journal of Engineering Science,* vol. 14, no. 10; 1976, p. 895-913. 7 refs.

The motion of a flexible body undergoing arbitrarily large rotations with respect to an inertial frame is split into a mean rigid-body motion, defining a dynamical reference frame, and a relative motion taking into account the deformations. The mean motion is usually taken to satisfy the Tisserand conditions of zero relative momentum and angular momentum, a choice that is shown to correspond to a minimum value of the relative kinetic energy. The condition of zero angular momentum is nonlinear and introduces discretization difficulties that can be overcome by another choice. This alternative minimizes the mean square of relative displacements, preserves the zero-momentum condition, but linearizes the angular-momentum condition in such a way that the relative displacements are representable exactly by an expansion in natural elastic vibration modes. (Author)

A77-42817 # **Flexible spacecraft control design using pole allocation technique.** G. T. Tseng (Aerospace Corp., El Segundo, Calif.) and R. H. Mahn, Jr. (TRW, Inc., Redondo Beach, Calif.). *American Institute of Aeronautics and Astronautics, Guidance and Control Conference, Hollywood, Fla., Aug. 8-10, 1977, Paper 77-1097.* 6 p. 10 refs.

A control design approach through pre-assigning desired closed-loop poles is proposed. The method is applied to a complex flexible spacecraft under multi-axis control to demonstrate its practical implications. The key contribution of the paper is to present a powerful design tool which allows an analyst to have direct control over the closed-loop system eigenvalues. With a proper choice of the number of control inputs and observable states, it is possible in some cases to generate a feedback gain matrix independent of flexible appendage modal coordinates. (Author)

A77-43644 * **Control and stability problems of remote orbital capture.** M. H. Kaplan and A. A. Nadkarni (Pennsylvania State University, University Park, Pa.). *(Conference on Remotely Manned Systems, 2nd, Los Angeles, Calif., June 9-11, 1975.) Mechanism and Machine Theory,* vol. 12, no. 1, 1977, p. 57-64. Grants No. NGR-39-009-162; No. NsG-7078.

Certain space shuttle missions may require retrieval of passive spinning and precessing satellites. One proposed means of retrieval utilizes a free-flying teleoperator launched from the shuttle. A study of misalignment, stability, and certain control aspects during capture of an object is reported here. The approach used is to model the dynamics by a Lagrangian formulation and apply torque components to dissipate motion. Differential angular rates between teleoperator and object are assumed, and control responses after capture are reviewed. (Author)

A77-51470 **Automatic control of the surface shape of large space radiotelescopes.** V. I. Buiakas, A. S. Gvamichava, L. N. Lupichyov, and Iu. V. Chekulaev (Institute of Control Sciences; TSNIIProektstalkonstruktsiia, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-194.* 16 p.

Maintaining the shape of the reflecting surface of large space radiotelescopes through controlled interaction of the surface elements is discussed. Two types of surface structure are considered, one employing hexagonal elements, the other using a square lattice. Vector analyses based on the number of element intersections and the degrees of freedom of the structure and its components are taken into account in specifying conditions under which the modification of the shape of the structure does not result in static elastic deformations. The analyses are also applied to ensuring that small manufacturing defects do not interfere with the overall stability of the radiotelescope surface structure. J.M.B.

A78-12095 # **A flexible passive space array with springs.** J. V. Breakwell (Stanford University, Stanford, Calif.) and G. B. Andeen (Stanford Research Institute, Menlo Park, Calif.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Symposium, Blacksburg, Va., June 13-15, 1977.
Blacksburg, Va., Virginia Polytechnic Institute and State University, 1977, p. 203-214.

A passive space communicator in synchronous orbit will consist of small aluminum beads chained together and aligned vertically by the earth's gravity-gradient. The analysis for small deviations from vertical uses a continuous chain model, and pitch and roll frequencies and mode-shapes are described. Damping of the lowest-order, otherwise rigid and undamped modes, can be obtained by inserting springs between the end portions and the main portion of the chain. The roll damping depends on tuning the springs so that energy is transferred out of roll. The appropriate spring constants are calculated. (Author)

A78-12096 # **Active control of flexible systems.** M. J. Balas (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Symposium, Blacksburg, Va., June 13-15, 1977.
Blacksburg, Va., Virginia Polytechnic Institute and State University, 1977, p. 217-236. 27 refs. Contract No. F04701-76-C-0178.

Active control of flexible spacecraft, restricted by on-board computer limitations and modeling error to the control of a few critical modes, is discussed. A class of distributed parameter systems which can be represented by a generalized wave equation relating the displacement of a body in n-dimensional space to the applied force distribution is used to model flexible spacecraft systems. A feedback controller for an arbitrary number of modes of a flexible system is developed on the basis of state variable techniques; the possibility of control and observation spillover due to the residual (uncontrolled) modes of the system is studied. Numerical analyses of the active control of a simply-supported beam are employed to examine and correct the destabilizing effect of control and observation spillover. J.M.B.

A78-12099 # **An active modal control system philosophy for a class of large space structures.** M. J. Balas and J. R. Canavin (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). In: Dynamics and control of large flexible spacecraft; Proceedings of the Symposium, Blacksburg, Va., June 13-15, 1977.
Blacksburg, Va., Virginia Polytechnic Institute and State University, 1977, p. 271-285. 15 refs. Contract No. F04701-76-C-0178.

The purpose of this paper is to provide a control formulation for a class of large flexible spacecraft that requires vibration suppression for a critical flexible section. The modal control or structure control provides for active isolation of the precision section from the main spacecraft, and active damping and alignment of the precision structure. A format is provided for partitioning the system dynamics, and the form of the modal control is established. The conditions necessary for the successful operation of the controller are displayed. A numerical example is presented in order to illustrate the formulation. (Author)

A78-29797 # **Damping augmentation for large space structures.** T. C. Henderson and J. R. Canavin (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). In: Structures, Structural Dynamics and Materials Conference, 19th, Bethesda, Md., April 3-5, 1978, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1978, p. 207-213. 8 refs. Contract No. F04701-76-C-0178. (AIAA 78-490)

Damping is increased in a large space structure by adding viscous damping elements to discrete members of the spacecraft structure. These member dampers introduce nonproportional damping. An efficient two-stage eigenvalue analysis is formulated to calculate the system complex modes and damping levels. A rationale for locating the member dampers in the structure is introduced. A coupling phenomenon is observed in the behavior of these systems which places physical limits on the amount of damping that can be obtained in certain modes. The efficiency of these systems is low because they act not only to increase damping, but also to redistribute the vibrational energy over the structure. (Author)

A78-31899 * # **Stochastic optimal attitude control of spacecraft with movable appendages.** R. Sellappan and P. M. Bainum (Howard University, Washington, D.C.). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Jackson Hole, Wyo., Sept. 7-9, 1977, Paper.* 25 p. 7 refs. Grant No. NsG-1181.

This paper deals with the application of linear optimal control and filtering theory to control a spinning spacecraft with movable telescoping appendages. The equations of motion are linearized about the desired final state. A feedback control system is designed to maintain this final state, with plant noise and measurement noise present in the system. Analytic results are obtained for special cases and numerical results are presented for the general case. (Author)

A78-35756 **Modal control of certain flexible dynamic systems.** M. J. Balas (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). *SIAM Journal on Control and Optimization,* vol. 16, May 1978, p. 450-462. 25 refs. Contract No. F04701-76-C-0178.

Distributed parameters in mechanically flexible systems under conditions of vibration, e.g., surface, air, and space transportation systems, are considered with reference to feedback control of N modes and spillover into the uncontrolled modes. A class of flexible systems is viewed within the context of a generalized wave equation, relating to the displacement of a body in n-dimensional space. Expansion and truncation of the system state in the eigenmodes of the operator is presented as a means whereby the N modes can be stabilized, provided the controlled modes are observable. D.M.W.

A78-44380 # **Optimal digital control of large space structures.** R. Gran, M. Rossi, and H. G. Moyer (Grumman Aerospace Corp., Research Dept., Bethpage, N.Y.). *American Astronautical Society, Annual Rocky Mountain Guidance and Control Conference, Keystone, Colo., Mar. 10-13, 1978, Paper 78-105.* 31 p. 5 refs.

A theory for the optimal digital control of large space structures in low earth orbit is developed. The design consists of a four-part sequence: (1) rigid body control, (2) continuous optimal control using only the momentum storage devices, (3) discrete optimal control, and (4) a control design utilizing only a reduced order model. The results for each of these designs are given. S.C.S.

A78-45683 # **The control of spacecraft vibrations using multivariable output feedback.** J. R. Canavin (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). *American Institute of Aeronautics and Astronautics and American Astronautical Society, Astrodynamics Conference, Palo Alto, Calif., Aug. 7-9, 1978, AIAA Paper 78-1419.* 12 p. 12 refs. Contract No. F04701-76-C-0178.

The control of structural vibrations in spacecraft presents severe problems to the ensurance of system stability. This paper examines multivariable output feedback without compensation. The model error for the linearized system comprises of both truncation error and parameter error. Stability tests which depend on the model are shown to be inconclusive due to the coupling between the controlled modes and the residual modes. The relationship of this coupling to system stability is developed. General theorems for system stability are developed that test matrices that depend only on the control design parameters. A decoupled controller algorithm is derived and implemented for a Large Space Structure. Robustness of the controller when significant model error exists is demonstrated by the numerical example. (Author)

A78-45684 # **Dynamics and control of large spinning spacecraft.** J.-N. Juang (Martin Marietta Aerospace, Denver, Colo.) and M. Balas (Bolt Beranek and Newman, Inc., Cambridge, Mass.). *American Institute of Aeronautics and Astronautics and American Astronautical Society, Astrodynamics Conference, Palo Alto, Calif., Aug. 7-9, 1978, AIAA Paper 78-1420.* 8 p. 11 refs.

With the advent of large space structures, flexibility has become an increasingly more important factor in the dynamics and control of current and proposed spacecraft. Here we consider the controllability and observability of large spinning spacecraft to determine the minimum actuator and sensor requirements for active control. Then we produce a modal feedback controller design based on these requirements; this design is modified to successfully operate in the presence of spillover without any serious deterioration in system performance. This approach is applied to the attitude controller design for the RAE/B (Radio Astronomy Explorer) Satellite, a typical large spinning spacecraft consisting of a rigid core with six flexible booms. (Author)

A78-49256 **Feedback control of flexible systems.** M. J. Balas (Bolt Beranek and Newman, Inc., Cambridge, Mass.). *IEEE Transactions on Automatic Control,* vol. AC-23, Aug. 1978, p. 673-679. 33 refs. Contract No. F04701-76-C-0178.

Feedback control is developed for the class of flexible systems described by the generalized wave equation with damping. The control force distribution is provided by a number of point force actuators and the system displacements and/or their velocities are measured at various points. A feedback controller is developed for a finite number of modes of the flexible system and the controllability and observability conditions necessary for successful operation are displayed. The control and observation spillover due to the residual (uncontrolled) modes is examined and the combined effect of control and observation spillover is shown to lead to potential instabilities in the closed-loop system. Some remedies for spillover, including a straightforward phase-locked loop prefilter, are suggested to remove the instability mechanism. The concepts of this paper are illustrated by some numerical studies on the feedback control of a simply-supported Euler-Bernoulli beam with a single actuator and sensor. (Author)

A78-52002 # **Control of large space structures via singular perturbation optimal control.** J. R. Sesak (General Dynamics Corp., Convair Div., San Diego, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1690.* 8 p. 12 refs.

A new optimal control approach - singular perturbation optimal control - is advanced and applied to control the elastic modes of a large space structure. This singular perturbation technique differs from the other singular perturbation techniques in that a stationary point is induced independently of the physics of the controlled object. Therefore, the open loop plant need not have slow and fast modes, and the final control law does not require separate solutions for slow and fast modes. Because the design algorithm allows implementation of a model reduction strategy, the dimension of the dynamic model characterizing the physical structure can be altered at will. Controller excitation of the neglected modeled vibration modes can be made arbitrarily small to provide reduced-order control of the high-order model and to assure closed-loop stability of the high-order model. The algorithm is also suitable for decentralized controller design. (Author)

A78-52003 # **Control technology for large space structures.** J. R. Canavin (Charles Stark Draper Laboratory, Inc., Cambridge, Mass.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1691.* 10 p. 10 refs. Contract No. F04701-76-C-0178.

The problem of increased structural flexibility of Large Space Structures is examined. A hierarchy of techniques for adding high values of damping to the structure is set forth. The member damper approach includes local damping elements (i.e., dashpots or their electronic equivalents) in the members of the structure. Output feedback introduces distributed control systems. Velocity output feedback with collocated sensors and actuators exhibits robust stability characteristics and may be viewed as a 'modal dashpot'. Modern control techniques lead to the inclusion of a dynamic estimator in the controller, which is used to reconstruct the modal state. Feedback gains applied to the estimated modal state (Modern Modal Control) lead, however, to 'spillover' into the unmodeled or truncated modes of vibration. The addition of a feedthrough term in the control law is suggested as a possible solution to the stability problems of Modern Modal Control. (Author)

A78-52747 * # **Control system technology and tradeoffs for large space structures.** J. C. Blair (NASA, Marshall Space Flight Center, Control Systems Div., Huntsville, Ala.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1686.* 7 p. 6 refs.

The role of the control system in large space structure design is examined. It is pointed out that control and dynamics aspects of the structure must be considered very early in the design. Innovative techniques will be needed, such as on-orbit dynamic testing, offsetting of disturbance torques, and advances in the analysis area, particularly with respect to system modeling and achieving a tractable dimension of the problem. The technology pursued, while necessarily being focused, must not be too narrow, but should be concerned with the multidisciplinary aspects of large space structures. G.R.

A78-52748 * # **Pointing and control technology needs for future automated space systems.** J. B. Dahlgren and S. M. Gunter (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1687.* 10 p. 7 refs. Contract No. NAS7-100.

Future automated space missions present challenging opportunities in the pointing and control technology disciplines. A NASA-OAST sponsored study at JPL, identified and assessed the enabling pointing and control system technologies for missions from 1985 to year 2000. A generic mission set including earth orbiter, planetary, and other missions which predominantly drive the pointing and control requirements was selected for detailed evaluation. Technology candidates identified in the study are discussed. (Author)

N68-23421 Rensselaer Polytechnic Inst., Troy, N. Y.
DESIGN OF AN ATTITUDE CONTROL SYSTEM FOR A LARGE SPACE VEHICLE
Edward John Smith (Ph.D. Thesis) 1966 299 p
Available from Univ. Microfilms: HC $13.50/MF $3.85 Order No. 67-4197

This research is concerned with the investigation of the large angle behaviour of the attitude of a space vehicle under the control of a nonlinear attitude control system. The attitude orientation is controlled by an on-off control system which contains a deadband. The large attitude angle excursion problem occurs during the injection into orbital flight when the acquisition of a unique attitude is desired, during rendezvous and docking maneuvers, during entry and reentry or atmospheric flight and during liftoff from the surface of alien planets. It represents an important but relatively unexplored area of investigation. An interplanetary flight was chosen for the synthesis of the control system. This type of mission contains all of the elements of the large excursion problem and offers a basis for the establishment of the closed loop system performance criterion. Dissert. Abstr.

N76-11216*# Howard Univ., Washington, D.C. School of Engineering.
THE DYNAMICS OF SPIN STABILIZED SPACECRAFT WITH MOVABLE APPENDAGES, PART 2 Semiannual Status Report, 16 May - 15 Nov. 1975
Peter M. Bainum and R. Sellappan 15 Nov. 1975 26 p refs
(Grant NsG-1181)
(NASA-CR-145605) Avail: NTIS HC $4.00 CSCL 22B

Research efforts on various methods that employ moving external parts for spacecraft control are presented. Two basic types of appendages were considered: (1) a hinged type, and (2) a telescoping type. Procedures for evaluating each type of appendage are listed, and control laws and equations of motion for each type are also discussed. Illustrations of the different types of appendages are shown. J.R.T.

N76-27352# British Aircraft Corp. (Operating) Ltd., Bristol (England). Electronics and Space Systems Group.
THE ATTITUDE CONTROL OF THREE-AXIS STABILISED SPACECRAFT WITH FLEXIBLE APPENDAGES, VOLUME 1 Final Report
R. S. Harris, D. C. Todman, and N. Swift Mar. 1976 183 p refs 3 Vol.
(Contract ESTEC-2312/74-AK)
(ESS/SS-695-Vol-1; ESA-CR(P)-808-Vol-1) Avail: NTIS HC $7.50

Methods of deriving the dynamic equations of motion of three-axis stabilized satellites with large flexible solar arrays and/or antennas, described in literature, are compared and summarized. Approaches adopted for analyzing flexible structures are discussed and their impact on the formulation of the dynamic equations is considered. A discussion of papers describing the design and synthesis of a suitable control law for a three-axis stabilized satellite with flexible appendages is presented. ESA

N76-27353# British Aircraft Corp. (Operating) Ltd., Bristol (England). Electronics and Space Systems Group.
THE ATTITUDE CONTROL OF THREE-AXIS STABILISED SPACECRAFT WITH FLEXIBLE APPENDAGES, VOLUME 2, BOOK 1 Final Report
R. S. Harris and D. C. Todman Mar. 1976 196 p 3 Vol.
(Contract ESTEC-2312/74-AK)
(ESS/SS-695-Vol-2-Bk-1; ESA-CR(P)-808-Vol-2-Bk-1) Avail: NTIS HC $7.50

The flexure-satellite attitude interaction due to two uniform beam arrays on a three-axis stabilized spacecraft is examined. The arrays are equivalent in mass and inertia distribution to 18 m x 2 m RAE-type arrays, being symmetrically disposed about the satellite roll/yaw plane and offset from the pitch axis. Three control actuators are used: thrusters, DGMW, and reaction wheels. On the assumption of a rigid structure, and after introduction of flexure dynamics, it is demonstrated that the performance degradation due to flexure in the pitch loops is negligibly small so that the three pitch controllers designed on the basis of a rigid satellite are adequate. This is also the situation for the roll/yaw loop of the DGMW system. In the case of the thruster roll and yaw loops, an increase in the number of thruster firings occurs; however, flexure interaction with the reaction wheel roll and yaw axes causes instability. ESA

N76-27354# British Aircraft Corp. (Operating) Ltd., Bristol (England). Electronics and Space Systems Group.
THE ATTITUDE CONTROL OF THREE-AXIS STABILISED SPACECRAFT WITH FLEXIBLE APPENDAGES, VOLUME 2, BOOK 2 Final Report
R. S. Harris and D. C. Todman Mar. 1976 202 p refs 3 Vol.
(Contract ESTEC-2312/74-AK)
(ESS/SS-695-Vol-2-Bk-2; ESA-CR(P)-808-Vol-2-Bk-2) Avail: NTIS HC $7.75

The flexure-satellite attitude interaction due to two uniform beam arrays on a three-axis stabilized spacecraft is examined. It is shown that flexure interaction with the reaction wheel roll and yaw axes causes instability. Improved control schemes which take flexure into account were therefore derived for the reaction wheel actuator system. Both classical and modern control techniques are employed resulting in the design of a compensation network and two observer-based multivariable feedback controllers. The result of a comparison of the three systems is that best control performance is given by an observer which is used to provide control signals for the rigid body mode, allowing the flexure mode to decay by structural damping. Methods of implementing in-flight experiment and data processing techniques to evaluate flexure parameters are compared. ESA

N76-28297# European Space Agency, Paris (France).
DYNAMICS AND CONTROL OF NON-RIGID SPACE VEHICLES
1976 338 p refs Partly in ENGLISH and partly in FRENCH
Proc. of Symp., held at Frascati, Italy, 24-26 May 1976 Sponsored in part by ESA
Avail: NTIS HC $10.00

Topics are presented in the field of flexible spacecraft configurations. Dynamic models are reviewed for spinning and non-spinning satellites. The attitude stability of flexible satellites is discussed. Applications are described of modern control theory and the design of control systems for these configurations is outlined. Test and flight verifications are reported, and some special dynamics problems are dealt with.

N76-28308 Pennsylvania State Univ., University Park.
ATTITUDE CONTROL OF SYNCHRONOUS SATELLITES POSSESSING FLEXIBLE SOLAR ARRAYS USING A DOUBLE GIMBALED MOMENTUM WHEEL
Stanley E. Hillard *In* ESA Dyn. and Control of Non-rigid Space Vehicles 1976 12 P refs

A symmetric vehicle possessing two large, highly flexible solar wings in synchronous orbit is investigated. Each wing is comprised of a solar cell blanket, rigid tip piece, and flexible support boom. The linearized satellite attitude equations are presented using a hybrid coordinate scheme along with ancillary flexible array component relations and their applicable boundary conditions. Continuous deformation coordinates are expressed in terms of normal modes while vehicle attitude perturbations are expressed using Euler angles. The uncontrolled vehicle natural frequencies are determined and the effects of inertial, material, and geometrical parameters are calculated. Acceptable control laws are presented assuming a double gimbaled momentum wheel configuration and attitude control transfer functions are determined. The effects of appendage flexibility are isolated and criteria are established for system stability using well known techniques. Author (ESA)

N76-28317* Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
AN APPLICATION OF MODERN CONTROL THEORY TO AN ELASTIC SPACECRAFT
Victor Larson and Peter W. Likins (Univ. of Calif., Los Angeles) *In* ESA Dyn. and Control of Non-rigid Space Vehicles 1976 5 p refs Sponsored in part by NASA

Results are presented to illustrate the application of established procedures of linear, quadratic, Gaussian optimal estimation and control to a spacecraft with dynamically significant elastic appendages. Interpretations are provided in both time domain and frequency domain, and conclusions are drawn for a wide class of problems of flexible spacecraft attitude control. Author (ESA)

N76-28319* Howard Univ., Washington, D.C. Dept. of Mechanical Engineering.
OPTIMAL CONTROL OF SPIN STABILIZED SPACECRAFT WITH TELESCOPING APPENDAGES
P. M. Bainum and R. Sellappan *In* ESA Dyn. and Control of Non-rigid Space Vehicles 1976 12 p refs

(Grant NsG-1181)
The control of a spin-stabilized spacecraft consisting of a rigid central hub and one or two movable offset telescoping booms (with end masses) is considered. The equations of rotational motion are linearized about either of two desired final states. A control law for the boom and mass position is sought such that a quadratic cost functional involving the weighted components of angular velocity plus the control is minimized when the final time is unspecified and involves the solution of the matrix Riccati algebraic equation. For three-axis control more than one offset boom (orthogonal to each other) is required. For two-axis control with a single boom offset from a symmetrical hub, an analytic solution is obtained; when this system is used for nutation decay the time constant is one order of magnitude smaller than previously achieved using non-optimal control logic. For the general case results are obtained numerically. Author (ESA)

N76-28323 British Aircraft Corp. (Operating) Ltd., Bristol (England).
THREE AXIS CONTROL OF SPACECRAFT WITH LARGE FLEXIBLE APPENDAGES
R. S. Harris and D. C. Todman *In* ESA Dyn. and Control of Non-rigid Space Vehicles 1976 10 p refs

(Contract ESTEC-2312/74-AK)
The applicability of control laws, derived for a completely rigid structure, to a three axis stabilized spacecraft with two large flexible appendages is examined. Three actuator devices are considered, being thrusters, DGMW (double gimbaled momentum wheel) and reaction wheels. For the configuration studied, it is demonstrated that the reaction wheel system is more susceptible to the effects of flexure. Control laws taking flexure into account are then designed for this system using both the classical approach (compensation networks) and modern techniques (observers with multivariable feedback). It is shown that the observer-based method produces a control scheme which maintains tight attitude control, is insensitive to realistic uncertainties in the system parameters and produces only a small array tip motion. Author (ESA)

N76-28324 Salford Univ. (England). Dept. of Aeronautical and Mechanical Engineering.
SYNTHESIS OF ACTIVE ON-BOARD CONTROLLERS FOR VIBRATORY SYSTEMS WITH RIGID BODY-MODES
B. Porter and A. Bradshaw *In* ESA Dyn. and Control of Non-rigid Space Vehicles 1976 6 p refs

A general method for the design of active on-board controllers for linear vibratory systems with rigid-body modes is illustrated by synthesizing an active vibration controller for a simple dynamical system consisting of flexible appendages and actuator-reaction inertias attached to a rigid center-body. Typical results of digital computer simulation studies are presented in order to illustrate the time-domain behavior of the controlled system. Author (ESA)

N76-28325 Hawker Siddeley Dynamics Ltd., Stevenage (England).
THE EFFECT OF FLEXIBILITY ON A CONTROL SYSTEM DESIGN FOR A RANGE OF SPACECRAFT AND HYBRID ARRAY CONFIGURATIONS
L. Flook and M. Burton *In* ESA Dyn. and Control of Non-rigid Space Vehicles 1976 10 p

The effect of large flexible solar arrays on a control system design for high power geostationary spacecraft is examined. The first anti-symmetric unconstrained bending mode and the first unconstrained twisting mode are determined for several configurations. The limit cycle frequencies in the roll and yaw axes during station keeping are derived. It is shown that control loop designs can be proposed for which the limit cycle frequency remains well below the first anti-symmetric unconstrained bending mode. The effect of the first twisting mode upon the pitch axis is examined by means of analog simulation. Although some disturbance of the main body occurs in all cases, the level may be reduced to a negligible one by a suitable choice of array drive loop parameters. It is suggested that careful design should enable any potential problems due to flexibility to be avoided for arrays of up to 4.5 kW. Author (ESA)

N76-31272*# Howard Univ., Washington, D.C. Dept. of Mechanical Engineering.
THE DYNAMICS OF SPIN STABILIZED SPACECRAFT WITH MOVABLE APPENDAGES, PART 2 Final Report
Peter M. Bainum May 1976 122 p refs
(Contract NsG-1181)
(NASA-CR-148815) Avail: NTIS HC $5.50 CSCL 22B
The dynamics and stability of a spin stabilized spacecraft with a hinged appendage system are treated analytically and numerically. The hinged system consists of a central hub with masses attached to (assumed) massless booms of fixed length whose orientation relative to the main part can change. The general three dimensional deployment dynamics of such a hinged system is considered without any restriction on the location of the hinge points. The equations of motion for the hinged system, with viscous damping at both hinge points, are linearized about the nominal equilibrium position where the booms are orthogonal to the nominal spin axis for the case of two dimensional and

three dimensional motion. Analytic stability criteria are obtained from the necessary condition on the sign of all the coefficients in the system characteristic equation. Author

N77-10142# European Space Agency, Paris (France).
DYNAMICS AND CONTROL OF NON-RIGID SPACECRAFT
Jul. 1976 376 p refs Proc. of the Symp. held at Frascati, Italy, 24-26 May 1976
(ESA-SP-117) Avail: NTIS HC A17/MF A01

Topics are presented in the field of flexible spacecraft configurations. Dynamic models are reviewed for spinning and non-spinning satellites. The attitude stability of flexible satellites is discussed. Applications of modern control theory are described. The design of control systems for these configurations is outlined. Test and flight verifications are reported, and some special dynamic problems are dealt with. ESA

N77-13912*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 3: NAVIGATION, GUIDANCE AND CONTROL PANEL Final Report
Aug. 1975 231 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73963) Avail: NTIS HC A11/MF A01 CSCL 17G

User technology requirements are identified in relation to needed technology advancement for future space missions in the areas of navigation, guidance, and control. Emphasis is placed on: reduction of mission support cost by 50% through autonomous operation, a ten-fold increase in mission output through improved pointing and control, and a hundred-fold increase in human productivity in space through large-scale teleoperator applications. J.M.S.

N77-23166# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (West Germany). Unternehmensbereich Raumfahrt.
COMPARATIVE SYSTEMS STUDY OF MAGNETICALLY SUSPENDED FLYWHEELS Final Report
Wolfgang Kleinau, Heinrich Weingarten, and Wolfgang Craemer Bonn Bundesmin. fuer Forsch. u. Technol. Dec. 1976 139 p refs In GERMAN; ENGLISH summary Report will also be announced as translation (ESA-TT-393)
(Contract BMFT-WRT-2074)
(BMFT-FB-W-76-20; MBB-URV-84) Avail: NTIS HC A07/MF A01; ZLDI, Munich DM 29,20

A comparative study is presented of flywheels with passive or active magnetic suspension for geostationary satellites with flexible appendages. The characteristic parameters of three available types were critically compared, and the possibility of their application in spacecraft studied. The application of magnetically suspended (fixed) flywheels was investigated for geostationary satellites with large flexible solar arrays of the OTS and TVBS type, by means of simulation. ESA

N77-27537# California Univ., Livermore. Lawrence Livermore Lab.
DESIGN AND BEHAVIOR OF RIBLESS SOLAR REFLECTORS Ph.D. Thesis
R. A. Hyde 21 Dec. 1976 297 p refs
(Contract W-7405-eng-48)
(UCRL-52191) Avail: NTIS HC A13/MF A01

A thin, shallow, orbiting solar reflector could retain its shape without either being mounted on a rigid truss or by being spun. In order to apply pointing torques to the reflector and to keep it in equilibrium as the gravity gradient forces and its attitude vary, it would be necessary to have some active control over out-of-plane surface forces. This control could be achieved by varying the reflector's shape, which would deviate from flatness by approximately less than 1 part in 100. Power from thin, low efficiency solar cells could be used to control the thermal stresses in the reflector, and thus its shape. Large, approximately 5 km, diameter reflectors could remain in tension while operating in stable Sun-polar orbits, for half of the time they reflected sunlight to the Earth, while the rest of the time would be devoted to attitude maneuvers to precess the orbital plane. Large scale use of these large, light, easy to deploy reflectors in the stable Sun-polar orbit might make it possible to augment the Earth's solar energy influx, and to control its climate. ERA

N77-29198# British Airports Authority, London (England). *Electronics and Space Systems Group.*
ATTITUDE CONTROL OF THREE-AXES STABILISED SPACECRAFT WITH FLEXIBLE APPENDAGES, VOLUME 1 Final Report
R. S. Harris, D. C. Todman, M. J. Hammond, and R. J. Annett Apr. 1977 390 p refs 2 Vol.
(Contract ESTEC-2312/74)
(ESA/SS-783-Vol-1; ESA-CR(P)-945-Vol-1) Avail: NTIS HC A17/MF A01

An investigation into the flexure-satellite attitude spacecraft interaction due to two uniform beam arrays on a three axis stabilized is reported. An extension is made to the parametric study to determine the applicability of a control scheme, designed neglecting flexure, to a reaction wheel stabilized flexible satellite. Charts are derived which show stability boundaries and attitude response magnitudes to a torque impulse. These provide a quantitative indication as to the extent of flexure interaction over a wide parameter range. The definition is extended of an observer-based control law designed, for the reaction wheel stabilized satellite, to reduce flexure interaction. The control scheme provides both attitude stabilization and active damping of the structural oscillations. It is optimized on the criteria of minimizing sensor noise effects whilst keeping the sensitivity to uncertainties in the system parameters low. The capability of providing active flexure damping, by optimizing the parameters of the DGMW gimbal servo loops is investigated. The servo loop structure was modified in order to improve the response to initial conditions which saturate the gimbal torquer. A similar analysis is performed for an SGMW system with both linear and stepper motor actuators and the flexure mode damping of the three systems is compared. The implementation of an in-orbit test program to identify the main structural parameters and to evaluate the control system performance of an SGMW and an FMW stabilized flexible satellite is investigated. The analysis and trade-off of sensor arrangements, excitation techniques, and data processing methods are presented. Author (ESA)

N77-29199# British Airports Authority, London (England). Electronics and Space Systems Group.
ATTITUDE CONTROL OF THREE-AXES STABILISED SPACECRAFT WITH FLEXIBLE APPENDAGES, VOLUME 2 Final Report
R. S. Harris, D. C. Todman, M. J. Hammond, and R. J. Annett Apr. 1977 240 p 2 Vol.
(Contract ESTEC-2312/74)
(ESS/SS-783-Vol-2; ESA-CR(P)-945-Vol-2) Avail: NTIS HC A11/MF A01

Computation, details, computer listings, graphs, and tables are presented for the investigation into flexure-satellite attitude interaction due to two uniform beam arrays on a three axis stabilized spacecraft. ESA

N77-33245# European Space Agency, Paris (France).
COMPARATIVE SYSTEMS STUDY OF MAGNETICALLY SUSPENDED FLYWHEELS
Wolfgang Kleinau, Heinrich Weingarten, and Wolfgang Craemer Jul. 1977 139 p refs Transl. into ENGLISH of 'Vergleichende Systemstudie fuer Magnetisch Gelagerte Schwungraeder', MBB G.m.b.H., Munich Report BMFT-FB-W-76-20; MBB-URV-84, Dec. 1976 Original report in GERMAN previously announced as N77-23166 Original GERMAN report available from ZLDI, Munich DM 29,20
(ESA-TT-393; BMFT-FB-W-76-20; MBB-URV-84) Avail: NTIS HC A07/MF A01

A comparative study is presented of flywheels with passive or active magnetic suspension for geostationary satellites with flexible appendages. The characteristic parameters of three available types were critically compared, and the possibility of their application in spacecraft studied. The application of magnetically suspended (fixed) flywheels was investigated for geostationary satellites with large flexible solar arrays of the OTS and TVBS type, by means of simulation. ESA

N78-20206# British Aircraft Corp. (Operating) Ltd., Bristol (England).
A PARAMETRIC STUDY INTO STRUCTURAL FLEXIBILITY. SATELLITE ATTITUDE INTERACTION FOR A THREE-AXIS STABILISED SATELLITE
R. S. Harris *In* ESA Attitude and Orbit Control Systems Nov. 1977 p 89-101 refs
(Contract ESTEC-2312/74-AK)
Avail: NTIS HC A24/MF A01

The flexure-satellite attitude interaction due to two uniform beam appendages on a three axis stabilized spacecraft are examined. Three basic actuator devices are considered - reaction wheels, a double gimballed momentum wheel (DGMW) using linear gimbal servo loops and a single gimballed momentum wheel (SGMW), gimballed about the roll axis, with either a linear or a stepper motor gimbal drive. Results of parametric studies are presented, demonstrating how the interaction is a function of the actuator type, the control law, the satellite size, the sensor characteristics and the appendage modal gains, frequencies and structural damping, all of which have a heavy impact on the system stability. Author (ESA)

N78-23139*# Howard Univ., Washington, D. C. Dept. of Mechanical Engineering.
THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES. PART A: DISCRETE MODEL AND MODAL CONTROL Final Report
Peter M. Bainum and R. Sellappan May 1978 59 p refs
(Grant NsG-1414)
(NASA-CR-156975) Avail: NTIS HC A04/MF A01 CSCL 22B

Attitude control techniques for the pointing and stabilization of very large, inherently flexible spacecraft systems were investigated. The attitude dynamics and control of a long, homogeneous flexible beam whose center of mass is assumed to follow a circular orbit was analyzed. First order effects of gravity gradient were included. A mathematical model which describes the system rotations and deflections within the orbital plane was developed by treating the beam as a number of discretized mass particles connected by massless, elastic structural elements. The uncontrolled dynamics of the system are simulated and, in addition, the effects of the control devices were considered. The concept of distributed modal control, which provides a means for controlling a system mode independently of all other modes, was examined. The effect of varying the number of modes in the model as well as the number and location of the control devices were also considered. Author

N78-26162 Stanford Univ., Calif.
A FINE POINTING CONTROL FOR A LARGE SPINNING SPACECRAFT IN EARTH ORBIT Ph.D. Thesis
Horst C. Salzwedel 1978 94 p
Avail: Univ. Microfilms Order No. 78-08838

A large spinning spacecraft in earth orbit includes a rigidly-mounted telescope, parallel to the spacecraft's intended spin-axis. The three principal moments-of-inertia are unequal. Electric thrustors are used to overcome the gravity-gradient torque components. Uncertainty of the spacecraft's inertia tensor, including misalignment of the telescope axis from the actual principal direction, as well as magnetic, solar pressure and aerodynamic forces, produce disturbing torques which are constant or vary sinusoidally during a spin-rotation. The constant torques and the coefficients of the sinusoidal torques are modeled as first order Markov processes and, consequently, increase the dimension of the dynamical state. Dissert. Abstr.

05
ELECTRONICS

Includes techniques for power and data distribution.

A72-36249 # **Wave propagation in glass-fiber light waveguides (Zur Wellenausbreitung in Glasfaser-Lichtwellenleitern).** O. Krumpholz. Karlsruhe, Universität, Fakultät für Elektrotechnik, Dr.-Ing. Dissertation, 1971. 122 p. 37 refs. In German.

Theoretical calculation and experimental measurement of the power distribution of the HE (sub 11) wave in double glass fibers over the fiber cross section and in the far field of a plane fiber end surface. A comparison of the two results shows that the experimentally determined diameter of the transmitted light beam in the fiber is significantly greater than the calculated value for an ideal fiber. In the case of the radiation lobes the situation is reversed; the measured half-width is about 30% less than the calculated value. It is shown that the reason for this lies in the existence of a nonabrupt refractive index transition region between the core and the mantle glass which results from mutual diffusion of the two glasses during the fabrication of the fiber. By heating the fibers to the softening point this diffusion can be accelerated, thus leading to a further narrowing of the radiation lobes. A.B.K.

A73-15389 * **Advanced aerospace power distribution and control techniques.** T. D. Jeffcoat and F. E. Eastman (NASA, Manned Spacecraft Center, Houston, Tex.). In: NTC '72; National Telecommunications Conference, Houston, Tex., December 4-6, 1972, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1972, p. 8E-1 to 8E-8.

Conventional power distribution and control systems as employed in Apollo space vehicles and modern aircraft are reviewed, and arguments are presented in favor of applying some new techniques in the design of electric power systems for future manned spacecraft. Current Space Shuttle studies show that each pound of weight for supporting subsystems causes overall vehicle weight at launch to increase by 34.5 lb, with proportional cost penalty. The presently available technology for an improved automatic or semi-automatic distribution and control system should be implemented. A systems approach based on the most current technology is discussed along with a unique method of system development, testing, and evaluation. T.M.

A73-26008 # **Integration of large electrical space power systems.** J. H. Hayden (General Electric Co., Philadelphia, Pa.) and A. Kirpich. In: Energy 70; Proceedings of the Fifth Intersociety Energy Conversion Engineering Conference, Las Vegas, Nev., September 21-25, 1970. Volume 2. Hinsdale, Ill., American Nuclear Society, 1972, p. 12-10 to 12-14.

A sequence of steps leading to the selection of the basic characteristics of distributed power is considered. The suggested power system characteristics are discussed, giving attention to the distribution of high voltage dc power, the distribution of ac power, the provision of emergency power as unconditioned battery output, the conditioning of power, the disposal of excess power, and the service characteristics. Questions of power system implementation are also investigated. Power from the solar array is transferred directly to the loads. Power to and from the battery is processed by the charge and boost regulators, respectively. A shunt regulator dissipates any excess power from the solar array, once load and charging demands are satisfied. G.R.

A73-26010 # **A 25 kW solar array/battery design for an earth orbiting space station.** R. D. Stevenson (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). In: Energy 70; Proceedings of the Fifth Intersociety Energy Conversion Engineering Conference, Las Vegas, Nev., September 21-25, 1970. Volume 2. Hinsdale, Ill., American Nuclear Society, 1972, p. 12-18 to 12-25. 15 refs.

Future manned space stations will require average power levels of 25 kW, and higher, with mission durations of up to 10 years. A recently completed study of a 12-man space station resulted in the design of a 25-kW solar array/battery electrical power system as one of the candidate systems. The study resulted in the design and integration of a large area solar array (7,500 sq ft) and large capacity batteries (100 amp-hr or greater). The design was based upon detailed analyses and tradeoffs to obtain an optimum integrated solar array and battery design. The design of the 25 kW solar array/battery system included a comparison of several rigid and rollout (flexible) solar cell panel designs, an optimization of the number and size of the panels, and a tradeoff on number of degrees of freedom for the arrays. (Author)

A76-31510 * # **Solid state remote power controllers for 120 VDC power systems.** G. R. Sundberg (NASA, Lewis Research Center, Cleveland, Ohio) and D. E. Baker (Westinghouse Electric Corp., Aerospace Electrical Div., Lima, Ohio). *Oklahoma State University, Annual National Relay Conference, 24th, Stillwater, Okla., Apr. 27, 28, 1976, Paper.* 18 p. 7 refs.

Remote Power controllers (RPCs) are devices that combine in one unit the capability to perform all the needed functions of load switching and provide total system protection of equipment and wires. The unique developments of solid-state RPCs for 120 Vdc power distribution systems are reviewed. The discussion covers design guidelines, power switch design concepts, and performance effectiveness. An NPN transistor is used as the the basic switch element. Since the ultimate goal of the 120 Vdc RPC program is to demonstrate technology readiness, the final phase is directed to the design, fabrication, and testing of multi-chip hybrid prototypes in hermetically sealed packages. RPCs have potential application in spacecraft and aircraft electrical systems, in transportation systems, and various industrial applications. The upper voltage limitation on the RPC design is related to the capability and availability of suitable high-voltage power transistors. The merits of solid-state RPCs are noted. S.D.

A76-41890 **Multimode optical fibers - Steady state mode exciter.** M. Ikeda, A. Sugimura, and T. Ikegami (Nippon Telegraph and Telephone Public Corp., Electrical Communication Laboratories, Tokai, Ibaraki, Japan). *Applied Optics,* vol. 15, Sept. 1976, p. 2116-2120. 18 refs.

The steady state mode power distribution of the multimode graded index fiber was measured. A simple and effective steady state mode exciter was fabricated by an etching technique. Its insertion loss was 0.5 dB for an injection laser. Deviation in transmission characteristics of multimode graded index fibers can be avoided by using the steady state mode exciter. (Author)

A76-43632 # **Losses in a statistically irregular focusing fiber (Poteri v statisticheski nereguliarnom fokusiruiushchem volokne).** R. F. Matveev and A. D. Shatrov. *Radiotekhnika i Elektronika,* vol. 21, May 1976, p. 989-996. In Russian.

The paper uses a two-dimensional model to examine the transmission of light in an irregular multi-wave focusing fiber with random variations of cross section. Rigorous methods are used to solve the system of coupled-wave equations, and expressions are obtained for parameters of the field (attenuation and power distribution with respect to modes) in an extended optical waveguide. The asymptotic nature of these parameters is studied in the case of a large critical mode number, and the losses of even and odd waves are examined as functions of critical mode number. B.J.

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A77-16826 **Steady-state losses of optical fibers and fiber resonators.** D. Marcuse (Bell Telephone Laboratories, Inc., Murray Hill, N.J.). *Bell System Technical Journal,* vol. 55, Dec. 1976, p. 1445-1462. 10 refs.

The losses and steady-state power distribution of an optical fiber with random nearest-neighbor mode coupling are compared with those of a cavity formed from a section of the same fiber. By obtaining approximate and exact numerical solutions to the eigenvalue equations of these systems for six modes, it is found that the fiber losses increase with an increase in the loss of the highest-order mode, but the cavity losses decrease as the loss of the highest-order mode approaches infinity. The analysis indicates that the losses of the solution with the lowest eigenvalue are higher than the loss of the lowest-order (uncoupled) mode and that two modes are coupled only if their propagation constants satisfy a certain relation. It is concluded that the cavity losses are the average of the mode losses of all those modes whose (uncoupled) loss values are less than the coupling strength of neighboring modes and that modes whose losses exceed the coupling strength do not contribute appreciably to the cavity loss. F.G.M.

DATA SUMMARY: Diverse data are presented; variables include cavity mode loss values, lowest fiber loss, steady-state fiber loss, fiber eigenvalues, cavity eigenvalues, normalized power, mode number distribution, lowest fiber cavity loss mode, coupling coefficients, coupled modes; seven figures and two tables include numeric data.

A77-51390 **Past experience - Basis for future advanced power systems for communications satellites.** B. Gohrbandt and J. Rath (Telefunken AG, Wedel, West Germany). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-22.* 18 p. 5 refs.

Multi-kilowatt solar power systems for advanced communications satellites are discussed. Solar generators with foldable or roll-out blankets and power outputs of 20 kW or greater are described; the power/mass ratios for various configurations of the flexible solar generators are compared. Problems associated with solar arrays, such as high initial power outputs and subsequent degradation, the need for advanced nickel-cadmium and nickel-hydrogen storage batteries, and charging of the solar generators by the plasma environment, are also mentioned. Modular design of booms, actuators and solar array blankets, as well as development of pulse-width-modulation shunt regulators and a.c. power distribution systems for satellite applications are considered. J.M.B.

A77-51441 **A highly reliable data handling and control system of a spaceborne power unit.** V. V. Bugrovskii, Iu. V. Kovachich, B. N. Petrov, and A. A. Sheviakov (Institute of Control Sciences, Moscow, USSR). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-138.* 15 p.

The paper discusses the operation and reliability characteristics of data handling and control systems, compatable with onboard computers, for deep-space spacecraft power units. The data handling and control system should incorporate two levels of controllers. The lower level consists of primary controllers which maintain the operating mode; the reliability of these controllers is augmented by self control and heat adaptation. The upper level is the onboard computer, its reliability augmented by the use of multiprocessor structures and algorithmic self repair. B.J.

A78-32751 * # **Spacecraft-generated plasma interaction with high voltage solar array.** D. E. Parks and I. Katz (Systems, Science and Software, La Jolla, Calif.). *American Institute of Aeronautics and Astronautics and Deutsche Gesellschaft für Luft- und Raumfahrt, International Electric Propulsion Conference, 13th, San Diego, Calif., Apr. 25-27, 1978, AIAA Paper 78-673.* 9 p. 11 refs. Contract No. NAS3-20119.

Calculations are made of the effect of interactions of spacecraft-generated plasmas and high voltage solar array components on an advanced Solar Electric Propulsion system. The plasma consists of mercury ions and electrons resulting from the operation of ion thrusters and associated hollow cathode neutralizers. Because large areas of the solar array are at high potential and not completely insulated from the surrounding plasma, the array can, under some conditions, collect excessive electron currents. Results are given for the parasitic currents collected by the solar arrays and means for reducing these currents are considered. (Author)

A78-51988 # **The installation of systems on large space structures.** A. J. Stefan (Rockwell International Corp., Space Systems Group., Downey, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1661.* 6 p.

This paper addresses the issues involved in installing electrical lines and subsystem units. The installation issues are illustrated by utilizing a mid-1980's communication satellite having a tri-beam structure fabricated in space with a beam builder. Pre-punched holes are required in the posts of the in-space fabricated beams for installing the electrical line harness. Special construction equipment to accommodate the assembly of adapters for attaching subsystem modules is indicated. A special electrical connector adopted for both remote manipulator and EVA operations is described. The issue of subsystem locations in relationship to the orbit transfer thrust vector is discussed. (Author)

N73-31988* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
POWERPLEXER Patent
Joseph M. Woods, inventor (to NASA) Issued 28 Aug. 1973 10 p Filed 31 May 1972 Supersedes N72-27063 (10 - 18, p 2380)
(NASA-Case-MSC-12396-1; US-Patent-3,755,686; US-Patent-Appl-SN-258331; US-Patent-Class-307-18; US-Patent-Class-307-28; US-Patent-Class-307-29; US-Patent-Class-307-38) Avail: US Patent Office CSCL 10A

An electrical power distribution system is described for use in providing different dc voltage levels. A circuit is supplied with DC voltage levels and commutates pulses for timed intervals onto a pair of distribution wires. The circuit is driven by a command generator which places pulses on the wires in a timed sequence. The pair of wires extend to voltage strippers connected to the various loads. The voltage strippers each respond to the pulse dc levels on the pair of wires and form different output voltages communicated to each load.
Official Gazette of the U.S. Patent Office

N74-19129 Martin Marietta Corp., Baltimore, Md.
HIGHLIGHTS OF THE LONG-LIFE ASSURANCE STUDY
R. W. Burrows *In* LMSC Proc. of Aerospace Testing Seminar 1 Jun. 1973 22 p

Procedures for conducting long-life assurance tests for achieving hardware with a service life of ten years are discussed. The subjects studied for long life assurance are: (1) integrated circuits, (2) derating, (3) electronic packaging, (4) tape recorders, (5) electric motors, (6) valves, and regulators, and (7) temperature cycling. Specific procedures to be followed in testing various components are outlined. Author

N74-28535*# TRW Systems Group, Redondo Beach, Calif.
MULTI-kw dc POWER DISTRIBUTION SYSTEM STUDY PROGRAM
E. A. Berkery and A. Krausz Apr. 1974 161 p
(Contract NAS8-28726)
(NASA-CR-120241) Avail: NTIS HC $11.25 CSCL 10B

The first phase of the Multi-kw dc Power Distribution Technology Program is reported and involves the test and evaluation of a technology breadboard in a specifically designed test facility according to design concepts developed in a previous study on space vehicle electrical power processing, distribution, and control. The static and dynamic performance, fault isolation, reliability, electromagnetic interference characterisitics, and operability factors of high distribution systems were studied in order to gain a technology base for the use of high voltage dc systems in future aerospace vehicles. Detailed technical descriptions are presented and include data for the following: (1) dynamic interactions due to operation of solid state and electromechanical switchgear; (2) multiplexed and computer controlled supervision and checkout methods; (3) pulse width modulator design; and (4) cable design factors. A.A.D.

N75-27263*# TRW Systems Group, Redondo Beach, Calif.
RESEARCH STUDY ON MULTI-KW-DC DISTRIBUTION SYSTEM Final Report
E. A. Berkery and A. Krausz May 1975 126 p
(Contract NAS8-30778)
(NASA-CR-143896) Avail: NTIS HC $5.75 CSCL 09C

A detailed definition of the HVDC test facility and the equipment required to implement the test program are provided. The basic elements of the test facility are illustrated, and consist of: the power source, conventional and digital supervision and control equipment, power distribution harness and simulated loads. The regulated dc power supplies provide steady-state power up to 36 KW at 120 VDC. Power for simulated line faults will be obtained from two banks of 90 ampere-hour lead-acid batteries. The relative merits of conventional and multiplexed power control will be demonstrated by the Supervision and Monitor Unit (SMU) and the Automatically Controlled Electrical Systems (ACES) hardware. The distribution harness is supported by a metal duct which is bonded to all component structures and functions as the system ground plane. The load banks contain passive resistance and reactance loads, solid state power controllers and active pulse width modulated loads. The HVDC test facility is designed to simulate a power distribution system for large aerospace vehicles. Author

N76-13204*# TRW Systems Group, Redondo Beach, Calif.
RESEARCH STUDY ON MULTI-KW DC DISTRIBUTION SYSTEM Final Report
E. A. Berkery Nov. 1975 73 p refs
(Contract NAS8-30778)
(NASA-CR-144091) Avail: NTIS HC $4.50 CSCL 09C

Power distribution system noise and transient stress on switchgear in large space vehicle power systems were investigated in terms of the effect of flight designs of long power distribution cables on load interface EMI requirements. A fifty meter cable pair was simulated to study interactions between the cable, load, and power source terminations. Power system noise characteristics were evaluated based on current spacecraft data, interface hardware filter designs, and power cable parameters. Parametric approaches were defined for evaluating switching transients at various distribution voltage levels. It is concluded that the state-of-the-art semiconductor switches represent a viable approach toward the implementation of power system design with distribution voltages of 120 VDC or less. The interface definition and design for the bus control unit was updated to be consistent with the established requirements. Author

N76-22304# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).
ELECTROMAGNETIC COMPATIBILITY OF AC POWER DISTRIBUTION Final Report
H. Hufnagel, F. Reisinger, M. Wagner, and G. Mounts Jun. 1975 81 p refs
(Contract ESTEC-1781/72-AA)
(ESA-CR(P)-792) Avail: NTIS HC $5.00

The susceptibility of normal spacecraft users and subsystems to electromagnetic fields observed in conjunction with ac power distribution was investigated. Essential ac-source parameters were frequency, voltage, current and waveshape. The susceptibility of components was determined on the basis of unit design experience and compared with tolerable suppression efforts on the distribution level. Practical measurements were then used to establish the degree of ac interference. The results were applied to the Helios engineering model. It is demonstrated that the application of square-wave ac power to conventional scientific or applications satellites should pose no problems essentially different from those encountered with an equivalent dc power system. Author (ESA)

N77-13910*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 1: DATA PROCESSING AND TRANSFER PANEL Final Report
Aug. 1975 206 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73961) Avail: NTIS HC A10/MF A01 CSCL 05K

The data processing and transfer technology areas that need to be developed and that could benefit from space flight experiments are identified. Factors considered include: user requirements, concepts in 'Outlook for Space', and cost reduction. Major program thrusts formulated are an increase in end-to-end information handling and a reduction in life cycle costs. J.M.S.

N77-13911*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 2: SENSING AND DATA ACQUISITIONS PANEL Final Report
Aug. 1975 287 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73962) Avail: NTIS HC A13/MF A01 CSCL 05K

Advanced technology requirements associated with sensing and data acquisition systems were assessed for future space missions. Sensing and data acquisition system payloads which would benefit from the use of the space shuttle in demonstrating technology readiness are identified. Topics covered include: atmospheric sensing payloads, earth resources sensing payloads, microwave systems sensing payloads, technology development/evaluation payloads, and astronomy/planetary payloads. J.M.S.

N77-13913*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 4: POWER TECHNOLOGY PANEL Final Report
Aug. 1975 195 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73964) Avail: NTIS HC A09/MF A01 CSCL 21H

Technology requirements in the areas of energy sources and conversion, power processing, distribution, conversion, and transmission, and energy storage are identified for space shuttle payloads. It is concluded that the power system technology currently available is adequate to accomplish all missions in the 1973 Mission Model, but that further development is needed to support space opportunities of the future as identified by users. Space experiments are proposed in the following areas: power generation in space, advanced photovoltaic energy converters, solar and nuclear thermoelectric technology, nickel-cadmium batteries, flywheels (mechanical storage), satellite-to-ground transmission and reconversion systems, and regenerative fuel cells. J.M.S.

N77-23317# AEG-Telefunken, Wedel (West Germany).
POWER SUPPLY SYSTEMS IN THE MULTI-kW POWER RANGE
B. Gohrbandt and J. Rath *In* ESA Satellite Broadcasting Feb. 1977 p 163-168
Avail: NTIS HC A09/MF A01

Flexible roll-out solar arrays and ac power distribution techniques in the multi-kW-range as they are currently under development are discussed. The state-of-the-art of these developments is explained. Author (ESA)

N77-27306*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

THE SOLID STATE REMOTE POWER CONTROLLER: ITS STATUS, USE AND PERSPECTIVE

G. R. Sundberg and W. W. Billings (Westinghouse Electric Corp., Lima, Ohio) 1977 13 p refs Presented at 1977 Power Elec. Specialists Conf., Palo Alto, Calif., 14-16 Jun. 1977, sponsored by IEEE

(NASA-TM-73695; E-9231) Avail: NTIS HC A02/MF A01 CSCL 09C

Solid state remote power controllers (RPC's) are now available to control and protect all types of loads in both ac and dc power distribution systems. RPC's possess many outstanding qualities that make them attractive for most system applications. A review is given of the present state-of-the-art and applications for solid state RPC's for both aerospace and terrestrial systems. Author

N77-33422# Jaros, Baum and Bolles, Los Angeles, Calif.

FEASIBILITY STUDY OF A 400 Hz, 4160 VOLT 3-PHASE ELECTRICAL POWER DISTRIBUTION SYSTEM

25 Feb. 1977 288 p refs

(Contract N00025-76-C-0011)

(AD-A042042) Avail: NTIS HC A13/MF A01 CSCL 10/2

This study has determined the feasibility of using a centralized 400 Hz power system. The benefits of a 4160 Volt 3-phase power distribution system are the economic advantages over individual generator units and the higher degree of reliability offered by the high frequency system. Author (GRA)

N78-31353*# TRW Defense and Space Systems Group, Redondo Beach, Calif.

MULTI-KW dc DISTRIBUTION SYSTEM TECHNOLOGY RESEARCH STUDY Final Report

S. G. Dawson Jul. 1978 119 p refs

(Contract NAS8-31719)

(NASA-CR-150789; Rept-29817-6001-TU-00) Avail: NTIS HC A06/MF A01 CSCL 09C

The Multi-KW DC Distribution System Technology Research Study is the third phase of the NASA/MSFC study program. The purpose of this contract was to complete the design of the integrated technology test facility, provide test planning, support test operations and evaluate test results. The subjet of this study is a continuation of this contract. The purpose of this continuation is to study and analyze high voltage system safety, to determine optimum voltage levels versus power, to identify power distribution system components which require development for higher voltage systems and finally to determine what modifications must be made to the Power Distribution System Simulator (PDSS) to demonstrate 300 Vdc distribution capability. G.Y.

06
ADVANCED MATERIALS

Includes matrix composites, polyimide films and thermal control coatings, and space environmental effects on these materials.

A70-27266 * **Thermal coated extendible boom for space environment.** M. Lauriente (Westinghouse Defense and Space Center, Baltimore, Md.) and C. Staugitis (NASA, Goddard Space Flight Center, Greenbelt, Md.). *(American Vacuum Society, National Symposium, 16th, Seattle, Wash., Oct. 28-31, 1969.) Journal of Vacuum Science and Technology,* vol. 7, Jan.-Feb. 1970, p. 248-250. 5 refs. NASA-supported research.

Long extendable and retractable tubular booms for space applications require a unique combination of mechanical and optical properties. The basic structure, BeCu alloy strip, is metallurgically treated to spring into a tubular configuration when deployed. To minimize thermal bending from solar radiation, a pattern of windows or perforations, in combination with selected thermal coatings for the inside and outside surfaces, was used. The combination developed was vacuum-evaporated aluminum on the outside, for an essentially specular reflection, and a chemically converted black copper oxide on the inside, for a diffuse reflection. An interlocking seam is used to reinforce the structure in the extended position. Of particular interest is the technique for metallizing such long strips in a vacuum to meet the stringent optical requirements. With an electron beam source and aluminum wire feeder, the process was made continuous. A second electron gun in the line outgassed the strip. (Author)

A72-28158 * # **Composite material characterization for large space structures.** C. E. MacNeill (Fairchild Industries, Inc., Fairchild Space and Electronics Div., Germantown, Md.). *Society of Aerospace Material and Process Engineers, National Symposium and Exhibition, Los Angeles, Calif., April 11-13, 1972, Paper.* 24 p. NASA-supported research.

A program phase to characterize advanced composite materials for a large reflector support truss on the ATS F & G spacecraft is described. The selection of a Hercules Incorporated, 2002M graphite fiber reinforced epoxy material was based on criteria of spacecraft system requirements and the potential of this material to meet these requirements. The objective of this phase was to develop materials data required for development, design, fabrication, test, and flight of a graphite-fiber, reinforced-plastic spacecraft structure. Testing within a temperature range from -300 F to +200 F covered the generation of data for physical, mechanical, thermophysical, and space environmental properties for the selected material. Additional testing covered adhesive bonded joint materials within the temperature ranges of the spacecraft environment. Descriptions of the spacecraft, reflector support truss, design, requirements, materials, tests, and developed data are presented. (Author)

A73-34811 # **The potential application of carbon fibres to spacecraft.** C. H. Martin (Hawker Siddeley Dynamics, Ltd., Stevenage, Herts., England). *Plastics Institute, Conference on Reinforced Plastics in Aerospace Applications, London, England, Apr. 5, 6, 1973, Paper.* 32 p.

The basic attractions of carbon fiber reinforced plastics (CFRP) to spacecraft are, besides its high specific strength, its high stiffness modulus, and its thermal stability. It is these characteristics which will bring the material into limited use on spacecraft when the basic missing properties are established, provided they are found to be satisfactory. Problem areas likely to be experienced are discussed. To assess the application of CFRP to spacecraft it is necessary to understand the harsh environment to which the material is exposed, hence this aspect is examined extensively. Properties required for spacecraft materials, and typical spacecraft applications are discussed. F.R.L.

A73-34812 # **An appreciation of the design of carbon fibre rigid solar panels for spacecraft.** W. Jonda, K. Schneider, H. Schweig, and W. Schafer (Messerschmitt-Bölkow-Blohm GmbH, Munich, West Germany). *Plastics Institute, Conference on Reinforced Plastics in Aerospace Applications, London, England, Apr. 5, 6, 1973, Paper.* 20 p. Research sponsored by the European Space Research Organization.

Rigid solar panels in the power range from 0.5 to about 1 kW can be built advantageously using materials with low density and high modulus of elasticity, especially if low weight and high panel stiffness is a strong requirement. Solar panels consisting of reinforced carbon fiber plastic face skins and Al-honeycomb as structure promises a very lightweight and stiff design. The most essential design parameters for lightweight rigid solar panels are given, and some results of an optimization study are shown. Design verification tests with small test samples and related test data are given. The overall design of a solar array consisting of three interhinged panels is shown. Some comments are made concerning the manufacturing and testing of the panels. Further weight reduction (by the same panel stiffness) seems possible using a full reinforced carbon fiber plastics concept. (Author)

A73-45143 **Improved mechanical properties of composites reinforced with neutron-irradiated carbon fibers.** E. L. McKague, Jr., R. E. Bullock, and J. W. Head (General Dynamics Corp., Convair Aerospace Div., Fort Worth, Tex.). *Journal of Composite Materials,* vol. 7, July 1973, p. 288-297. 18 refs.

A74-24881 # **Curved, tapered, circular cross section graphite/epoxy antenna ribs.** R. E. Randolph (Hercules, Inc., Magna, Utah) and M. R. Sullivan (Harris-Intertype Corp., Radiation Div., Melbourne, Fla.). In: The wide world of reinforced plastics; Proceedings of the Twenty-ninth Annual Conference, Washington, D.C., February 5-8, 1974. New York, Society of the Plastics Industry, Inc., 1974, p. 18-E,1 to 18-E,8.

The objective of the study described in this paper was to demonstrate the potential advantages of using graphite/epoxy composite in rib-dominated deployable antenna structures. The design, fabrication, and load testing of a graphite/epoxy rib segment for highly accurate deployable antennas are described. The ribs are generally stability/critical (both mechanical and thermal) and form the basic structure of a Radiation Incorporated antenna design. The graphite/epoxy ribs and the current aluminum ribs are compared. (Author)

A74-26644 **Mechanical of a boron-reinforced composite material radiation-induced of its epoxy matrix.** R. E. Bullock (General Dynamics Corp., Convair Aerospace Div., Fort Worth, Tex.). *Journal of Composite Materials,* vol. 8, Jan. 1974, p. 97-101. 10 refs.

A75-21365 # **Investigation of the physical-mechanical properties and supramolecular structure of epoxy resins exposed to UV radiation under atmospheric conditions (Issledovanie fiziko-mekhanicheskikh svoistv i nadmolekuliarnoi struktury epoksidnykh smol pri vozdeistvii UF-oblucheniia i atmosfernykh uslovii).** L. S. Koretskaia, T. I. Tkachenko, V. F. Stepanov, V. E. Bakhareva, and L. V. Petrova (Akademiia Nauk Belorusskoi SSR, Institut Mekhaniki Metallopolimernykh Sistem, Gomel, Ukrainian SSR). *Fiziko-Khimicheskaia Mekhanika Materialov,* vol. 10, no. 6, 1974, p. 100-103. 6 refs. In Russian.

A75-24190 # **Behaviour of carbon fibre composites under simulated space environment.** H. von Bassewitz (Messerschmitt-Bölkow-Blohm GmbH, Munich, West Germany). In: Evaluation of the effect of the space environment on materials; International Conference, Toulouse, France, June 17-21, 1974, Proceedings. Paris, Centre National d'Etudes Spatiales, 1974, p. 525-537.

An ultralightweight solar array for telecommunications spacecraft in the power range of 5-10 kW is being developed. The array structure consists of carbon-fiber-reinforced plastic (CFRP), a material whose behavior under space conditions has been investigated in detail. This compound material has been accepted by ESTEC for space application and will be used in the OTS (Orbital Test Satellite) solar array. Samples of CFRP have been exposed to different radiation modes (UV, electrons, protons) and subjected to thermal shocks to discover possible degradations of mechanical properties like stiffness and strength. Conditions of a 10-year lifetime in a synchronous orbit have been simulated where possible. The simulated space environment caused a property change in the range of 13% improvement to 28% degradation. Where accelerated tests with higher radiation intensities (up to a factor of 10) have been applied, the measured degradation is more critical than it will be under orbital conditions. (Author)

A76-16569 **Reliability of composite zero-expansion structures for use in orbital environment.** L. D. Berman (TRW Systems, Redondo Beach, Calif.). In: Composite reliability; Proceedings of the Symposium, Las Vegas, Nev., April 15, 16, 1974. Philadelphia, Pa., American Society for Testing and Materials, 1975, p. 288-297.

The reliability of composite sandwich structures during and after exposure to extensive thermal cycling in vacuum is studied. The effect of cycling on mechanical, physical, and thermal properties is evaluated. A high relative humidity storage environment is examined for its effect on dimensional and contour measurement. It is shown that thermally induced stresses in composite structures result in deterioration of the microstructure without a marked degradation of the mechanical properties. Thermal expansion and flatwise tensile characteristics are affected, but only within a range acceptable for most applications. S.D.

A77-39510 * # **Effects of space radiation on thin polymers and nonmetallics.** L. B. Fogdall, S. S. Cannaday (Boeing Co., Seattle, Wash.), and W. S. Slemp (NASA, Langley Research Center, Hampton, Va.). *American Institute of Aeronautics and Astronautics, Thermophysics Conference, 12th, Albuquerque, N. Mex., June 27-29, 1977, Paper 77-741.* 7 p. 14 refs. Research supported by the Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt and Gesellschaft für Weltraumforschung; Contracts No. NAS1-13530; No. NAS1-14328.

Advanced materials for various spacecraft systems in the 1980s and 1990s have been evaluated in situ after exposure to space radiation. Emphasis has been placed on materials having little or no previous base of environmental effects data. Applications ranging from earth orbit to near-sun have been covered. High temperature polymers and composites have been included. Silica composites may offer improved reflectance stability compared with metallized fluorocarbons. Directional reflectance properties of FEP are a function of charged particle energy and flux as well as total exposure fluence and material characteristics. Data obtained on polyimides and polyxylylenes under high temperature radiation exposure conditions will be discussed in the context of near-sun solar sailing and rendezvousing. (Author)

A77-40199 # **Influence of ionizing radiation on the mechanical properties of fiberglass strengthened polyethylene (Vliianie ioniziruiushchego izlucheniia na mekhanicheskie svoistva polietilena, napolnennogo steklovoloknom).** V. I. Grigor'ev, V. P. Gordienko, R. E. Il'enko, and A. N. Tynnyi (Akademiia Nauk Ukrainskoi SSR, Fiziko-Mekhanicheskii Institut, Lvov; Institut Fizicheskoi Khimii, Kiev, Ukrainian SSR). *Fiziko-Khimicheskaia Mekhanika Materialov,* vol. 13, Mar.-Apr. 1977, p. 100-104. 9 refs. In Russian.

In the specimens tested, the adhesive bonds between fibers and matrix were strengthened by exposure to radiation. The specimens were prepared from low-density polyethylene strengthened with 5 to 6 mm long, 8 to 10 micron diam fibers in contents of 0, 1.7, 4.2, 5.6, 8.0, and 12.0 vol %. The absorbed radiation doses equaled 0, 10, 20, 50, and 100 Mrad. The mechanical properties were tested at -196, +20, 110, and 140 C. The feasibility of controlling the mechanical properties by varying the fiber content is demonstrated. V.P.

A77-44414 **Graphite epoxy test program for space telescope.** S. Baber and D. T. Jones (Boeing Aerospace Co., Seattle, Wash.). In: Aerospace Testing Seminar, 3rd, Los Angeles, Calif., September 16, 17, 1976, Proceedings. Mt. Prospect, Ill., Institute of Environmental Sciences, 1977, p. 101-106; Discussion, p. 107.

A graphite epoxy truss was selected for the optical support system of the Space Telescope since the material can be designed to provide a nearly zero coefficient of thermal expansion. Attention is given to design requirements of truss, and material tests, structural element tests, assembly static and dynamic tests, and assembly thermal vacuum tests are considered. B.J.

A78-11519 **Electrons in the solar corona. II - Coronal streamers from K-coronameter measurements.** A. Dollfus and M.-J. Martres (Paris, Observatoire, Meudon, Hauts-de-Seine, France). *Solar Physics,* vol. 53, Aug. 1977, p. 449-464. 24 refs. Research supported by the Centre National de la Recherche Scientifique.

The coronal electron survey carried out with the aid of the solar photoelectric polarimeters at Meudon and Pic-du-Midi Observatories have revealed some persistent coronal features. This paper discusses a special kind of fan-shaped feature called 'lame coronale', or coronal blade, above quiescent prominences. For one streamer, calculations give an electron density at 60,000 km above the surface of 150 million per cu cm, a total number of 14 times 10 to the 39th power electrons, a hydrostatic temperature of 1.7 million K, and a total thermal energy of 1 times 10 to the 31st power ergs. When a new emerging active center disturbed the area, the 'en lame' feature was replaced by a nonelongated streamer, with electron densities three times higher than in the 'en lame' feature but with only one-third the total number of electrons. P.T.H.

A78-17251 **Designing with fibre reinforced materials; Proceedings of the Conference, London, England, September 27, 28, 1977.** Conference sponsored by the Institution of Mechanical Engineers. London, Mechanical Engineering Publications, Ltd.; Institution of Mechanical Engineers (I Mech E Conference Publications, No. 1977-9), 1977. 82 p. $27.30.

The use of fiber-reinforced composites for commercial aircraft components, helicopter rotors, the hinge for a deployable spacecraft boom, sandwich panels, and skeletal frame structures is discussed. Topics of the papers include the use of bolted connections to join carbon-reinforced plastics, carbon fiber composites applied to components subjected to axially loaded tension/compression, fiber/aluminum systems for pressure vessel end closures and for centrifuge rotors, fatigue properties of glass-reinforced plastics, and the design and testing of aircraft rudders produced from composites. J.M.B.

A78-32930 # **Considerations on the use of graphite-reinforced plastics for space erectable antennas.** A. A. Woods, Jr. and M. Kural (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). In: Communications Satellite Systems Conference, 7th, San Diego, Calif., April 24-27, 1978, Technical Papers. New York, American Institute of Aeronautics and Astronautics, Inc., 1978, p. 423-432. 5 refs. Research supported by the Lockheed Independent Development and Research Program. (AIAA 78-591)

The desire for high-accuracy, large-diameter erectable antennas has led to the selection of graphite-reinforced plastics as a primary structural material. Many design approaches require bending or folding of structural elements to achieve the required ascent packaging density. Since the deployed fully formed antenna must be highly accurate, viscoelastic behavior in flexure is of significant concern. This characteristic has not been previously identified and is the subject of this paper. The results of an investigation of the relationships between time, humidity, vacuum, lay up geometry and initial strain, and viscoelastic behavior are presented and compared to theoretical solutions. (Author)

A78-33058 **Effect of ionizing radiation on mechanical properties of glass-fiber-filled polyethylene.** V. I. Grigor'ev, V. P. Gordienko, R. E. Il'enko, and A. N. Tynnyi (Akademiia Nauk Ukrainskoi SSR, Fiziko-Mekhanicheskii Institut, Lvov; Akademiia Nauk Ukrainskoi SSR, Institut Fizicheskoi Khimii, Kiev, Ukrainian SSR). *(Fiziko-Khimicheskaia Mekhanika Materialov,* vol. 13, Mar.-Apr. 1977, p. 100-104.) *Soviet Materials Science,* vol. 13, no. 2, Jan. 1978, p. 200-203. 9 refs. Translation.

In the specimens tested, the adhesive bonds between fibers and matrix were strengthened by exposure to radiation. The specimens were prepared from low-density polyethylene strengthened with 5 to 6 mm long, 8 to 10 micron diam fibers in contents of 0, 1.7, 4.2, 5.6, 8.0, and 12.0 vol %. The absorbed radiation doses equaled 0, 10, 20, 50, and 100 Mrad. The mechanical properties were tested at -196, +20, 110, and 140 C. The feasibility of controlling the mechanical properties by varying the fiber content is demonstrated. V.P.

A78-36430 **Thermally inert composite hardware applications for spacecraft.** H. D. Neubert (TRW Defense and Space Systems Group, Redondo Beach, Calif.). *SAMPE Journal,* vol. 14, May-June 1978, p. 6-14.

The feasibility of using composite materials for spacecraft primary structure is evaluated. It is noted that while composites offer physical properties which are well adapted to spaceflight, e.g., stiffness and light weight, theyre also expensive and do not always compensate for the fuel savings resulting from a lighter payload. The FLTSATCOM satellite system is presented as an illustration of the use of composite materials, and design characteristics of a separate deployable receive antenna are described, including: a total weight of less than 15 kg, a stowed natural frequency greater than 10 Hz and a deployed natural frequency greater than 1 Hz, a maintenance of structural integrity between -360 and +300 F, and very high reliability. Also discussed are a composite helical receive antenna (together with boom), and a graphite epoxy star tracker. D.M.W.

N68-17090*# General Dynamics/Convair, San Diego, Calif.
GRAVITY GRADIENT BOOM AND ANTENNA MATERIAL STUDY Final Report
H. R. Wiant 18 Aug. 1967 196 p ref
(Contract NAS5-9597)
(NASA-CR-92680; GD/C-ZZL-67-010) CFSTI: HC $3.00/MF $0.65 CSCL 09F

The study was conducted in three phases consisting of (1) the development of woven screen rigidizing procedures, (2) the generation of a mathematical model to predict thermal deflection of uncoated screen materials, and (3) a limited testing and evaluation program to verify the mechanical properties of rigidized screens. Three elgiloy–copper beryllium screens having different percent open-areas were rigidized by brazing and formed into 45-foot booms. A theoretical thermodynamic analysis of the screen-type boom was conducted and used as a basis for the practical application. An engineering prototype deployment mechanism was designed, fabricated, and tested. The wire screen boom concept proved to be a highly practical approach to the development of a low thermal distortion boom for space application. The complex nature of a rigidized, woven, dual material screen boom precluded analytical stress analysis, but selected physical parameters produced booms well within the envelope of usability. The thermal analysis of uncoated wire screen booms was used as a basis for final fabrications. The entire analysis and computer program is presented in full detail. The testing phase, although limited in extent, showed the wire screen boom to be uniform and reliable. The basic design was developed as potential space hardware. Author

N68-27470*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
APPLICATIONS OF COMPOSITE MATERIALS IN SPACE VEHICLE STRUCTURES
Richard R. Heldenfels [1967] 36 p refs Presented at the Intern. Conf. on Mech. of Composite Mater., Philadelphia, 8–10 May 1967
(NASA-TM-X-60069) CFSTI: HC$3.00/MF$0.65 CSCL 22B

The characteristics of filamentary composite materials are reviewed and evaluated for use in structural design of space vehicles. Several potential applications are discussed, among them: (1) propellant tanks, interstage structures, payload shrouds, and rocket nozzles for solid, liquid, and reusable launch vehicles; (2) pressure vessels, antennas, power arrays, meteoroid shields, and trusses for manned spacecraft and stations; (3) thermal protection, aeroshells, and deployable decelerators for Earth and planetary entry vehicles; and (4) energy abosrbers, frameworks, and cabin walls for landing modules and shelters. K.W.

N68-28689*# Lockheed Missiles and Space Co., Sunnyvale, Calif.
STUDY OF ATTACHMENT METHODS FOR ADVANCED SPACECRAFT THERMAL-CONTROL MATERIALS Final Report
N. H. Kordsmeir, Jr. and L. A. McKellar [1967] 98 p refs
(Contract NAS2-4252)
(NASA-CR-73219) CFSTI: HC$3.00/MF$0.65 CSCL 13H

An investigation was made to develop attachment methods for a thermal-control composite system comprised of optical solar reflectors and multilayer insulation. Basic systems design constraints were: (1) Systems must be removable for access to vehicle skin, (2) Nonmagnetic materials must be used in the construction of the composite, (3) attachments should not appreciably degrade thermal conductivity of multilayer, (4) composite system must withstand long-term exposure to high temperature (700°F.) and vacuum environment, (5) structural integrity must be sufficient to withstand loads imposed during an Atlas-Agena launch, and (6) Application techniques must be usable on cylindrical and flat shapes. Various techniques for attaching the composite system were evaluated. Two compositites were fabricated utilizing different attachment methods and were subjected to environmental conditions anticipated for a near-solar spacecraft mission. Both composites employ optical solar reflectors in combination with aluminized polyimide-tissueglass multilayer insulation. Exposure to flight sinusoidal loads caused the pyrex attachment posts to fracture on one sample. Both systems showed no evidence of structural damage during additional environmental testing. Author

N69-28424*# Lockheed-Georgia Co., Marietta. Nuclear Lab.
RADIATION EFFECTS ON COMPOSITE STRUCTURES Final Report
Jan. 1969 48 p refs
(Contract NAS8-21050)
(NASA-CR-98473; ER-10056) Avail: CFSTI CSCL 11D

The implementation and performance of a series of tests to determine the effects of a near space temperature and radiation environment on the Pegasus micrometeorite detection system is described. A discussion of detector panel response to induced charges is also presented. Analyses of test data indicates little degradation of system data due to environmental changes. Author

N69-35951*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
EFFECT OF VACUUM ON MATERIALS
Henry E. Frankel Paris ESRO Jan. 1969 49 p refs
(NASA-TM-X-61789; ESRO-TN-77) Avail: CFSTI CSCL 11C

Most of the parameters of the space environment are the same as those of terrestrial environments, except that the former are generally more severe. However, in space a new condition is imposed: a vacuum. The degradative effects of this alien condition on metals, alloys, lubricants, ceramics, coatings, thin films, and polymeric systems are discussed. In some instances, a vacuum environment can be extremely beneficial to systems, so that a component can be designed to take advantage of the environment. Methods of prevention of premature failure in a space environment, as well as proper testing, are also presented. ESRO

N69-36884# Royal Netherlands Aircraft Factories Fokker, Amsterdam.
EFFECT OF SPACE ENVIRONMENT ON MATERIALS
P. C. van der Waal 4 Jul. 1968 40 p refs
(RV-22) Avail: CFSTI

The origins and the problems of outgassing are discussed. Experiments are described where adhesives for metal bonding and fiberglass reinforced plastics were exposed to a thermal vacuum environment. Some of the adhesives show a loss of strength of more than 10% after 20 days. Weight loss curves obtained from the plastics provides more information about the behavior of these materials. Author

N70-21226*# Lockheed Missiles and Space Co., Palo Alto, Calif. Research Lab.
SPACE MATERIALS HANDBOOK
John B. Rittenhouse and John B. Singletary Washington NASA 1969 760 p refs Sponsored in part by NASA and AF 3d edition
(NASA-SP-3051; AMFL-TR-68-205) Avail: CFSTI HC $10.00/MF $0.65 CSCL 11F

Data are presented on the ascent and space environments, the effect of the environment on material, space materials experience in actual spacecraft applications, and biological interactions with materials.

N70-21237*# Lockheed Missiles and Space Co., Palo Alto, Calif. Research Lab.
ORGANIC MATERIALS FOR STRUCTURAL APPLICATIONS
R. E. Mauri *In its* Space Mater. Handbook 1969 p 355 382 refs
Avail: CFSTI HC $10.00/MF $0.65 CSCL 11I

Data on the effects of space environment on reinforced plastics are discussed. For spacecraft structural applications, the changes in mechanical properties occurring in these composite materials from exposure to the individual and combined environments of penetrating radiation, temperature, vacuum, and solar ultraviolet radiation are considered. Author

N71-16681*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
MATERIALS
In its Space Programs Sum. No. 37-65, Vol. 3, Aug. - Sep. 1970 31 Oct. 1970 p 122 135 refs
Copyright. Avail: NTIS CSCL 09E

Research progress is reported on mesh materials for deployable antennas, irradiation test results for Mariner Venus-Mercury 1973 solar array components, and the crack propagation threshold for isopropanol and Ti-6Al-4V titanium alloy. R.B.

N73-19556*# Stanford Research Inst., Menlo Park, Calif.
DETERMINATION OF CONTAMINATION CHARACTER OF MATERIALS IN SPACE TECHNOLOGY TESTING Summary Report, 22 Apr. 1970 - 30 Jun. 1971
Daniel L. Haynes 30 Jun. 1971 71 p
(Contract NAS5-11697; SRI Proj. PSU-7907)
(NASA-CR-122374; Rept-2) Avail: NTIS HC $5.75 CSCL 11D

The contamination characters of selected materials used in space technology testing. Specific materials were subjected to a thermal vacuum environment, and the outgases were collected on a cold test mirror surface. Approximately one-half of the surface of the mirror was subjected to ultraviolet irradiation while the outgases were being deposited on the mirror. The purpose of these experiments was to determine the effect of ultraviolet irradiation on the contaminative character of outgases from selected materials. The degree of contamination was measured in terms of degradation of the optical properties of the test mirror and the amount of deposit per unit area on quartz crystal microbalances placed near the test mirror, and by means of quadrupole mass spectral measurements of outgases from the test samples. Author

N74-17297# Hawker Siddeley Dynamics, Ltd., Hatfield (England). Space Div.
STUDY ON THE USE OF CARBON FIBRE REINFORCED PLASTICS IN SATELLITE STRUCTURES, PHASE 1 Final Report
J. A. Dickinson, comp. Oct. 1973 174 p refs Prepared jointly with UKAEA
(Contract ESTEC-1735/72-PP)
(HSD-TP-7427; ESRO-CR(P)-331) Avail: NTIS HC $11.75

Assessments of carbon fiber reinforced plastics (CFRP) as suitable materials for structural use in satellites are reported. Mechanical and physical property data of CFRP in environments typically encountered by satellites are discussed and compared to test the applicability of CFRP as structural materials. The performance data of other fiber reinforced plastics were collected and compared with those of CFRP. Proposals for future work are included. ESRO

N75-20483*# Grumman Aerospace Corp., Bethpage, N.Y. Advanced Composite Group.
DESIGN, FABRICATION AND TEST OF GRAPHITE/EPOXY METERING TRUSS STRUCTURE COMPONENTS, PHASE 3 Final Report, Jun. 1972 - Sep. 1974
Sep. 1974 140 p refs
(Contract NAS8-26675)
(NASA-CR-120705) Avail: NTIS HC $5.75 CSCL 11D

The design, materials, tooling, manufacturing processes, quality control, test procedures, and results associated with the fabrication and test of graphite/epoxy metering truss structure components exhibiting a near zero coefficient of thermal expansion are described. Analytical methods were utilized, with the aid of a computer program, to define the most efficient laminate configurations in terms of thermal behavior and structural requirements. This was followed by an extensive material characterization and selection program, conducted for several graphite/graphite/hybrid laminate systems to obtain experimental data in support of the analytical predictions. Mechanical property tests as well as the coefficient of thermal expansion tests were run on each laminate under study, the results of which were used as the selection criteria for the single most promising laminate. Further coefficient of thermal expansion measurement was successfully performed on three subcomponent tubes utilizing the selected laminate. Author

N78-17151*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, Md.
AN OUTGASSING DATA COMPILATION OF SPACECRAFT MATERIALS
William A. Campbell, Jr., Richard S. Marriott, and John J. Park Jan. 1978 181 p refs
(NASA-RP-1014; G7702-F-24) Avail: NTIS HC A09/MF A01 CSCL 11D

Outgassing data derived from tests at 398 K(25 C) or 24 hours in vacuum, were compiled for numerous materials for spacecraft use. The data presented are the total mass loss and the collected volatile condensable materials. The various materials were compiled by likely usage and alphabetically. Author

N78-30657*# Midwest Research Inst., Minnetonka, Minn.
THE PRODUCTION OF ULTRATHIN POLYIMIDE FILMS FOR THE SOLAR SAIL PROGRAM AND LARGE SPACE STRUCTURES TECHNOLOGY (LSST): A FEASIBILITY STUDY Final Report
R. H. Forester 1978 25 p refs Prepared for JPL
(Contract JPL-954489; MRI Proj. 4437-N)
(NASA-CR-157569) Avail: NTIS HC A02/MF A01 CSCL 10A

Polyimide membranes of a thickness range from under 0.01 micron m to greater than 1 micron m can be produced at an estimated cost of 50 cents per sq m (plus the cost of the polymer). The polymer of interest is dissolved in a solvent which is solube in water. The polymer or casting solution is allowed to flow down an inclined ramp onto a water surface where a pool of floating polymer develops. The solvent dissolves into the water lowering the surface tension of the water on equently, the contact angle of the polymer pool is very low and the edge of the pool is very thin. The solvent dissolves from this thin region too rapidly to be replenished from the bulk of the pool and a solid polymer film forms. Firm formation is rapid and spontaneous and the film spreads out unaided, many feet from the leading edge of the pool. The driving force for this process is the exothermic solution of the organic solvent from the polymer solution into the water. A.R.H.

N78-33266*# TRW Defense and Space Systems Group, Redondo Beach, Calif.
FEASIBILITY DEMONSTRATION FOR ELECTROPLATING ULTRA-THIN POLYIMIDE FILM Final Report, 22 Aug. 1977 - 1 Jun. 1978
R. Schneier, T. V. Braswell, and R. W. Vaughn Aug. 1978 25 p Prepared for JPL
(Contract NAS7-100; JPL-954771)
(NASA-CR-157775; TRW-32052-6009-RU-00) Avail: NTIS HC A02/MF A01 CSCL 13H

The effect of electrodeposition variables on film thickness was investigated using a dilute polyimide solution as a bath into which aluminum (as foil or as a vapor deposited coating) was immersed. The electrodeposited film was dried for 2 hours at 93 C (primarily to remove solvent) and cured for 18 hours at 186 C. Infrared studies indicate that imide formation (curing) occurs at 149 C under vacuum. From a conceptual viewpoint, satisfactory film metallized on one side can be obtained by this method. The cured ultra thin polyimide film exhibits properties equivalent to those of commercial film, and the surface appearance of the strippable polyimide film compares favorably with that of a sample of commercial film of thicker gauge. The feasibility of manufacturing approximately one million sq m of ultra thin film capable of being joined to fabricate an 800 m by 9 800 m square from starting material 0.5 to 1 m wide for space erectable structures was demonstrated. A.R.H.

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07
ASSEMBLY CONCEPTS

Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.

A68-27391#
SATELLITES AND VEHICLES ASSEMBLED IN SPACE.
A. H. Bertapelle (Grumman Aircraft Engineering Corp., Bethpage, N. Y.).
American Society of Mechanical Engineers, Design Engineering Conference and Show, Chicago, Ill., Apr. 22-25, 1968, Paper 68-DE-61. 7 p.
Members, $0.75; nonmembers, $1.50.

Discussion of space challenges as they relate to future manned systems. Five particularly cogent reasons for assembling vehicles in space are discussed. They include launch constraints, form factor, technology development, logistics, and maintainability. Design implications arising from assembly in space are discussed, and some predictions concerning large earth-orbiting manned system configurations are made. M.F.

A68-27476*
STATUS OF ELECTRON-BEAM WELDING FOR IN-SPACE APPLICATIONS.
F. R. Schollhammer (United Aircraft Corp., Hamilton Standard Div., Windsor Locks, Conn.).
IN: INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, ANNUAL SYMPOSIUM ON ELECTRON, ION, AND LASER BEAM TECHNOLOGY, BERKELEY, CALIF., MAY 9-11, 1967, RECORD.

Symposium sponsored by the Electron Devices Group of the Institute of Electrical and Electronics Engineers, the University of California, the U.S. Army, and the U.S. Navy.
Edited by R.F.W. Pease.
San Francisco, San Francisco Press, Inc., 1967, p. 215-238.
Contracts No. AF 33(657)-9926; No. NAS 9-4501.

Discussion of electron-beam welding and its suitability for fabricating the structures and joint configurations encountered in the assembly of space stations and spacecraft. A comparison is made of several welding processes including gas-shielded tungsten-arc welding, gas-shielded metal-arc welding, soldering, adhesive bonding, and laser welding as to their adaptability to high vacuum, and filler material required. A lightweight breadboard electron-beam gun is described which measures 3.5 in. in diameter and approximately 7 in. in length. A reduction in accelerating potential from 80 to 20 kv significantly reduces the intensity of radiation emitted from the workpiece. The electon-optical portion consists of a triode-type gun. The gun has been successfully operated at 2 kw (20 kv and 100 ma). Weld penetration capabilities of the prototype gun are evaluated. M.G.

A72-25049 * # **Space tools and support equipment - Current technology and future requirements.** N. E. Brown and E. L. Saenger (URS/Matrix Co., Huntsville, Ala.). *American Institute of Aeronautics and Astronautics, Man's Role in Space Conference, Cocoa Beach, Fla., Mar. 27, 28, 1972, Paper 72-230.* 18 p. 21 refs. Members, $1.50; nonmembers, $2.00. Contracts No. NAS8-27502; No. NAS8-27013.

Space tools and supporting equipment developed for past and current missions are summarized, along with projected tool and powered maneuvering aid requirements for future earth orbital missions. These tools, designed for functions such as general maintenance, replacement and repair, are reviewed and classified according to their intended application. A synopsis of the Skylab on-orbit maintenance requirements is presented, and the tools necessary for accomplishing the maintenance functions are listed. The proposed missions for future Earth Orbital Systems are summarized, and the potential functions (e.g., Remove/Replace, Cargo Transfer, etc.) are outlined. The current tool and support technology status is compared with future requirements for crew equipment to determine if these future requirements can be adequately satisfied. Of particular interest is a discussion of the augmentation of the astronaut with teleoperators (remote manipulator systems). (Author)

A72-29075 * # **A remote manipulator system for the space shuttle.** L. E. Livingston (NASA, Manned Spacecraft Center, Spacecraft Design Div., Houston, Tex.). *American Institute of Aeronautics and Astronautics, Man's Role in Space Conference, Cocoa Beach, Fla., Mar. 27, 28, 1972, Paper 72-238.* 5 p.

Shuttle mission objectives are examined. The outstanding characteristic of the payload handling system will be its versatility. A practical system is needed that combines man's adaptability, skill, and reflexes with the strength, endurance, and relative indestructibility of a machine. Systems that meet these standards, called teleoperators, have been in use for many years. The other half of the problem, the retention of man's natural manipulative skills, is solved by use of a 'master-slave' control system. Two independent, parallel preliminary design studies based on the requirements considered were conducted. G.R.

A72-32315 * # **Manipulator systems extend man's capabilities in space.** S. Deutsch (NASA, Washington, D.C.) and E. Heer (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *Astronautics and Aeronautics,* vol. 10, June 1972, p. 30-41. 49 refs.

Teleoperator components include manipulators and end effectors, sensors, a mobility unit, radio or hard-wire communications receiver and information processor, information display, man in the control loop at various levels of sophistication, the controls, and the transmitter. Possible applications of teleoperators in space cover a wide spectrum from various research and operational missions in earth orbit in conjunction with the space shuttle, space stations, and satellites to vehicles to explore the moon, planets and their moons, asteroids and comets. G.R.

A72-45174 # A teleoperator system for space application. W. Wienss, H. H. Stolte (ERNO Raumfahrttechnik GmbH, Bremen, West Germany), H. Kleinwächter (Labor Kleinwächter, West Germany), and H. H. von Muldau (Kybertronic GmbH und Co., Rossdorf, West Germany). *International Astronautical Federation, International Astronautical Congress, 23rd, Vienna, Austria, Oct. 8-15, 1972, Paper.* 37 p.

Analysis of an unmanned manipulator module which is remotely controlled by men from a control station based either on earth or in space. This teleoperator module is assumed to be transported by the Space Shuttle into an initial orbit and from there by the Space Tug to the 'operational' orbit, where repair and/or maintenance activities are to be carried out. The tasks to be carried out by the teleoperator spacecraft are reviewed, and the possibility of performing attitude-control maneuvers, in-orbit maneuvers, and maneuvers to other orbits is considered. Details of the manipulator system are presented, including a description of the manipulator arm system, the end effectors and docking tethers, and the TV system and illumination of the working field. Some comments are made regarding the location of the control station and the project development costs. A.B.K.

A73-35317 **X-reference frame bilateral control for the Shuttle Attached Manipulator System.** R. A. Booker and G. W. Smith (Martin Marietta Corp., Manned Experiments and Life Sciences Dept., Denver, Colo.). In: Institute of Electrical and Electronics Engineers, International Convention and Exposition, New York, N.Y., March 26-30, 1973, Technical Papers. New York, Institute of Electrical and Electronics Engineers, Inc., 1973, p. 40/3-1 to 40/3-12.

Some of the control system modes that will be built into the Shuttle Attached Manipulator System (SAMS) are discussed. Of particular interest to this group is the man-machine interface through which man's dexterity can be communicated across a barrier to actuators that can operate under loads too great for an unaided man in the hostile space environment. The SAMS, as distinguished from a robot operator, is a teleoperator that combines the best features of man and machine on a real-time basis. The system requirements are to perform payload handling, docking assistance, and servicing. Control problems associated with achieving the general purpose SAMS are examined. Critical capabilities are coordinate indexing, variable position gain ratios, and positive indexing. SAMS will incorporate a position master controller and will possess two seven-degrees-of-freedom slave members. F.R.L.

A73-37301 * Remotely manned systems: Exploration and operation in space; Proceedings of the First National Conference, California Institute of Technology, Pasadena, Calif., September 13-15, 1972. Conference sponsored by NASA and California Institute of Technology. Edited by E. Heer. Pasadena, Calif., California Institute of Technology, 1973. 511 p. $25.

Free-flying teleoperator systems are discussed, giving attention to earth-orbit mission considerations and Space Tug requirements, free-flying teleoperator requirements and conceptual design, system requirements for a free-flying teleoperator to despin, and the experimental evaluation of remote manipulator systems. Shuttle-Attached Manipulator Systems are considered, together with remote surface vehicle systems, manipulator systems technology, remote sensor and display technology, the man-machine interface, and control and machine intelligence. Nonspace applications are also explored, taking into account implications of nonspace applications, naval applications of remote manipulators, and hand tools and mechanical accessories for a deep submersible. G.R

A73-37305 * Experimental evaluation of remote manipulator systems. H. Fornoff (Bell Aerospace Co., Buffalo, N.Y.) and W. G. Thornton (NASA, Marshall Space Flight Center, Huntsville, Ala.). In: Remotely manned systems: Exploration and operation in space; Proceedings of the First National Conference, Pasadena, Calif., September 13-15, 1972. Pasadena, Calif., California Institute of Technology, 1973, p. 43-61. Contract No. NAS8-27021.

The objectives of the experimental studies described include an evaluation of existing anthropomorphic manipulators and several controller/display combinations. Inherent limitations of the 12-M type manipulator are identified and recommendations are made concerning manipulator and work site designs that will permit servicing and maintenance tasks to be performed by manipulators. Regions needing additional analytical and experimental investigations are identified. The experiments conducted are concerned with thruster replacement, battery replacement, compartment inspection, antenna installation, fluid coupling, and maneuvering and docking. G.R.

A73-37307 * Shuttle-Attached Manipulator System requirements. C. E. Bodey (North American Rockwell Corp., Downey, Calif.) and F. J. Cepollina (NASA, Goddard Space Flight Center, Greenbelt, Md.). In: Remotely manned systems: Exploration and operation in space; Proceedings of the First National Conference, Pasadena, Calif., September 13-15, 1972. Pasadena, Calif., California Institute of Technology, 1973, p. 77-85. 5 refs.

Shuttle mission requirements and cost objectives have led to the selection of a Shuttle-Attached Manipulator System (SAMS) as a general purpose mechanism for docking, payload handling, and the general launch and retrieval of free-flying satellites. SAMS design requirements are discussed, giving attention to end effectors, kinematics, timelines, dynamics, load ratings, TV cameras and lights. Requirements for low-cost payload satellites are considered, taking into account satellites with modular subsystems which are designed for replacement and for resupply in orbit by SAMS. G.R.

A73-37308 Shuttle Payload Accommodation System teleoperator. G. W. Smith and W. L. DeRocher, Jr. (Martin Marietta Aerospace, Denver, Colo.). In: Remotely manned systems: Exploration and operation in space; Proceedings of the First National Conference, Pasadena, Calif., September 13-15, 1972. Pasadena, Calif., California Institute of Technology, 1973, p. 85-103.

The two viable approaches for accomplishing teleoperation include the Shuttle-Attached Teleoperator (SATO) and the Free-Flying Teleoperator (FFTO). The SATO is more suitable for the close-in applications and the FFTO better for the longer range missions. Advances made in the development of SATO technology are reported. Remote manipulator system functions are examined, taking into account payload handling, docking assistance, and servicing. A one-arm manipulator system is considered together with a two-arm manipulator system, an automated mechanism, a free-flying teleoperator, and an extended space teleoperator. Attention is given to control systems, the control station and the visual system, mechanical systems, and terminal devices. G.R.

A73-37309 * Preliminary design and simulations of a *Shuttle-Attached Manipulator System*. S. B. Brodie and C. H. Johnson (Martin Marietta Aerospace, Denver, Colo.). In: Remotely manned systems: Exploration and operation in space; Proceedings of the First National Conference, Pasadena, Calif., September 13-15, 1972. Pasadena, Calif., California Institute of Technology, 1973, p. 105-118. Contract No. NAS9-11932.

The preliminary design of a Shuttle-Attached Manipulator System is based on two arms that are articulated at shoulder, elbow, and wrist. Details of manipulator design are considered, giving attention to arm reach, velocity, acceleration, torque, joint angular travel limits, control, crew systems and man-machine interface, and telecommunications. The results of man-in-the-loop simulations show the feasibility of grappling a representative space payload from the Shuttle using a long boom manipulator system. The task, however, is sufficiently difficult to require the full concentration of one operator who should be relieved of any other tasks while performing operations with the manipulator system. G.R.

A73-37310 Simulation concepts for a full-sized Shuttle manipulator system. A. E. Wudell and J. D. Yatteau (Martin Marietta Aerospace, Denver, Colo.). In: Remotely manned systems: Exploration and operation in space; Proceedings of the First National Conference, Pasadena, Calif., September 13-15, 1972. Pasadena, Calif., California Institute of Technology, 1973, p. 119-129.

A remote manipulator system (RMS) space operations simulator must simulate the inertial reactions of the Shuttle, the manipulator arms, and the target as they interact with each other during each of the RMS missions. A functional analysis of a number of space mission elements is presented, taking into account the deployment of the manipulator system, the berthing of the Shuttle to an orbiting payload, the cargo transfer, and the retrieval of the orbiting payload. Simulation methods are discussed, giving attention to simulation modes, cable suspensions, and neutral buoyancy. G.R.

A74-12814 # Orbit assembly of unmanned spacecraft. M. R. Mesnard and C. J. Holden. *International Astronautical Federation, International Astronautical Congress, 24th, Baku, Azerbaidzhan SSR, Oct. 7-13, 1973, Paper.* 16 p. 5 refs.

Discussion of the advantages and capabilities derivable from the assembly of spacecraft in earth orbit, and review of some of the problems involved. The assembled-in-orbit (AIO) spacecraft is considered in terms of its basic and structural design, its propulsion, reaction, attitude, guidance, and thermal-control systems, its electronics, electric-power, RF transmission and reception systems, and its test requirements. Special attention is given to human factor considerations in the design of the manned orbiting workshop, the modular design of the spacecraft for manned orbital assembly, and the shuttle delivery system. Contemplated missions for AIO spacecraft include: exploration of other star-planet systems; uses inside the solar system; and such geosynchronous satellite applications as domestic communications satellites, solar power relay stations, outer space communications relays, and large astronomical observatories. M.V.E.

A74-14117 * Teleoperators and EVA for Shuttle missions. T. B. Malone (Essex Corp., Alexandria, Va.) and S. Deutsch (NASA, Office of Life Sciences, Bioengineering Div., Washington, D.C.). In: Space Shuttle payloads; Proceedings of the Symposium, Washington, D.C., December 27, 28, 1972. Tarzana, Calif., American Astronautical Society, 1973, p. 303-324.

Review of the methods currently being contemplated for enabling the Space Shuttle to perform the Shuttle and payload support missions. Two general approaches to carrying out such activity are discussed - namely, the use of teleoperators and astronaut extravehicular activity (EVA). Detailed descriptions are given of an attached manipulator system (AMS) and a free-flying teleoperator (FFTO), noting the applications, capabilities, and limitations of each. The primary technology development areas for the AMS are in the areas of stabilization, structure, and manual control, while the technology areas of primary concern in the case of the FFTO include the manipulator-grappler system, the control system, the video system, and the mobility system. Four modes of EVA that are possible for the Shuttle are cited, noting the unlikelihood of direct applicability of EVA to payload deployment and retrieval and its feasibility for payload servicing and experiment support. A.B.K.

A74-39127 * # The role of EVA on Space Shuttle. M. A. Carson (NASA, Johnson Space Center, Houston, Tex.). *SAE, AIAA, ASME, ASMA, and AIChE, Intersociety Conference on Environmental Systems, Seattle, Wash., July 29-Aug. 1, 1974, ASME Paper 74-ENAs-24.* 9 p. 10 refs. Members, $1.00; nonmembers, $3.00.

The purpose of this paper is to present the history of Extravehicular Activity (EVA) through the Skylab Program and to outline the expected tasks and equipment capabilities projected for the Space Shuttle Program. Advantages offered by EVA as a tool to extend payload capabilities and effectiveness and economic advantages of using EVA will be explored. The presentation will conclude with some guidelines and recommendations for consideration by payload investigators in establishing concepts and designs utilizing EVA support. (Author)

A75-13588 Orbit assembly of unmanned spacecraft. M. R. Mesnard and C. J. Holden. In: Technology today for tomorrow; Proceedings of the Eleventh Space Congress, Cocoa Beach, Fla., April 17-19, 1974. Volume 1. Cape Canaveral, Fla., Canaveral Council of Technical Societies, 1974, p. 7-23 to 7-31. 5 refs.

The advantages of the assembly of a spacecraft in orbit are discussed along with questions of system design of the assembled-in-orbit (AIO) spacecraft, the structural design of the AIO spacecraft, the propulsion and reaction control of the AIO spacecraft, and aspects of attitude and guidance control. Attention is also given to the electric-electronic design of the AIO spacecraft, the electric power design, the thermal control, RF reception and transmission design, and test requirements. The assembly operations will be conducted by astronauts with the aid of the facilities of manned orbiting workshops. The techniques described for the assembly of unmanned spacecraft in orbit are equally applicable to manned spacecraft. G.R.

A75-19712 * A manipulator system designed for Free-Flying Teleoperator Spacecraft. J. R. Tewell, R. A. Spencer, and J. J. Lazar (Martin Marietta Aerospace, Denver, Colo.). In: Human Factors Society, Annual Meeting, 18th, Huntsville, Ala., October 15-17, 1974. Santa Monica, Calif., Human Factors Society, 1974, p. 493-497. 5 refs. Contract No. NAS8-30266.

A preliminary design of a manipulator system, applicable to a Free-Flying Teleoperator Spacecraft operating in conjunction with the Shuttle or Tug, is presented. The manipulator arm incorporates two 4-ft segments to the wrist with actuators located at the shoulder, elbow, and wrist. The wrist provides three degrees-of-freedom through pitch, yaw and continuous roll joints. An interchangeable end effector provides multiple task performance and satellite worksite versatility. A tip force of 10 lbs and a torque of 15 ft-lbs is provided. Man-in-the-loop simulations, using both unilateral and bilateral control techniques, were conducted. Based upon the simulation, a new, but relatively simple, control technique was proposed for the manipulator system. (Author)

A75-27199 * # Free-flying teleoperator for space missions. J. C. Hung (Tennessee, University, Knoxville, Tenn.), J. D. Irwin (Auburn University, Auburn, Ala.), and F. B. Moore (NASA, Marshall Space Flight Center, Astrionics Laboratory, Huntsville, Ala.). *International Federation of Automatic Control, Symposium on Automatic Control in Space, 6th, Tsakhkadzor, Armenian SSR, Aug. 26-31, 1974, Paper.* 14 p. 6 refs.

The design of a free-flying teleoperator (FFTO) intended to assist the Space Shuttle in performing its various missions is discussed, where FFTO is to be carried into earth orbit and returned to earth by the Shuttle. The FFTO system is described as to configuration, major subsystems, and mechanization concept. The kinematics of the manipulator and methods of sedating a satellite are discussed. Satellite equations of motion are provided, and cases of zero tumbling rate and non-zero tumbling rate are examined. Cases for which use of FFTO is compulsory are indicated, and the FFTO contributions to the Shuttle missions are analyzed. S.D.

A76-36475 # Some results of studies in space technology in the USSR. A. S. Okhotin, V. F. Lapchinskii, and G. S. Shonin (Akademiia Nauk SSSR, Institut Kosmicheskikh Issledovanii, Moscow, USSR). *COSPAR, Plenary Meeting, 19th, Philadelphia, Pa., June 8-19, 1976, Paper.* 14 p.

Major trends in the development of new technologies which exploit the advantages and avoid the limitations of the space environment are discussed. Among the topics considered are the effects of external disturbances, in particular ultrasonic vibration, on the crystallization of multiphase media and the development of the technology for repair, maintenance, and assembly operations. Special attention is given to the Vulkan electron beam welding system. C.K.D.

A76-42361 # Remote Manipulator System and satellite servicing experiment for Space Shuttle. G. M. Lindberg (National Research Council, Ottawa, Canada) and J. D. MacNaughton (Spar Aerospace Products, Ltd., Toronto, Canada). *American Astronautical Society and Deutsche Gesellschaft für Luft- und Raumfahrt, International Meeting on Utilization of Space Shuttle and Spacelab, Bonn, West Germany, June 2-4, 1976, Paper.* 18 p.

The paper describes the basic concepts of two Shuttle-related projects: (1) the Shuttle Attached Remote Manipulator System (RMS), intended for the deployment and retrieval by the Space Shuttle orbiter vehicle of space transportation system payloads; and (2) a Special Purpose Manipulator System for the on-orbit repair and servicing of multimission modular spacecraft to be operated in conjunction with the Space Shuttle orbiter vehicle and its RMS. The RMS consists of a six-degree-of-freedom manipulator arm operated in the aft area of the Shuttle's crew compartment. A general description of operation, payloads, performance requirements, and control modes of the RMS is given. The main part of the Special Purpose Manipulator System is the module exchange mechanism, which accomplishes transportation of new and used modules between storage magazine and the multimission modular spacecraft. The system has been built and tested in the Orbiter mock-up. P.T.H.

A77-11899 **Shuttle manipulator design reviewed.** *Aviation Week and Space Technology,* vol. 105, Nov. 1, 1976, p. 38, 39.

The paper deals with the Canadian-built remote manipulator system that will deploy and retrieve space shuttle payloads in orbit. The first manipulator flight is planned on the third shuttle orbital flight when the long-duration exposure facility is expected to be deployed. The manipulator system will be 50 ft long and have six degrees of freedom. The shoulder joint (the point which attaches to the orbiter payload bay about 7 ft aft of the main cabin bulkhead) will have pitch and yaw capability. The unit's elbow joint that connects the two boom sections will have a pitch capability, while the RMS wrist joint that joins the end effector will have pitch, roll, and yaw. Design capability is for maneuvering payloads on the order of 32,000 lb. Shuttle free-flying payload deployment simulations, currently under way, are discussed, along with some aspects of manipulator control. V.P.

A77-25746 # **Vehicle/manipulator/packaging interaction - A synergistic approach to large erectable space system design.** R. T. Mayer (General Electric Co., Re-Entry and Environmental Systems Div., Philadelphia, Pa.). In: Structures, Structural Dynamics and Materials Conference, 18th, March 21-23, 1977, and Aircraft Composites: The Emerging Methodology for Structural Assurance, San Diego, Calif., March 24, 25, 1977, Technical Papers. Volume A. New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 176-185. (AIAA 77-394)

The position is taken that mechanical manipulators in one form or another will be employed to assemble and erect Large Space Systems in orbit. Various generic types and parameters effecting their applicability are discussed. More specifically, limitations at their current stage of development are considered and the hypothesis advanced that much can be achieved by a systematic approach which imposes restrictions and caveats on vehicle design, packaging and erection procedures which would simplify the roll of the manipulator, moderate its complexity and hasten its use. Attention is focused on the relatively near term wherein the first wave of moderate size erectable systems will be deployed and space manipulator system development is still in the exploratory stage. (Author)

A77-26628 * **Shuttle remote manipulator system workstation - Man-machine engineering.** J. W. Brown (NASA, Johnson Space Center, Houston, Tex.). In: International Ergonomics Association, Congress, 6th, and Human Factors Society, Annual Meeting, 20th, College Park, Md., July 11-16, 1976, Proceedings. Santa Monica, Calif., Human Factors Society, 1976, p. 149-153.

A major subsystem aboard the Shuttle Orbiter, the Remote Manipulator System (RMS) provides the capability to deploy and retrieve free-flying satellites, support attached payload operations, and aid in crewmember rescue from a disabled vehicle should the requirement arise. The Remote Manipulator System consists of 15.3-m (50 ft) articulated booms, end effectors, operator workstation, and closed circuit video, power and control subsystems. The manipulator booms (or arms) and end effectors are located in the Orbiter payload bay and operated from inside the cabin by one crewmember. This paper is primarily concerned with the design and development of the RMS operator's workstation, the man-machine engineering features and interfaces, and man-in-the-loop simulations and testing results obtained to date by the National Aeronautics and Space Administration (NASA). (Author)

A77-26629 **Manipulator evaluation criteria.** N. L. Shields, Jr., M. Kirkpatrick, and T. B. Malone (Essex Corp., Alexandria, Va.). In: International Ergonomics Association, Congress, 6th, and Human Factors Society, Annual Meeting, 20th, College Park, Md., July 11-16, 1976, Proceedings. Santa Monica, Calif., Human Factors Society, 1976, p. 154-156. 6 refs.

Selected problems encountered in the definition of appropriate evaluation measures for remote manipulator systems are discussed, particularly as they relate to the extent to which standardized measures and procedures employed are suitable for a wide range of manipulator systems, environmental systems, and system tasks. Attention is focused on a generalizable manipulator evaluation approach and not on general purpose manipulator systems. Approaches adopted during the evaluation of remotely operated manipulator systems for space applications are examined. S.D.

A77-41568 * # **Satellite power system LEO vs GEO assembly issues.** J. Mockovciak, Jr. and R. J. Adornato (Grumman Aerospace Corp., Bethpage, N.Y.). In: New options in energy technology; Proceedings of the Conference, San Francisco, Calif., August 2-4, 1977. New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 124-132. 6 refs. Contract No. NAS8-31308. (AIAA 77-1029)

A strawman crystal-silicon 5-GW Satellite Power System (SPS) concept formed the basis of a study of construction concepts for building a complete SPS in low earth orbit (LEO) or geosynchronous orbit (GEO). Construction scenarios were evolved, including factory-in-space concepts and operations. Design implications imposed on the SPS satellite as a consequence of in-orbit assembly operations, and related attitude control requirements during assembly in LEO or GEO environments, were also evaluated. Results are presented indicating that complete assembly of an operational SPS in LEO, followed by transport to GEO, does not appear technically desirable. The best mix, however, of LEO versus GEO construction activity remains to be resolved. (Author)

A77-51017 **Development of a shuttle manipulator simulator.** D. A. Kugath (General Electric Co., Fairfield, Conn.). *Society of Manufacturing Engineers, Paper MR76-606*, 1976. 11 p.

The paper describes a manipulator having a reach of 15 m built to provide engineering simulations of the shuttle orbiter's remote manipulator system (RMS). It is essentially a redesigned version of a commercial manipulator with resolved rate control supplementing the original force feedback master/slave control. The facility is being used to study handling techniques, manipulator-to-payload interfaces, man-machine interfaces, and other aspects. The facility also includes the controller's station, which is a partial mock-up of the orbiter's aft flight deck. P.T.H.

A77-51518 * **Shuttle remote manipulator system safety and rescue support capabilities.** J. W. Brown (NASA, Johnson Space Center, Houston, Tex.) and G. D. Whitehead (Spar Aerospace Products, Ltd., Toronto, Canada). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper A-77-38.* 31 p. 6 refs.

The Remote Manipulator System (RMS) incorporates a manipulator arm with a payload-handling end effector, an arm positioning mechanism and a control system. The RMS is designed to capture and deploy free-flying payloads up to 4.6 m in diameter and 18.3 m long, weighing 14,515 kg. This paper describes the RMS with attention given to the arm, the supporting subsystems, and safety design features (displays and controls, the mechanical subsystem and operations). Man-in-the-loop simulations for the assurance of RMS of fill words are discussed to ensure nonambiguity of data and fill work. (Author)

A77-51567 **Application of optimal and adaptive algorithm control to the system robot-manipulator in cosmic space.** P. Neuman (Prague, University, Prague, Czechoslovakia). *International Astronautical Federation, International Astronautical Congress, 28th, Prague, Czechoslovakia, Sept. 25-Oct. 1, 1977, Paper 77-ST-02.* 22 p. 6 refs.

Mathematical models of spacecraft robot-manipulators are considered with reference to the development of an exact control algorithm which ensures the generation of a specific trajectory. Pontriagin's maximum principle is applied, and equivalent initial conditions are solved by means of sensitivity methods which rely on an iterative process. The derived method permits the realization of optimal control of a real mechanical system operating in real time. The method was tested by means of a simple model of a manipulator with the mass concentrated to the mass point. M.L.

A78-19036 **The design of compressor and turbine disks operating in the elastoplastic regime (Sul progetto dei dischi di compressori e turbine funzionanti in campo elasto-plastico).** R. Ciuffi and A. Grasso (Torino, Politecnico, Turin, Italy). In: Associazione Italiana di Aeronautica e Astronautica, National Congress, 3rd, Turin, Italy, September 30-October 3, 1975, Proceedings. Volume 1. Turin, Libreria Editrice Universitaria Levrotto e Bella, 1975, p. 131-140. 7 refs. In Italian.

A design program is developed to create the lightest possible compressor and turbine disks for high-temperature operation, i.e., for operation in an elastoplastic regime. Procedures for determining the transition from the elastic to the elastoplastic regime in such materials as nickel/chromium/cobalt alloys are reviewed, and a simple technique for the computer analysis of alloy disks entering the plastic regime at either the peripheral or the internal region is presented. Lengthening of the service life of the disks through prestressing is also considered. J.M.B.

A78-24447 # **The remote manipulator system for the Space Shuttle Orbiter.** K.-H. Doetsch, Jr. (National Research Council, Ottawa, Canada). *Deutsche Gesellschaft für Luft- und Raumfahrt, Jahrestagung, 10th, Berlin, West Germany, Sept. 13-15, 1977, Paper 77-060.* 30 p.

A remote manipulator system under development for the Space Shuttle Orbiter is described; the electromechanical manipulator, controlled by an operator within the Orbiter, is designed to have a maximum radius of about 15 m. In addition, the system is required to deploy payloads with masses as great as 30,000 kg and volumes up to 4.5 m in diameter and 18.3 m in length. Evaluation of the reach envelope of the manipulator arm in six degrees of freedom is reported. J.M.B.

A78-31877 # **Dynamics of a flexible manipulator arm for the Space Shuttle.** P. C. Hughes (Toronto, University, Toronto, Canada). *American Astronautical Society and American Institute of Aeronautics and Astronautics, Astrodynamics Specialist Conference, Jackson Hole, Wyo., Sept. 7-9, 1977, Paper.* 28 p. 8 refs. National Research Council of Canada Grant No. A-4183.

Motivated by the manipulator arm for the Shuttle, a dynamical analysis is presented for a chain of bodies; the two bodies at the extremities are rigid, corresponding to the orbiter vehicle and the payload, and the interior bodies are structurally flexible, corresponding to the arm segments. The equations of motion are linearized in terms of orbiter motion, angular rates at the arm hinges, and structural deflections, but arbitrary arm configuration is retained. The coefficient matrix of this system of equations is shown to be symmetric and positive definite. Comments are also made on the use of these equations in dynamics and control simulations. (Author)

A78-42474 **Tank tests validate structure assembly.** C. Covault. *Aviation Week and Space Technology,* vol. 108, June 26, 1978, p. 55-59, 62.

A 75 ft dia x 40 ft deep neutral buoyancy tank at the Marshall Space Flight Center is used to simulate the zero g environment encountered during the assembly of large structures in space. Attention is given to mass handling, beam structure assembly, shuttle mechanical aids, i.e., a remote manipulator system (RMS), and crew safety. It is found that 9 ton loads can be maneuvered with relative ease by a single operator, that foot restraints are unnecessary for many beam-building operations, that while better visibility from the space suit is desirable, it is not significantly impaired in the current generation of suits, and that skill in maneuvering along the beams increases rapidly with practice. D.M.W.

A78-49164 * # **New luster for space robots and automation.** E. Heer (California Institute of Technology, Jet Propulsion Laboratory, Office of Technology and Space Program Development, Pasadena, Calif.). *Astronautics and Aeronautics,* vol. 16, Sept. 1978, p. 48-60. 33 refs.

Consideration is given to the potential role of robotics and automation in space transportation systems. Automation development requirements are defined for projects in space exploration, global services, space utilization, and space transport. In each category the potential automation of ground operations, on-board spacecraft operations, and in-space handling is noted. The major developments of space robot technology are noted for the 1967-1978 period. Economic aspects of ground-operation, ground command, and mission operations are noted. S.C.S.

A78-51991 # **Advanced teleoperator spacecraft.** J. R. Tewell and R. A. Spencer (Martin Marietta Aerospace, Denver, Colo.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1665.* 8 p. 9 refs.

This paper discusses the results of work being conducted on a Teleoperator Retrieval System (TRS) by Martin Marietta Corporation under contract to NASA-MSFC, and its potential future role in supporting the construction of large space systems. This includes the assessment of future teleoperator type missions, generalized mission scenarios and major mission constraints. Evolution of a teleoperator system is shown as it progresses from a simple inspection vehicle to the Skylab boost vehicle along with projected configurations that satisfy future mission requirements. The emphasis in future missions includes payload deployment, payload retrieval, experiment and mission support roles, on-orbit service and repair, hazardous material handling, and standardized large space structure material transfer and assembly tasks. (Author)

A78-53605 # **Assembly of large space structures.** F. C. Runge (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). *American Astronautical Society and Deutsche Gesellschaft für Luft- und Raumfahrt, Goddard Memorial Symposium, 16th, Washington, D.C., Mar. 8-10, 1978, AAS Paper 78-052.* 16 p. (MDAC-WD-2852)

Designers of large space structures must consider carefully all aspects of Shuttle and upper stage transport, on-orbit assembly operations and related interfaces. An overview of such prospects is presented including pre-launch, stowage, orbit assembly equipment, payload peculiar vs. common equipment, EVA, Shuttle interfaces, accessibility and conclusions to date on orbit assembly. Deployment/assembly capabilities will escalate in complexity through the years from simpler Shuttle-tended modes to multi-user operations on a space construction platform by the late 1980's. Performance of early assembly operations analyses is stressed to assure selection of the most cost effective large structure concept approach. (Author)

N68-18870*# National Aeronautics and Space Administration, Washington, D. C.

TELEOPERATORS AND HUMAN AUGMENTATION. AN AEC–NASA TECHNOLOGY SURVEY

Edwin G. Johnson and William R. Corliss Dec. 1967 273 p
(NASA-SP-5047) GPO: HC$1.00; CFSTI: MF$0.65 CSCL 05H

This book surveys general purpose, dexterous, cybernetic machines developed in the last 25 years, emphasizing the principal subsystems of contemporary designs of such teleoperators. The purpose of the work is to present the concepts and techniques of teleoperators now used in nuclear and aerospace work for possible adaptation in exploring the seas, increasing industrial productivity, and aiding physically handicapped persons. Covered are: (1) present and potential teleoperator applications; (2) subsystems and man–machine integration; (3) design principles of structure, control, actuator, and sensor subsystems; and (4) teleoperator terminal devices. A glossary and an extensive bibliography are included. K.W.

N68-27934# Air Force Systems Command, Wright-Patterson AFB, Ohio. Air Force Aero Propulsion Lab.
THE REQUIREMENTS AND ROLE OF EVA ASSOCIATED WITH ORBITAL STRUCTURES
R. G. Clodfelter and R. A. Stewart (Textron's Bell Aerosystems Co.) *In its* Expandable and Modular Struct. Conf. May 1967 p 345–363 refs Presented at the 3d Aerospace Expandable and Modular Struct. Conf., May 1967

Requirements and the role of an EVA (extravehicular astronaut) in the deployment, assembly and maintenance of in-space erectable structures during earth orbital missions are discussed. The relative effectiveness of EVA is delineated, and equipment requirements for providing EVA orbital support to the erection of large structures are defined. The potential EVA role associated with each of the following assembly techniques are identified: modular, erectable, expandable, formed in place, chemical rigidizing, and combination. A number of fundamental EVA tasks were synthesized from a review of the assembly techniques and joining operations associated with these techniques, i.e., welding, brazing, metal fastening, adhesive, and pyrotechnic, as well as the specific mission requirements. These fundamental EVA tasks reduce themselves to the following: module positioning, alignment, and attachment; erection monitoring; adjustment of elements; thermal joining; mechanical fastening; modification; and maintenance. Pertinent characteristics regarding astronaut capabilities and limitations in a full pressure suit which are primarily guidelines in defining the ability to perform extravehicular tasks; and more pertinent equipment items which have been identified for EVA across the spectrum of orbital structure utilization; are summarized. Equipment classifications include primary equipment such as personnel life support packs and space suits; EVA secondary support equipment common to all missions such as handrails for surface locomotion, and finally mission support equipment which could be required to support a particular mission. S.C.W.

N69-21478*# National Aeronautics and Space Administration, Washington, D. C.
TELEOPERATOR CONTROL An AEC-NASA Technology Survey
William R. Corliss and Edwin G. Johnsen Dec. 1968 169 p refs
(NASA-SP-5070) Avail: CFSTI CSCL 06B

A comprehensive survey on engineering problems in teleoperator control and man machine integration is given. The various technical chapters are divided into: (1) control theory; (2) man-machine interface; (3) control hardware; and (4) displays. Design principles and configurations cover the wide range between hot-cell master slaves to walking machines and their varying electronic subsystems. G.G.

N70-28670*# National Aeronautics and Space Administration, Washington, D.C.
ADVANCEMENTS IN TELEOPERATOR SYSTEMS An AEC-NASA Technology Utilization Publication
1970 242 p Presented at a colloq., Denver, 26 27 Feb. 1969
(NASA-SP-5081) Avail: CFSTI CSCL 05H

Advances in computers, television, and electronic and mechanical devices which have contributed to the widespread use of the teleoperator are discussed. Emphasis is placed on transfer and teleoperator device technology to medical, aeronautical, and industrial fields. S.S.

N72-20438# Entwicklungsring Nord, Bremen (West Germany).
TELEOPERATOR SYSTEM STUDY Summary Report
Dec. 1971 144 p refs
(Contract ESTEC-1436-71-EL)
Avail: NTIS

The design of an unmanned space module with manipulator arms, remotely controlled from an earth or spaceborne control station, for orbital satellite inspection, maintenance, and repair, is reported. Special emphasis is placed upon the construction of the manipulator arms and end-effectors. The system is intended for use in conjunction with the post Apollo program-shuttle, tug, space station, in order to avoid extravehicular activity. ESRO

N72-22886*# MB Associates, San Ramon, Calif.
A SHUTTLE AND SPACE STATION MANIPULATOR SYSTEM FOR ASSEMBLY, DOCKING, MAINTENANCE CARGO HANDLING AND SPACECRAFT RETRIEVAL (PRELIMINARY DESIGN). VOLUME 1: MANAGEMENT SUMMARY Final Report
7 Jan. 1972 119 p refs 4 Vol.
(Contract NAS9-11943)
(NASA-CR-115480; MB-R-71/105-Vol-1) Avail: NTIS CSCL 22B

A preliminary design is established for a general purpose manipulator system which can be used interchangeably on the shuttle and station and can be transferred back and forth between them. Control of the manipulator is accomplished by hard wiring from internal control stations in the shuttle or station. A variety of shuttle and station manipulator operations are considered including servicing the Large Space Telescope; however, emphasis is placed on unloading modules from the shuttle and assembling the space station. Simulation studies on foveal stereoscopic viewing and manipulator supervisory computer control have been accomplished to investigate the feasibility of their use in the manipulator system. The basic manipulator system consists of a single 18.3 m long, 7 degree of freedom (DOF), electrically acutated main boom with an auxiliary 3 DOF electrically actuated, extendible 18.3 m maximum length, lighting, and viewing boom. A 3 DOF orientor assembly is located at the tip of the viewing boom to provide camera pan, tilt, and roll. Author

N72-22887*# MB Associates, San Ramon, Calif.
A SHUTTLE AND SPACE STATION MANIPULATOR SYSTEM FOR ASSEMBLY, DOCKING, MAINTENANCE, CARGO HANDLING AND SPACECRAFT RETRIEVAL (PRELIMINARY DESIGN). VOLUME 2: CONCEPT DEVELOPMENT AND SELECTION Final Report
7 Jan. 1972 194 p refs 4 Vol.
(Contract NAS9-11943)
(NASA-CR-115481; MB-R-71/105-Vol-2) Avail: NTIS CSCL 22B

The overall program background, the various system concepts considered, and the rationale for the selected design are described. The concepts for each subsystem are also described and compared. Details are given for the requirements, boom configuration and dynamics, actuators, man/machine interface and control, visual system, control system, environmental control and life support, data processing, and materials. N.E.N.

N72-22888*# MB Associates, San Ramon, Calif.
A SHUTTLE AND SPACE STATION MANIPULATOR SYSTEM FOR ASSEMBLY, DOCKING, MAINTENANCE, CARGO HANDLING AND SPACECRAFT RETRIEVAL (PRELIMINARY DESIGN). VOLUME 3: CONCEPT ANALYSIS. PART 1: TECHNICAL Final Report
7 Jan. 1972 251 p refs 4 Vol.
(Contract NAS9-11943)
(NASA-CR-115482-Vol-3-Pt-1) Avail: NTIS CSCL 22B

Information backing up the key features of the manipulator system concept and detailed technical information on the subsystems are presented. Space station assembly and shuttle cargo handling tasks are emphasized in the concept analysis because they involve shuttle berthing, transferring the manipulator boom between shuttle and station, station assembly, and cargo handling. Emphasis is also placed on maximizing commonality in the system areas of manipulator booms, general purpose end effectors, control and display, data processing, telemetry, dedicated computers, and control station design. N.E.N.

N72-22889*# MB Associates, San Ramon, Calif.
A SHUTTLE AND SPACE STATION MANIPULATOR SYSTEM FOR ASSEMBLY, DOCKING, MAINTENANCE, CARGO HANDLING AND SPACECRAFT RETRIEVAL (PRELIMINARY DESIGN). VOLUME 3: CONCEPT ANALYSIS. PART 2: DEVELOPMENT PROGRAM Final Report
7 Jan. 1972 11 p refs 4 Vol.
(Contract NAS9-11943)
(NASA-CR-115484; MB-R-71/105-Vol-3-Pt-2) Avail: NTIS CSCL 22B

A preliminary estimate is presented of the resources required to develop the basic general purpose walking boom manipulator system. It is assumed that the necessary full scale zero g test facilities will be available on a no cost basis. A four year development effort is also assumed and it is phased with an estimated shuttle development program since the shuttle will be developed prior to the space station. Based on delivery of one qualification unit and one flight unit and without including any ground support equipment or flight test support it is estimated (within approximately + or - 25%) that a total of 3551 man months of effort and $17,387,000 are required. Author

N72-22890*# MB Associates, San Ramon, Calif.
A SHUTTLE AND SPACE STATION MANIPULATOR SYSTEM FOR ASSEMBLY, DOCKING, MAINTENANCE, CARGO HANDLING AND SPACECRAFT RETRIEVAL (PRELIMINARY DESIGN). VOLUME 4: SIMULATION STUDIES Final Report
7 Jan. 1972 57 p refs 4 Vol.
(Contract NAS9-11943)
(NASA-CR-115483; MB-R-71/105-Vol-4) Avail: NTIS CSCL 22B

Laboratory simulations of three concepts, based on maximum use of available off-the-shelf hardware elements, are described. The concepts are a stereo-foveal-peripheral TV system with symmetric steroscopic split-image registration and 90 deg counter rotation; a computer assisted model control system termed the trajectory following control system; and active manipulator damping. It is concluded that the feasibility of these concepts is established. N.E.N.

N72-29830*# Essex Corp., Alexandria, Va.
TELEOPERATOR SYSTEM MAN-MACHINE INTERFACE REQUIREMENTS FOR SATELLITE RETRIEVAL AND SATELLITE SERVICING. VOLUME 2: DESIGN CRITERIA Final Report
Thomas B. Malone Jun. 1972 142 p refs
(Contract NASw-2220)
(NASA-CR-123755) Avail: NTIS HC $10.25 CSCL 22C

Requirements were determined analytically for the man machine interface for a teleoperator system performing on-orbit satellite retrieval and servicing. Requirements are basically of two types; mission/system requirements, and design requirements or design criteria. Two types of teleoperator systems were considered: a free flying vehicle, and a shuttle attached manipulator. No attempt was made to evaluate the relative effectiveness or efficiency of the two system concepts. The methodology used entailed an application of the Essex Man-Systems analysis technique as well as a complete familiarization with relevant work being performed at government agencies and by private industry. Author

N72-24339*# General Electric Co., Syracuse, N.Y. Electronics Lab.
REMOTE MANIPULATOR DYNAMIC SIMULATION Final Report
E. C. Wild, P. K. Donges, and W. A. Garand Apr. 1972 69 p
(Contract NAS9-11948)
(NASA-CR-115636) Avail: NTIS HC $5.50 CSCL 14B

A simulator to generate the real time visual scenes required to perform man in the loop investigations of remote manipulator application and design concepts for the space shuttle is described. The simulated remote manipulator consists of a computed display system that uses a digital computer, the electronic scene generator, an operator's station, and associated interface hardware. A description of the capabilities of the implemented simulation is presented. The mathematical models and programs developed for the simulation are included. Author

N73-27176*# Martin Marietta Corp., Denver, Colo.
ATTACHED MANIPULATOR SYSTEM DESIGN AND CONCEPT VERIFICATION FOR ZERO-g SIMULATION Final Report
R. Booker, W. Burkitt, P. Corveleyn, P. Cramer, O. Duwaik, C. Flatau, P. Garber, C. Grant, F. Greeb, C. Johnson et al Jun. 1973 498 p refs
(Contract NAS9-13027)
(NASA-CR-133964; JSC-08021) Avail: NTIS HC $27.00 CSCL 14B

The attached manipulator system (AMS) is to simulate and demonstrate zero-g shuttle manipulator cargo handling operations. It is not the design or development of the shuttle attached manipulator system (SAMS); however, every effort is being made, to insure that the AMS will be functionally similar to the SAMS. Author

N74-29459*# Essex Corp., Alexandria, Va.
MANIPULATOR SYSTEM MAN-MACHINE INTERFACE EVALUATION PROGRAM
Thomas B. Malone, Mark Kirkpatrick, and Nicholas L. Shields Jan. 1974 102 p
(Contract NAS8-28298)
(NASA-CR-120218; H-4-3) Avail: NTIS HC $8.25 CSCL 05H

Application and requirements for remote manipulator systems for future space missions were investigated. A manipulator evaluation program was established to study the effects of various systems parameters on operator performance of tasks necessary for remotely manned missions. The program and laboratory facilities are described. Evaluation criteria and philosophy are discussed. E.J.O.

N74-31582*# Martin Marietta Aerospace, Denver, Colo.
CONFIGURATION AND DESIGN STUDY OF MANIPULATOR SYSTEMS APPLICABLE TO THE FREE FLYING TELEOPERATOR. VOLUME 1: EXECUTIVE SUMMARY Final Report
J. R. Tewell Jul. 1974 81 p refs
(Contract NAS8-30266)
(NASA-CR-120402; MCR-74-290-Vol-1) Avail: NTIS HC $7.25 CSCL 05H

A preliminary design of a manipulator system, applicable to a free flying teleoperator spacecraft operating in conjunction with the shuttle or tug, is presented. A new control technique is proposed for application to the manipulator system. This technique, a range/azimuth/elevation rate-rate mode, was selected based upon the results of man-in-the-loop simulations. Several areas are identified in which additional emphasis must be placed prior to the development of the manipulator system. The study results in a manipulator system which will provide an effective method for servicing, maintaining, and repairing satellites to increase their useful life. Author

N75-12036*# Essex Corp., Alexandria, Va.
STUDY OF ROLES OF REMOTE MANIPULATOR SYSTEMS AND EVA FOR SHUTTLE MISSION SUPPORT, VOLUME 1
Thomas B. Malone and Angelo J. Micocci Oct. 1974 132 p refs
(Contract NAS9-13710)
(NASA-CR-140364) Avail: NTIS HC $5.75 CSCL 22B

Alternate extravehicular activity (EVA) and remote manipulator system (RMS) configurations were examined for their relative effectiveness in performing an array of representative shuttle and payload support tasks. Initially a comprehensive analysis was performed of payload and shuttle support missions required to be conducted exterior to a pressurized inclosure. A set of task selection criteria was established, and study tasks were identified. The EVA and RMS modes were evaluated according to their applicability for each task and task condition. The results are summarized in tabular form, showing the modes which are chosen as most effective or as feasible for each task/condition. Conclusions concerning the requirements and recommendations for each mode are presented. Author

N75-26651*# Essex Corp., Huntsville, Ala.
EARTH ORBITAL TELEOPERATOR MANIPULATOR SYSTEM EVALUATION PROGRAM
M. Kirkpatrick, III, N. L. Shields, Jr., P. N. Frederick, R. Brye, and T. B. Malone Feb. 1975 84 p refs
(Contract NAS8-30545)
(NASA-CR-143874; Rept-2) Avail: NTIS HC $4.75 CSCL 05E

The performance of an orbital teleoperator system which includes small dextrous servicing manipulators to be used in satellite servicing was examined. System/operator performance testing was implemented and the results of a fine positioning control test using two different manipulator systems varying widely in manipulator configuration and control systems are presented. Fine position control is viewed as representing a fundamental requirement placed on manipulator control. The relationship of position control to more complex tasks which directly represent on-orbit servicing operations are also presented. Author

N75-26652*# Essex Corp., Huntsville, Ala.
EARTH ORBITAL TELEOPERATOR VISUAL SYSTEM EVALUATION PROGRAM
N. L. Shields, Jr., M. Kirkpatrick, III, P. N. Frederick, and T. B. Malone Feb. 1975 85 p refs
(Contract NAS8-30545)
(NASA-CR-143875; Rept-3) Avail: NTIS HC $4.75 CSCL 05E

Empirical tests of range estimation accuracy and resolution, via television, under monoptic and steroptic viewing conditions are discussed. Test data are used to derive man machine interface requirements and make design decisions for an orbital remote manipulator system. Remote manipulator system visual tasks are given and the effects of system parameters of these tasks are evaluated. E.H.W.

N75-27041* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
VARIABLE RATIO MIXED-MODE BILATERAL MASTER-SLAVE CONTROL SYSTEM FOR SHUTTLE REMOTE MANIPULATOR SYSTEM Patent
Fredrick J. Greeb (Martin Marietta Corp., Denver), Shepard B. Brodie (Martin Marietta Corp., Denver), and Carl R. Flatau, inventors (to NASA) (Martin Marietta Corp., Denver) Issued 8 Jul. 1975 13 p Filed 20 Aug. 1973 Supersedes N73-30832 (11 - 21, p 2599) Sponsored by NASA
(NASA-Case-MSC-14245-1; US-Patent-3,893,573; US-Patent-Appl-SN-389916; US-Patent-Class-214-1CM) Avail: US Patent Office CSCL 22B

A control system for a remotely operated manipulator system which incorporates a slave arm of substantial length and strength having multiple degrees of freedom at an adequate number of joints to enable the arm to accomplish specified tasks, and a master arm for use by an operator was disclosed. The two are operated by a servo system which provides a variable ratio which is varied dependent on the task required for the slave arm. Gross movements of the slave arm are readily accomplished with small movements of the master. When the manipulator arm is close to the target, the ratio is preferably changed providing better master-arm response to the operator to enable grasping with the manipulator terminal device.
Official Gazette of the U.S. Patent Office

N75-29773*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
CONCEPT DESIGN OF THE PAYLOAD HANDLING MANIPULATOR SYSTEM
Jun. 1975 122 p
(NASA-TM-X-72447; JSC-09709) Avail: NTIS HC $5.25 CSCL 05H

The design, requirements, and interface definition of a remote manipulator system developed to handle orbiter payloads are presented. End effector design, control system concepts, and man-machine engineering are considered along with crew station requirements and closed circuit television system performance requirements. J.M.S.

N75-29780*# Kanner (Leo) Associates, Redwood City, Calif.
ROBOT MANIPULATORS
Ye. P. Popov Washington NASA Aug. 1975 54 p refs Transl. into ENGLISH from the book "Roboty-Manipulyatory" Moscow, Znaniye Press, 1974 64 p
(Contract NASw-2790)
(NASA-TT-F-16482) Avail: NTIS HC $4.25 CSCL 05H

The general use of robot manipulators is explained and the basics of their design and operation are described for the average reader. Several pages of the first chapter include a discussion on the use of robot manipulators in space. Possibilities for fully and partially automatic robots, robot manipulator and information robots for space shuttles, space stations, and planetary exploration are outlined. The only example given of robots actually used in space is a mention of the Soviet Lunokhod, which is characterized as the initial stage of planetary robot development. A short list of references is included. Author

N75-32144*# Martin Marietta Corp., Denver, Colo.
ORBITAL ASSEMBLY AND MAINTENANCE STUDY Final Report
D. Gorman, C. Grant, G. Kyrias, C. Lord, J. Rombach, M. Salis, R. Skidmore, and R. Thomas Aug. 1975 414 p refs
(Contract NAS9-14319)
(NASA-CR-144422; MCR-75-319-1) Avail: NTIS HC $10.50 CSCL 22A

The requirements, conceptual design, tradeoffs, procedures, and techniques for orbital assembly of the support structure of the microwave power transmission system and the radio astronomy telescope are described. Thermal and stress analyses, packaging, alignment, and subsystems requirements are included along with manned vs. automated and transportation tradeoffs. Technical and operational concepts for the manned and automated maintenance of satellites were investigated and further developed results are presented. J.M.S.

N75-32971*# Martin Marietta Corp., Denver, Colo.
ORBITAL ASSEMBLY AND MAINTENANCE STUDY. EXECUTIVE SUMMARY Final Report
D. Gorman, C. Grant, G. Kyrias, C. Lord, J. P. Rombach, M. Salis, R. Skidmore, and R. Thomas Aug. 1975 45 p
(Contract NAS9-14319)
(NASA-CR-144448; MCR-75-319-2) Avail: NTIS HC $3.75 CSCL 03A

A sound, practical approach for the assembly and maintenance of very large structures in space is presented. The methods and approaches for assembling two large structures are examined. The maintenance objectives include the investigation of methods to maintain five geosynchronous satellites. The two assembly examples are a 200-meter-diameter radio astronomy telescope and a 1,000-meter-diameter microwave power transmission system. The radio astronomy telescope operates at an 8,000-mile altitude and receives RF signals from space. The microwave power transmission system is part of a solar power satellite that will be used to transmit converted solar energy to microwave ground receivers. Illustrations are included. Author

N76-19174* Martin Marietta Corp., Denver, Colo.
A MANIPULATOR ARM FOR ZERO-g SIMULATIONS
Shepard B. Brodie, Christopher Grant, and Janos J. Lazar *In* NASA. Kennedy Space Center 9th Aerospace Mech. Symp. Aug. 1975 p 19-29
CSCL 05H

A 12-ft counterbalanced Slave Manipulator Arm (SMA) was designed and fabricated to be used for resolving the questions of operational applications, capabilities, and limitations for such remote manned systems as the Payload Deployment and Retrieval Mechanism (PDRM) for the shuttle, the Free-Flying Teleoperator System, the Advanced Space Tug, and Planetary Rovers. As a developmental tool for the shuttle manipulator system (or PDRM), the SMA represents an approximate one-quarter scale working model for simulating and demonstrating payload handling, docking assistance, and satellite servicing. For the Free-Flying Teleoperator System and the Advanced Tug, the SMA provides a near full-scale developmental tool for satellite servicing, docking, and deployment/retrieval procedures, techniques, and support equipment requirements. For the Planetary Rovers, it provides an oversize developmental tool for sample handling and soil mechanics investigations. The design of the SMA was based on concepts developed for a 40-ft NASA technology arm to be used for zero-g shuttle manipulator simulations. Author

N76-31265*# McDonnell-Douglas Technical Services Co., Inc., Houston, Tex. Astronautics Div.
APPLICATION OF SHUTTLE EVA SYSTEMS TO PAYLOADS. VOLUME 1: EVA SYSTEMS AND OPERATIONAL MODES DESCRIPTION
Jun. 1976 201 p refs
(Contract NAS9-14678)
(NASA-CR-147732; MDC-W0014-Vol-1) Avail: NTIS HC $7.75 CSCL 22B
Descriptions of the EVA system baselined for the space shuttle program were provided, as well as a compendium of data on available EVA operational modes for payload and orbiter servicing. Operational concepts and techniques to accomplish representative EVA payload tasks are proposed. Some of the subjects discussed include: extravehicular mobility unit, remote manipulator system, airlock, EVA translation aids, restraints, workstations, tools and support equipment. Author

N77-24768*# Martin Marietta Corp., Denver, Colo.
PROTO-FLIGHT MANIPULATOR ARM (P-FMA) Final Report
W. R. Britton Apr. 1977 119 p
(Contract NAS8-31487)
(NASA-CR-150277; MCR-77-201) Avail: NTIS HC A06/MF 01 CSCL 05H
The technical development of the Proto-Flight Manipulator Arm (P-FMA) which is a seven-degree-of-freedom general-purpose arm capable of being remotely operated in an earth orbital environment is discussed. The P-FMA is a unique manipulator, combining the capabilities of significant dexterity, high tip forces, precise motion control, gear backdriveability, high end effector grip forces and torques, and the quality of flightworthiness. The 2.4-meter (8-foot) arm weighs 52.2 kilograms (115 pounds). Author

N77-25786*# Essex Corp., Huntsville, Ala.
EARTH ORBITAL TELEOPERATOR MOBILITY SYSTEM EVALUATION PROGRAM
Ronald G. Brye, Nicholas L. Shields, Jr., and Mark Kirkpatrick, III 28 Jan. 1977 34 p refs
(Contract NAS8-31848)
(NASA-CR-150285; H-77-4; Rept-1) Avail: NTIS HC A03/MF A01 CSCL 05H
The proximity translation and final docking of the space teleoperator evaluation vehicle (STEV) with large mass and small mass satellites was studied. Operations that may be performed by the STEV during the shuttle experiments are approximated. Author

N77-25787*# Essex Corp., Huntsville, Ala.
EARTH ORBITAL TELEOPERATOR MANIPULATOR SYSTEM EVALUATION PROGRAM
Ronald G. Brye, P. Norman Frederick, Mark Kirkpatrick, III, and Nicholas L. Shields, Jr. 29 Jan. 1977 59 p refs
(Contract NAS8-31848)
(NASA-CR-150286; H-77-2; Rept-4) Avail: NTIS HC A04/MF A01 CSCL 05H
The operator's ability to perform five manipulator tip movements while using monoptic and stereoptic video systems was assessed. Test data obtained were compared with previous results to determine the impact of camera placement and stereoptic viewing on manipulator system performance. The tests were performed using the NASA MSFC extendible stiff arm Manipulator and an analog joystick controller. Two basic manipulator tasks were utilized. The minimum position change test required the operator to move the manipulator arm to touch a target contract. The dexterity test required removal and replacement of pegs. Author

N77-26804*# Lockheed Electronics Co., Houston, Tex. Systems and Services Div.
REMOTE MANIPULATOR SYSTEM STEERING CAPABILITY FOR SVDS
D. T. Martin May 1977 49 p refs
(Contract NAS9-15200)
(NASA-CR-151438; LEC-10595; JSC-12628) Avail: NTIS HC A03/MF A01 CSCL 05H
Details of the remote manipulator system steering capability to be implemented into the space vehicle dynamics simulator are reported. The resolve rate law is included as part of the overall steering capability. The steering model includes three automatic modes, four manual augmented modes, and a single joint rate mode. Author

N77-27157*# Martin Marietta Corp., Denver, Colo.
ORBITAL CONSTRUCTION SUPPORT EQUIPMENT Final Report
Jun. 1977 437 p refs
(Contract NAS9-15120)
(NASA-CR-151460; MCR-77-234) Avail: NTIS HC A19/MF A01 CSCL 22A
Approximately 200 separate construction steps were defined for the three solar power satellite (SPS) concepts. Detailed construction scenarios were developed which describe the specific tasks to be accomplished, and identify general equipment requirements. The scenarios were used to perform a functional analysis, which resulted in the definition of 100 distinct SPS elements. These elements are the components, parts, subsystems, or assemblies upon which construction activities take place. The major SPS elements for each configuration are shown. For those elements, 300 functional requirements were identified in seven generic processes. Cumulatively, these processes encompass all functions required during SPS construction/assembly. Individually each process is defined such that it includes a specific type of activity. Each SPS element may involve activities relating to any or all of the generic processes. The processes are listed, and examples of the requirements defined for a typical element are given. Author

N77-27162*# Lockheed Electronics Co., Houston, Tex. Systems and Services Div.
RMS MASSLESS ARM DYNAMICS CAPABILITY IN THE SVDS
H. A. Flanders Jun. 1977 34 p refs
(Contract NAS9-15200)
(NASA-CR-151458; JSC-12632; LEC-10633) Avail: NTIS HC A03/MF A01 CSCL 14B
The equations of motion for the remote manipulator system, assuming that the masses and inertias of the arm can be neglected, are developed for implementation into the space vehicle dynamics simulation (SVDS) program for the Orbiter payload system. The arm flexibility is incorporated into the equations by the computation of flexibility terms for use in the joint servo model. The approach developed in this report is based on using the Jacobian transformation matrix to transform force and velocity terms between the configuration space and the task space to simplify the form of the equations. Author

N77-29770*# Martin Marietta Corp., Denver, Colo.
THE ASSEMBLY OF LARGE STRUCTURES IN SPACE
George W. Smith and Shepard B. Brodie *In* JPL The 2nd Conf. on Remotely Manned Systems (RMS) Jun. 1975 p 43-44

Contracts NAS9-14319; NAS3-17835
Avail: NTIS HC A06/MF A01 CSCL 05H

Techniques developed for orbital assembly of the support structure for a 1000 meter diameter microwave power transmission system antenna are described. The operation is performed in two phases using the shuttle remote manipulator system in low earth orbit, and a mobile assembler in geosynchronous orbit. Author

N78-15158*# Analytical and Computational Mathematics, Inc., Houston, Tex.
ANALYTICAL FORMULATION OF SELECTED ACTIVITIES OF THE REMOTE MANIPULATOR SYSTEM
K. J. Zimmerman Nov. 1977 52 p refs
(Contract NAS9-15171)
(NASA-CR-151608) Avail: NTIS HC A04/MF A01 CSCL 22B

Existing analysis of Orbiter-RMS-Payload kinematics were surveyed, including equations dealing with the two body kinematics in the presence of a massless RMS and compares analytical explicit solutions with numerical solutions. For the following operational phases of the RMS numerical demonstration, problems are provided: (1) payload capture; (2) payload stowage and removal from cargo bay; and (3) payload deployment. The equation of motion provided accounted for RMS control forces and torque moments and could be extended to RMS flexibility and control loop simulation without increasing the degrees of freedom of the two body system. Author

N78-19773*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala.
END EFFECTOR DEVICE Patent Application
Keith H. Clark, inventors (to NASA) and James D. Johnston
Filed 9 Mar. 1978 11 p
(NASA-Case-MFS-23692-1; US-Patent-Appl-SN-885061) Avail: NTIS HC A02/MF A01 CSCL 05H

A lightweight structure adapted for gripping objects of a variety of sizes and shapes with uniform tightness was designed for a mechanical manipulator arm of a space vehicle or other remote manipulator. The end effector device includes a pair of movable jaws in opposed relation for gripping an object. Each jaw has laterally spaced gripping fingers in the form of flat plates. Each finger has a gripping face in which a notch is formed. The gripping fingers of one of the jaws are carried alternately offset with respect to the fingers of the opposed jaw to permit the fingers to intermesh and provide a variably closed channel for gripping objects of various sizes and shapes. The jaws are connected to an adapter mechanism by couplings which include a pair of spaced pivots on which a pair of linkage bars are mounted. Each jaw is connected to its coupling through a flexible cartilage which prevents shearing of connecting rods and pins and provides for more effective gripping action. The adapter mechanism is in turn connected to a mechanical wrist joint of a manipulator arm. NASA

N78-23112*# General Dynamics/Convair, San Diego, Calif.
SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS), PART 2 Final Briefing
3 Feb. 1978 136 p
(Contract NAS9-15310)
(NASA-CR-151705; CASD-ASP-77-016-Pt-2) Avail: NTIS HC A07/MF A01 CSCL 22A

The techniques, processes, and equipment required for automatic fabrication and assembly of structural elements in using Shuttle as a launch vehicle, and construction were defined. Additional construction systems operational techniques, processes, and equipment which can be developed and demonstrated in the same program to provide further risk reduction benefits to future large space systems were identified and examined. Author

N78-25111*# General Dynamics/Convair, San Diego, Calif. Dept. of Advanced Space Programs.
SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS). VOLUME 1: EXECUTIVE SUMMARY Final Report
12 May 1978 36 p
(Contract NAS9-15310)
(NASA-CR-151731; CASD-ASP77-017-Vol-1) Avail: NTIS HC A03/MF A01 CSCL 22A

The techniques, processes, and equipment required for automatic fabrication and assembly of structural elements in space using the space shuttle as a launch vehicle and construction base were investigated. Additional construction/systems/operational techniques, processes, and equipment which can be developed/demonstrated in the same program to provide further risk reduction benefits to future large space systems were included. Results in the areas of structure/materials, fabrication systems (beam builder, assembly jig, and avionics/controls), mission integration, and programmatics are summarized. Conclusions and recommendations are given. Author

N78-25112*# General Dynamics/Convair, San Diego, Calif. Dept. of Advanced Space Programs.
SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS). VOLUME 2: STUDY RESULTS Final Report
26 May 1978 382 p
(Contract NAS9-15310)
(NASA-CR-151730; CASD-ASP77-017-Vol-2) Avail: NTIS HC A17/MF A01 CSCL 22A

For abstract, see N78-25111.

N78-25113*# General Dynamics/Convair, San Diego, Calif. Dept. of Advanced Space Programs.
SPACE CONSTRUCTION AUTOMATED FABRICATION EXPERIMENT DEFINITION STUDY (SCAFEDS). VOLUME 3: REQUIREMENTS Final Report
5 May 1978 117 p
(Contract NAS9-15310)
(NASA-CR-151729; CASD-ASP77-018-Vol-3) Avail: NTIS HC A06/MF A01 CSCL 22A

The performance, design, and verification requirements for the space construction automated fabrication experiment (SCAFE) are defined and the source of each imposed or derived requirement is identified. Author

N78-25786# Sandia Labs., Albuquerque, N. Mex. Model Shops and Inspection Div.
MICROPROCESSOR-BASED DATA ACQUISITION SYSTEM INCORPORATING A FLOATING-POINT ARITHMETIC UNIT FOR COMPLEX MATHEMATICAL COMPUTATIONS
J. Hopwood Feb. 1978 67 p ref
(Contract EY-76-C-04-0789)
(SAND-77-8046) Avail: NTIS HC A04/MF A01

A microprocessor-based, stored-program controller which incorporates a floating-point arithmetic unit to perform complex mathematical computations was developed to determine the thickness of conductors on printed wiring boards. Conductor thickness is calculated from measured resistance by means of curve-fitting equations in the stored program. Called a film thickness calculator, the instrument demonstrates a method which may serve as a basis for other designs involving microprocessor-based data acquisition systems requiring low-speed calculations. ERA

N78-30147*# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena.
THE ROLE OF ROBOTS AND AUTOMATION IN SPACE
Ewald Heer 1 Sep. 1978 43 p refs
(Contract NAS7-100)
(NASA-CR-157560; JPL-Pub-78-78) Avail: NTIS HC A03/MF A01 CSCL 22A

Advanced space transportation systems based on the shuttle and interim upper stage will open the way to the use of large-scale industrial and commercial systems in space. The role of robot and automation technology in the cost-effective implementation and operation of such systems in the next two decades is discussed. Planning studies initiated by NASA are described as applied to space exploration, global services, and space industrialization, and a forecast of potential missions in each category is presented. The appendix lists highlights of space robot technology from 1967 to the present. Author

N78-30168*# Martin Marietta Corp., Denver, Colo.
STRUCTURAL ATTACHMENTS FOR LARGE SPACE STRUCTURES. TASK 1 REPORT: DEVELOPMENT OF ATTACHMENT CONCEPTS Final Report
W. R. Britton, R. A. Spencer, and M. D. Thulson Jul. 1978 82 p
(Contract NAS8-32654)
(NASA-CR-150773; MCR-78-596) Avail: NTIS HC A05/MF A01 CSCL 22B

Methodology and results are reported from the concept development study on structural attachments for large space structures. Key elements of each structure were identified in tabular form. These data were used to develop joint angles, beam elements used, size of structure, and to provide information of available construction support equipment. Attachment methods for constructing rectangular, trapezoidal, and tetrahedral large structures were also identified. G.G.

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08
PROPULSION

Includes propulsion designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.

A70-40202 # **Space electric rocket test solar array power system.** G. A. D. Shaw and J. C. Falconer (Lockheed Missiles and Space Co., Sunnyvale, Calif.). *American Institute of Aeronautics and Astronautics, Electric Propulsion Conference, 8th, Stanford, Calif., Aug. 31-Sept. 2, 1970, Paper 70-1159.* 8 p. Members, $1.25; nonmembers, $2.00.

Description of one of the largest power systems placed into a sun synchronous orbit with a capability of providing over six million watt hours of electrical energy for a period of six months. The 56-volt 1100-watt section output is provided directly to a power conditioning unit with no batteries in the system. The 28-volt 180-watt section provided the power to the spacecraft for housekeeping and auxiliary experiments. The deployment technique using springs in each leaf joint to extend the folded array into a flat fixed position is discussed, along with redundant electrical pyrotechnic circuits to enhance probability of deployment. (Author)

A74-10693 * # **Thermal control of the solar electric propulsion stage.** L. E. Ruttner (Rockwell International Corp., Space Div., Downey, Calif.). *American Institute of Aeronautics and Astronautics, Electric Propulsion Conference, 10th, Lake Tahoe, Nev., Oct. 31-Nov. 2, 1973, Paper 73-1118.* 11 p. 5 refs. Members, $1.50; nonmembers, $2.00. Contract No. NAS8-27360.

The thermal control requirements consist of functional requirements related to the various mission phase natural environments, operational requirements of induced power loadings by the solar electric propulsion stage subsystems, and design temperature limits for performance and reliability. The design approach utilizes passive thermal control techniques combining insulation, surface coatings, and sunshields with thermostatically controlled louvers. Heaters are used to regulate certain temperatures for extreme conditions. Details regarding the thruster array thermal control design are discussed, giving attention to the parameters used in the mathematical model, questions of conductive coupling, and thruster estimated power distribution. G.R.

A76-46136 * # **The ubiquitous solar electric propulsion stage.** R. E. Austin (NASA, Marshall Space Flight Center, Huntsville, Ala.), R. E. Dod, and C. H. Terwilliger (Boeing Aerospace Co., Kent, Wash.). *International Astronautical Federation, International Astronautical Congress, 27th, Anaheim, Calif., Oct. 10-16, 1976, Paper 76-171.* 12 p. Contract No. NAS8-31444.

Mission analyses indicate there are several near-term interplanetary missions that cannot be performed with any degree of sophistication without electric propulsion. Cost and performance benefits are suggested when this same technology is included in the Shuttle-based earth-orbital transportation system. Specific earth-orbital payload programs gain from increased weight allowances, decreased costs through simplification, and reduced numbers of spacecraft due to on-orbit servicing. More ambitious mission planners looking toward space industrialization will find uses ranging from GSO debris clearance to a versatile support element for a multi-purpose manned space station. (Author)

A77-15106 * # **Ion thruster design and analysis.** S. Kami and D. E. Schnelker (Hughes Research Laboratories, Malibu, Calif.). *American Institute of Aeronautics and Astronautics, International Electric Propulsion Conference, Key Biscayne, Fla., Nov. 14-17, 1976, Paper 76-1048.* 11 p. 16 refs. Contracts No. NAS3-17803; No. NAS3-18917.

Questions concerning the mechanical design of a thruster are considered, taking into account differences in the design of an 8-cm and a 30-cm model. The components of a thruster include the thruster shell assembly, the ion extraction electrode assembly, the cathode isolator vaporizer assembly, the neutralizer isolator vaporizer assembly, ground screen and mask, and the main isolator vaporizer assembly. Attention is given to the materials used in thruster fabrication, the advanced manufacturing methods used, details of thruster performance, an evaluation of thruster life, structural and thermal design considerations, and questions of reliability and quality assurance. G.R.

A77-48860 * **SEP full-scale wing technology development.** R. V. Elms, Jr. (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.) and L. E. Young (NASA, Marshall Space Flight Center, Huntsville, Ala.). In: Intersociety Energy Conversion Engineering Conference, 12th, Washington, D.C., August 28-September 2, 1977, Proceedings. Volume 2. La Grange Park, Ill., American Nuclear Society, Inc., 1977, p. 1329-1334. Contract No. NAS8-31352.

A technology development program has generated a detail design of a lightweight 25 kW solar array for Solar Electric Propulsion (SEP). The fabrication and test of a full-scale array wing, 32.0 m x 4.06 m, is in progress to demonstrate technology readiness for fabrication, testing and flight of the large area lightweight solar array system. This paper presents the requirements for the 66 W/kg array and the component testing that has been performed to demonstrate technology readiness in the areas of SEP mission environmental survival, zero-gravity flat-fold array retraction, and NDT development testing. A zero-gravity test program was performed in the NASA KC-135 aircraft using a three-panel, full-width segment of the flat-fold array blanket with three degrees of panel stiffening. The full-scale solar array wing being fabricated is composed of three electrical modules, 76 x 200 cm, and mass simulator panels each 76 x 400 cm employing 2 x 4 cm glass slides (4.5 panels) and aluminum mass simulators (35 panels). (Author)

A78-27931 # **Propulsion options for orbital transfers in cis-lunar space.** J. P. Layton (Techno-Systems Analysis Corp., Princeton, N.J.). In: Space manufacturing facilities II - Space colonies; Proceedings of the Third Conference, Princeton, N.J., May 9-12, 1977. New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 53-64. 16 refs.

Mission characteristics for the economic exploitation of cis-lunar space are reviewed in terms of present technology, and projected until the end of the century. Attention is given to the construction of public service platforms (including SSPS) and the types of vehicles and propulsion systems which will be needed for their assembly, e.g., the Space Shuttle and its heavier derivatives, HLLV, IUS, manned orbital transfer vehicles, solar and nuclear electric propulsion, and solid core nuclear fission rockets. More exotic means of propulsion, for use during the 21 century, are also mentioned, including mass-drivers, nuclear fusion, lasers, and matter/anti-matter pods. D.M.W.

A78-30247 # **Electric propulsion ready for space missions.** E. Stuhlinger (Alabama, University, Huntsville, Ala.). *Astronautics and Aeronautics,* vol. 16, Apr. 1978, p. 66-77.

Electric propulsion is now considered sufficiently well developed to permit its use in spaceflight applications. Among the applications discussed are orbit-to-orbit transfers, attitude control for large space structures, and homogeneous ion sources for space manufacturing. Attention is given to the present state-of-the-art, i.e., the electron bombardment engine with Kaufman thrusters, but extensions of today's technology are also considered, especially argon thrusters, with a 0.6-1.0 m nozzle diameter, 200-400 kW input power, and a specific impulse of 8,000-13,000 seconds. Tests of engine lifetime are described for various thruster configurations, most notably of the MPD variety. D.M.W.

A78-32733 * # **System design of an ion drive spacecraft.** J. Stuart (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *American Institute of Aeronautics and Astronautics and Deutsche Gesellschaft für Luft- und Raumfahrt, International Electric Propulsion Conference, 13th, San Diego, Calif., Apr. 25-27, 1978, AIAA Paper 78-642.* 18 p. 20 refs. Contract No. NAS7-100.

As electric propulsion technology has improved and mission requirements have changed, a series of Ion Propulsion Module (IPM) design concepts have evolved. The most recent iteration occurred in the NASA-sponsored Halley Comet Rendezvous Mission (HCRM) study of ion drive. Spacecraft system design considerations introduced by the integration of such an IPM as the primary propulsion source are described with reference to the synthesis of the HCRM spacecraft and spacecraft design considerations for other interplanetary applications. IPM interactions with the system (especially telecommunications and science) are found to be manageable. The spacecraft design developed for the HCRM indicates the interface simplicity between the IPM and the spacecraft. Methods are shown for readily applying this IPM to a variety of planetary missions. Methods are also described for the IPM to provide up to 5 kW to the spacecraft for increasing the mission science return. (Author)

A78-32765 * # **Self-powered electric propulsion of satellite power systems.** J. B. Weddell, W. V. McRae, and S. T. Cerri (Rockwell International Corp., Space Div., Downey, Calif.). *American Institute of Aeronautics and Astronautics and Deutsche Gesellschaft für Luft- und Raumfahrt, International Electric Propulsion Conference, 13th, San Diego, Calif., Apr. 25-27, 1978, AIAA Paper 78-694.* 10 p. 9 refs. Research supported by the Rockwell International Corp.; Contract No. NAS8-42375.

Electric propulsion using argon ion bombardment thrusters is described as a means of transferring solar power satellites from low earth orbit (LEO) to geosynchronous equatorial orbit (GEO). A portion of the satellite GaAs solar array is constructed in LEO and provides power for ascent propulsion; the remainder of the array is constructed in GEO. The electric propulsion system is returned to LEO by detaching a section of the solar array. Alternatively, an autonomous electric propulsion vehicle is assembled in LEO and transports power satellite materials to a GEO construction site. Maximum thrust per thruster and minimum argon consumption are achieved at specific impulse (Isp) 13,000 s. The thrust/power relationship leads to minimum transportation vehicle mass, including the solar array, at Isp 9,000 s. Thruster screen, accel, and discharge supplies are obtained directly from the solar array. (Author)

A78-37440 # **Size, performance and cost trades of large solar electric propulsion systems.** H. F. Meissinger (TRW Defense and Space Systems Group, Redondo Beach, Calif.). *American Institute of Aeronautics and Astronautics and Deutsche Gesellschaft für Luft- und Raumfahrt, International Electric Propulsion Conference, 13th, San Diego, Calif., Apr. 25-27, 1978, AIAA Paper 78-697.* 22 p. 10 refs.

The trend toward development of large, primary solar-electric propulsion (SEP) systems for interplanetary and earth-orbital applications calls for re-examination from a cost-effectiveness standpoint. The size-versus-performance tradeoff is dominated by the fact that a large increase in solar-electric power level tends to yield only a limited increase in thrust-to-weight ratio, thus the system performance is not improved in proportion with cost. Conversely, major cost reductions are achievable by reducing the size of a proposed SEP system at only a modest loss in performance. The influence on this tradeoff of principal parameters such as payload ratio, thrust system efficiency, specific impulse and solar array and propulsion system specific mass is derived, recommendations regarding system and mission design are presented and the impact of technology advances is assessed. (Author)

A78-37441 * # **Economics of ion propulsion for large space systems.** T. D. Masek, J. W. Ward (Hughes Research Laboratories, Malibu, Calif.), and V. K. Rawlin (NASA, Lewis Research Center, Cleveland, Ohio). *American Institute of Aeronautics and Astronautics and Deutsche Gesellschaft für Luft- und Raumfahrt, International Electric Propulsion Conference, 13th, San Diego, Calif., Apr. 25-27, 1978, AIAA Paper 78-698.* 19 p. Contract No. NAS3-20101.

This study of advanced electrostatic ion thrusters for space propulsion was initiated to determine the suitability of the baseline 30-cm thruster for future missions and to identify other thruster concepts that would better satisfy mission requirements. The general scope of the study was to review mission requirements, select thruster designs to meet these requirements, assess the associated thruster technology requirements, and recommend short- and long-term technology directions that would support future thruster needs. Preliminary design concepts for several advanced thrusters were developed to assess the potential practical difficulties of a new design. This study produced useful general methodologies for assessing both planetary and earth orbit missions. For planetary missions, the assessment is in terms of payload performance as a function of propulsion system technology level. For earth orbit missions, the assessment is made on the basis of cost (cost sensitivity to propulsion system technology level). (Author)

A78-43879 * **Solar electric propulsion and interorbital transportation.** R. E. Austin (NASA, Marshall Space Flight Center, Huntsville, Ala.). In: The industrialization of space; Proceedings of the Twenty-third Annual Meeting, San Francisco, Calif., October 18-20, 1977. San Diego, Calif., American Astronautical Society; Univelt, Inc., 1978. 27 p. 11 refs. (AAS 77-221)

In-house MSFC and contracted systems studies have evaluated the requirements associated with candidate SEP missions and the results point to a standard system approach for both program flexibility and economy. The prospects for economical space transportation in the 1980s have already provided a stimulus for Space Industrialization (SI) planning. Two SI initiatives that are used as examples for interorbital transportation requirements are discussed - Public Service Platforms and Satellite Power System. The interorbital requirements for SI range from support of manned geosynchronous missions to transfers of bulk cargo and large-delicate space structures from low earth orbit to geosynchronous orbit. B.J.

N69-28861*# Astro Research Corp., Santa Barbara, Calif.
HELIOGYRO SOLAR SAILER Summary Report
Richard H. Mac Neal, John M. Hedgedeth, and Hans U. Schuerch
Washington NASA Jun. 1969 84 p refs
(Contract NAS7-427)
(NASA-CR-1329; ARC-R-297) Avail: CFSTI CSCL 22B

Studies have been performed on the feasibility of a large solar-sail vehicle using long, narrow blades and operating in the manner of a helicopter rotor. This vehicle, the Heliogyro, is superior to other propulsion and attitude-control systems for many missions requiring large total impluse and long flight times. A conceptual configuration has been evolved in which the thin aluminized film blades are unrolled from spools during deployment. Centrifugal forces are used for stiffening the long, narrow solar sails. Control of the attitude of the sail with respect to the solar rays is accomplished by pivoting the deployment spools and thus rotating the long blades about their lengthwise axes. Combinations of collective and cyclic blade pitch can provide all of the required control responses. Results of the various theoretical analyses which have led to this Heliogyro solar-sail concept are summarized. Evaluations of a number of missions are presented. The desirability of an experimental program to develop technology and establish feasibility is indicated. Author

N73-33002*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
THE ADVANTAGES OF THE HIGH VOLTAGE SOLAR ARRAY FOR ELECTRIC PROPULSION
Bernard L. Sater 1973 28 p refs Presented at 10th Elec. Propulsion Conf., Lake Tahoe, Nev., 31 Oct. - 2 Nov. 1973; sponsored by AIAA
(NASA-TM-X-71462; E-7758) Avail: NTIS HC $3.50 CSCL 10A

The high voltage solar array offers improvements in efficiency, weight, and reliability for the electric propulsion power system. Conventional power processes and problems associated with ion thruster operation using SERT 2 experience are discussed and the advantages of the HVSA concept for electric propulsion are presented. Tests conducted operating the SERT 2 thruster system in conjunction with HVSA are reported. Thruster operation was observed to be normal and in some respects improved. Author

N76-14161*# Aerospace Corp., El Segundo, Calif. Vehicle Systems Div.
STS SPIN-STABILIZED UPPER STAGE STUDY (STUDY 2.6). VOLUME 1: EXECUTIVE SUMMARY Final Report
30 Sep. 1975 46 p
(Contract NASw-2727)
(NASA-CR-145907; ATR-75(7367)-1-Vol-1) Avail: NTIS HC $4.00

Spinning solid propellant upper stage rocket engines designed for geosynchronous satellite payloads are investigated. Factors considered include: impact of the spinning stages on the payloads; applicability to 1981-1991 NASA mission model; and cost effectiveness. J.M.S.

N76-14162*# Aerospace Corp., El Segundo, Calif. Vehicle Systems Div.
STS SPIN-STABILIZED UPPER STAGE STUDY (STUDY 2.6). VOLUME 2: TECHNICAL REPORT Final Report
30 Sep. 1975 469 p refs
(Contract NASw-2727)
(NASA-CR-145908; ATR-75(7367)-1-Vol-2) HC $12.00 CSCL 22B

For abstract, see N76-14161.

N77-11106*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
ELECTRON BOMBARDMENT PROPULSION SYSTEM CHARACTERISTICS FOR LARGE SPACE SYSTEMS
D. C. Byers and V. K. Rawlin 1976 33 p refs Presented at the 12th Intern. Elec. Propulsion Conf., Key Biscayne, Fla., 15-17 Nov. 1976; sponsored by AIAA
(NASA-TM-X-73554; E-8992) Avail: NTIS HC A03/MF A01 CSCL 21C

The results of an anlaysis of electron bombardment ion propulsion systems for use in the transportation and on-orbit operations of large space systems are presented. Using baseline technology from the ongoing primary propulsion program and other sources, preliminary estimates of the expected characteristics of key system elements such as thrusters and propellant storage systems were performed. Projections of expected thruster performance on argon are presented based on identified constraints which limit the achievable thrust and/or power density of bombardment thrusters. System characteristics are then evaluated as a function of thruster diameter and specific impulse. Author

N77-13914*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 5: PROPULSION TECHNOLOGY PANEL, PART 1 Final Report
Aug. 1975 242 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73965) Avail: NTIS HC A11/MF A01 CSCL 21H

Payload experiments which could be carried out in near earth space using the shuttle orbiter, its payload bay, the Spacelab, and/or some free-flying device that might be used for long duration testing were identified. Specific areas examined in terms of user requirements include: chemical propulsion, nuclear propulsion (fission, fussion, radioisotopes), and collected energy (coherent energy and solar electromagnetic energy). Cost reduction objectives for advanced propulsion technology development were also developed. J.M.S.

N78-26154*# General Research Corp., McLean, Va.
SOLAR SAIL-SOLAR ELECTRIC TECHNOLOGY READINESS AND TRANSFER ASSESSMENT Final Report
Ramon L. Chase Aug. 1977 62 p
(Contract NASw-2973)
(NASA-CR-157239; Rept-709-01-CR; WGRC-77-4764) Avail: NTIS HC A04/MF A01 CSCL 22A

A method of conducting a technology readiness assessment was developed. It uses existing OAST technology readiness and risk criteria to define a technology readiness factor that considers both the required gain in technology readiness level to achieved technology readiness plus the degree of effort associated with achieving the gain. The results indicate that Solar Electric Propulsion is preferred based on technology readiness criteria. Both Solar Sail and Solar Electric Propulsion have a high level of transfer potential for future NASA missions, and each has considerable technology spillover for non-NASA applications. Author

N78-30659*# Lockheed Missiles and Space Co., Sunnyvale, Calif. Electrical Power Systems Dept.
STUDY OF SEP SOLAR ARRAY MODIFICATIONS Final Report
G. J. Antonides 14 Jul. 1978 57 p refs
(Contracts NAS7-100; JPL-995070)
(NASA-CR-157403; LMSC-D573788) Avail: NTIS HC A04/MF A01 CSCL 10A

The feasibility of modifying the solar electric propulsion (SEP) 66 watt/kilogram, 12.5 kilowatt solar array blanket design to incorporate ultra-low mass blanket technology and to generate conceptual design data by modifying the SEP solar array design to 17.5kW power output was performed. Five modified designs were developed, which substituted present SEP solar array design components with one or more of 50 micron thick solar cells, 75 micron cell coverglasses, and a different blanket substrate developed by GE. A parametric analysis was performed to determine the solar array mast least weight and blanket tension required to maintain a minimum natural frequency of 0.04 Hz. The solar array wing assembly weights and power outputs were calculated, and preliminary cost estimates for flight hardware development, fabrication and qualification were made for each case studied. S.E.S.

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FLIGHT EXPERMENTS

Includes controlled experiments requiring high vacuum and zero G environment.

A71-21368 * Applications technology satellites F and G. H. L. Gerwin (NASA, Goddard Space Flight Center, Greenbelt, Md.). *Society of Automotive Engineers, National Aeronautic and Space Engineering and Manufacturing Meeting, Los Angeles, Calif., Oct. 5-9, 1970, Paper 700759.* 7 p. Members, $1.00; nonmembers, $1.50.

A brief description of the NASA Applications Technology Satellite Program and the basic design features of the ATS-F and -G spacecraft, the latest in the series, is presented. The Applications Technology Satellites F and G will be geostationary platforms for conducting a number of communication technology experiments. The main feature of these spacecraft is a 30-foot parabolic deployable antenna which can be precisely pointed (0.1 deg). Descriptions of the technology experiments planned for ATS-F are included to illustrate some of the objectives of the ATS program. (Author)

A76-12889 * # **Large Deployable Antenna Shuttle Experiment.** R. E. Freeland, J. G. Smith, J. C. Springett, and K. E. Woo (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Calif.). *AAS, AIAA, IEEE, ORSA, and IMS, Meeting on Space Shuttle Missions of the 80's, Denver, Colo., Aug. 26-28, 1975, AAS Paper 75-253.* 14 p. 13 refs. Contract No. NAS7-100.

An experiment designed to use the Space Shuttle in tests of the mechanical and electrical properties of spaceborne deployable antennas under zero-gravity conditions is outlined. Space-erectable 20-meter diameter phased arrays or reflector/feed systems, and self-deploying mechanisms, are to be tested. Reflector surface integrity will be tested by an AM laser technique, and electrical behavior will be tested by a spin-stabilized RF beacon injected into orbit prior to unfurlment of the antenna. Focusing and gain measurements, static pattern measurements, dynamic RF gain measurements, and measurements of cross-polarized signals will be conducted, and the reflector will be illuminated by separate feeds for the S-, X-, and K-bands. Mechanical features of the mesh-wrapped rib furlable antenna design are described. R.D.V.

N68-27931# Air Force Systems Command, Wright-Patterson AFB, Ohio. Air Force Aero Propulsion Lab.
ZERO-G SIMULATION AND ITS RELATIONSHIP TO SPACE EXPERIMENTS
Gary B. Reid (AMRL) and Daniel R. Seger *In* its Expandable and Modular Struct. Conf. May 1967 p 285–298 refs

Techniques for achieving or simulating zero g are discussed, and their applicability in the design and procedures determination for the D-021 and D-023 space structure experiments is reviewed. The three primary methods used in simulating zero g are: aircraft flying keplerian trajectories, water immersion to attain neutral buoyancy, and mechanical simulators consisting of frictionless platforms with gimballed support structure. Of the three types, only two, zero g aircraft and neutral buoyancy, were used extensively. The simulation effort was primarily applied to minimize operational difficulties involved with the D-021 (Expandable Airlock Experiment) and D-023 (10-ft diameter parabolic antenna) experiments. The Expandable Airlock Experiment (D-021) consists of an expandable airlock module complete with an instrumentation system capable of monitoring all aspects of the experiment. The simulation effort was directed primarily toward solving problems associated with the ingress/egress operation. In addition, an emergency retrieval procedure was developed. The zero g aircraft will be used in the D-021 experiment primarily to validate the ingress/egress procedures, the handhold locations, and hatch actuation. The second experiment simulated consists of a modularly assembled 10 foot diameter parabolic antenna. The experiment, designated D-023, is planned to be assembled inside the SIVB tank by a crewman in a pressurized suit. Improvements resulting from simulation are discussed. No zero g aircraft simulation was performed on the D-023 experiment due to the inability of the assembled structure to sustain the 2 g loading encountered in the flight profile. S.C.W.

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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 nine categories. Shuttle payload requirements, on-board requirements, data rates, and shuttle interfaces, and publications of conferences, seminars, and workshops will be covered in this area.

A71-35427 # **Payload handling for the Space Shuttle.** Ralph G. Schmitt (North American Rockwell Corp., Space Div., Downey, Calif.). *American Institute of Aeronautics and Astronautics, Space Systems Meeting, Denver, Colo., July 19, 20, 1971, Paper 71-811.* 9 p. Members, $1.50; nonmembers, $2.00.

Recommendation of an on-orbit payload handling concept for the Space Shuttle is traced back to tradeoffs involving both docking (Space Station resupply mission) and payload handling (all missions). Mechanism alternatives that satisfy requirements for both docking and payload handling fall into three classes: rotation, translation, and articulation. The most attractive concept is articulation (manipulator arms). Arms are used to draw two vehicles together for docking, as well as to deploy and retrieve payloads. In addition to manipulator arms, the concept includes a manipulator operation station, a payload retention assembly, an airlock docking port, illumination, and closed-circuit television. (Author)

A71-36018 # **Study of aerospace mechanisms in weightlessness (Etude des mécanismes aérospatiaux en impesanteur).** Roger Marguet and Jean Trichard (ONERA, Châtillon-sous-Bagneux, Hauts-de-Seine, France). *(Centro Studi Trasporti Missilistici, Conférence Internationale sur la Technologie Spatiale, 3rd, Rome, Italy, May 3-8, 1971.) ONERA, TP* no. 940, 1971. 28 p. In French.

Study of the actual behavior in relative weightlessness of space mechanisms such as stage separation devices or of satellites of small perturbation, yoyos, and development mechanisms for probes and masts. The principle utilized consists of simulating flight conditions by releasing the material to be tested, then carrying out, in the course of free flight, the sequences to be studied. A gyrometric system, accurate to 0.15 deg/sec, transmits by telemetry the information concerning the motions of the elements released. The installation, situated in a tower, permits studies on assemblies weighing up to 1000 kg, with the possibility of rotating them from 0 to 6 rps, with fall height of 6 m. The studies and tests carried out on behalf of French and European space programs are reviewed and analyzed. F.R.L.

A76-28871 * ***Shuttle avionics system.*** R. A. Gardiner and W. C. Bradford (NASA, Johnson Space Center, Houston, Tex.). In: International Federation of Automatic Control, Triennial World Congress, 6th, Boston and Cambridge, Mass., August 24-30, 1975, Proceedings. Part 4. Pittsburgh, Pa., Instrument Society of America, 1975, p. 6.1 1-6.1 8.

The avionics system of the Space Shuttle is designed in a fail operational/fail safe architecture. The guidance, navigation and control system is implemented, through the onboard Orbiter digital computers. Guidance, navigation and control sensors are triplex, while the flight control effectors are mechanized either in load sharing or quad structure. Two sets of basic flight instruments and controls are provided along with electronic interfaces to allow for multiple selection of input destination and display source selection. Communications, tracking and instrumentation subsystems are mechanized as a dual hardware design for key operational elements. The data processing system allows for quad, triplex, dual or single computer operation. The power distribution subsystem provides a triple bus system with appropriate tie elements. A functional description is given of the computer system, the data bus, the mass memory unit, the multiplexer/demultiplexer and the CRT display system. B.J.

A76-29321 * # **Building large structures in space.** T. Hagler (NASA, Office of Manned Space Flight, Washington, D.C.). *Astronautics and Aeronautics,* vol. 14, May 1976, p. 56-61. 5 refs.

The building of large structures in space would be required for the establishment of a variety of systems needed for different forms of space utilization. The problems involved in the building of such structures in space and the approaches which can be used to solve these problems are illustrated with the aid of an example involving a concept for packaging, transporting, and assembling two representative large space structures. The structure of a radio-astronomy telescope 200 m in diam was felt to be representative of the many medium-size structures of the Shuttle era. A typical very large structure is represented by the supporting structure for the transmission system of a 5000-Mw space solar power station. G.R.

A77-20563 **Utilization of Space Shuttle and Spacelab; Proceedings of the International Meeting, Bonn, West Germany, June 2-4, 1976.** *Meeting sponsored by the Deutsche Gesellschaft für Luft- und Raumfahrt and American Astronautical Society.* Cologne, Deutsche Gesellschaft für Luft- und Raumfahrt, 1976. 759 p. In English and German.

Perspectives of space technology with respect to industrially usable innovations are considered along with the significance of Spacelab utilization for materials science, the space processing of gas turbine blades, the investigation of new communication technologies, optical radar payloads for atmospheric research, and the concept of a multidisciplinary optical radar. Attention is also given to questions concerning the international usage of the Space Transportation System, a two-frequency microwave scatterometer for measuring ocean waves, large ultralight deployable antennas and solar generators, and an evaluation of the potential for future space solar systems.

Individual items are announced in this issue. G.R.

A77-31833 * # **Toward large space systems.** C. J. Daros (McDonnel Douglas Astronautics Co., Huntington Beach, Calif.), R. F. Freitag (NASA, Office of Space Flight, Washington, D.C.), and R. L. Kline (Grumman Aerospace Corp., Bethpage, N.Y.). *Astronautics and Aeronautics,* vol. 15, May 1977, p. 22-30.

The design of the Space Transportation System, consisting of the Space Shuttle, Spacelab, and upper stages, provides experience for the development of more advanced space systems. The next stage will involve space stations in low earth orbit with limited self-sufficiency, characterized by closed ecological environments, space-generated power, and perhaps the first use of space materials. The third phase would include manned geosynchronous space-station activity and a return to lunar operations. Easier access to space will encourage the use of more complex, maintenance-requiring satellites than those currently used. More advanced space systems could perform a wide range of public services such as electronic mail, personal and police communication, disaster control, earthquake detection/prediction, water availability indication, vehicle speed control, and burglar alarm/intrusion detection. Certain products, including integrated-circuit chips and some enzymes, can be processed to a higher degree of purity in space and might eventually be manufactured there. Hardware including dishes, booms, and planar surfaces necessary for advanced space systems and their development are discussed. M.L.

A77-31834 * # **Integrating Shuttle payloads.** O. C. Jean and R. C. Lester (NASA, Marshall Space Flight Center, Huntsville, Ala.). *Astronautics and Aeronautics,* vol. 15, May 1977, p. 31-35.

The paper discusses the relationships that will develop among experimenters, mission managers, and operators when satellites, using equipment transported by the Space Shuttle, are constructed in space. Since these satellites do not have to be lifted and guided from the earth's surface, and since they are more accessible for maintenance, future hardware will be built to less demanding standards, which will permit a greater variety of research and more of it in terms of costs. Present and future interrelationships among management authority, interface documentation, accommodations allocation, experiment autonomy, and assembly and checkout are analyzed, so that less costly payload-integration procedures can be developed. M.L.

A77-35825 * # **Summary of problems of greatest urgency.** R. F. Freitag (NASA, Washington, D.C.). In: Space manufacturing facilities: Space colonies; Proceedings of the Princeton Conference, Princeton, N.J., May 7-9, 1975. New York, American Institute of Aeronautics and Astronautics, Inc., 1977, p. 203-207; Discussion, p. 207, 208.

A description is presented of the activities which would be important in connection with the objective to find a course of action to achieve permanent occupancy of space. One of the technical problems to be solved is related to the development of a closed ecological system in space. Lunar material transportation and collection is a second major problem. The development of either automated, manned, or mixed construction technologies for the assembly of large structures in space is also important. Attention is also given to the design of the habitat, the need for a better understanding of the genetic effects of an increased radiation dosage over long periods of time, and the current status of space activities. G.R.

A77-47268 # **Orbital antenna farms.** B. I. Edelson and W. L. Morgan (COMSAT Laboratories, Clarksburg, Md.). *Astronautics and Aeronautics,* vol. 15, Sept. 1977, p. 20-28. 9 refs.

It is predicted that in the 1990s there will be a small number of very large platforms in geostationary orbit furnishing multiple communications and mission support functions. Such a platform would be an Orbiting Antenna Farm (OAF) serving many missions with common functional support systems. An OAS could furnish intercontinental trunking, regional and domestic trunking, business networks, maritime services, TV broadcast, intersatellite communication, and meteorological missions. Projected requirements, frequencies, and power levels for a single platform to service these missions are given. An OAF may be serviced in space, and missions may be modified or added. P.T.H.

A78-16698 * # **Learning to build large structures in space.** T. Hagler (NASA, Office of Space Flight, Washington, D.C.), H. G. Patterson (NASA, Johnson Space Center, Houston, Tex.), and C. A. Nathan (Grumman Aerospace Corp., Bethpage, N.Y.). *Astronautics and Aeronautics,* vol. 15, Dec. 1977, p. 51-57.

The paper examines some of the key technologies and forms of construction know-how that will have to be developed and tested for eventual application to building large structures in space. Construction of a shuttle-tended space construction/demonstration platform would comprehensively demonstrate large structure technology, develop construction capability, and furnish a construction platform for a variety of operational large structures. Completion of this platform would lead to demonstrations of the Satellite Power System (SPS) concept, including microwave transmission, fabrication of 20-m-deep beams, conductor installation, rotary joint installation, and solar blanket installation. P.T.H.

A78-19543 * # **Next steps in space transportation and operations.** J. H. Disher (NASA, Office of Space Transportation Systems, Washington, D.C.). *Astronautics and Aeronautics,* vol. 16, Jan. 1978, p. 22-30. 8 refs.

Design of a 25-kW power or utilities module, capable of extending the effective duration of Spacelab missions, is discussed. The power module, planned for availability in 1984, could also support a Spacelab modified to be a free-flyer by providing attitude control and power. In addition, development of a 250-kW power module to support a Shuttle-tended space platform or a Shuttle-tended space construction base is projected. A free-flying teleoperator capable of deboosting Skylab, systems to construct large planar arrays in space, and a habitable module providing crew quarters for continuously manned operations are also described. J.M.B.

A78-36701 **The industrialization of space; Proceedings of the Twenty-third Annual Meeting, San Francisco, Calif., October 18-20, 1977. Parts 1 & 2.** Meeting sponsored by AAS, AIAA, American Society for Quality Control, et al. Edited by R. A. Van Patten (Stanford University, Stanford, Calif.), P. Siegler, and E. V. B. Stearns (Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.). San Diego, Calif., American Astronautical Society (Advances in the Astronautical Sciences. Volume 36, pts. 1 & 2); Univelt, Inc., 1978. Pt. 1, 608 p.; pt. 2, 541 p. Price of two parts, $85.

The technical aspects of large space structures are discussed, taking into account freedoms from constraints in solar power satellite design, the automated space fabrication of structural elements, a near-term space demonstration program for large structures, solar power satellite construction concepts, and structural and assembly concepts for large erectable space systems. Advanced transportation systems are considered along with the technical aspects of systems implementation, the key steps in the development program to space industrialization, communications and navigation, the technical aspects of space habitation, historical precursors and analogs, the economic realities of space operations, psycho-social and biological considerations, and problems of space law. Questions of space community planning are also investigated, giving attention to space community planning in a down-to-earth context, design principles and cultures, a preliminary investigation of space habitat atmospheres, alternative social structures in a vacuum, and space industrialization as a challenge to private enterprise capitalism. G.R.

A78-36704 * **A near term space demonstration program for large structures.** C. A. Nathan (Grumman Aerospace Corp., Bethpage, N.Y.). In: The industrialization of space; Proceedings of the Twenty-third Annual Meeting, San Francisco, Calif., October 18-20, 1977. Part 1. San Diego, Calif., American Astronautical Society; Univelt, Inc., 1978, p. 57-77. 6 refs. Contract No. NAS9-14916. (AAS 77-202)

For applications involving an employment of ultralarge structures in space, it would be necessary to have some form of space fabrication and assembly in connection with launch vehicle payload and volume limitations. The findings of a recently completed NASA sponsored study related to an orbital construction demonstration are reported. It is shown how a relatively small construction facility which is assembled in three shuttle flights can substantially advance space construction know-how and provide the nation with a permanent shuttle tended facility that can further advance large structures technologies and provide a construction capability for deployment of large structural systems envisioned for the late 1980s. The large structures applications identified are related to communications, navigation, earth observation, energy systems, radio astronomy, illumination, space colonization, and space construction. G.R.

A78-38774 **Structure assembly demonstration slated.** C. Covault. *Aviation Week and Space Technology,* vol. 108, June 12, 1978, p. 49, 52, 53.

A proposal to test the large structures fabrication capability of the STS is presented with reference to a 10 x 30 meter structure that could be deployed as early as 1983 with a science/applications payload, or remain attached to the Shuttle. Attention is given to the prospect of deploying large antennas in both LEO and GEO, the first of which would be powered by a 25 kW module. The use of aluminum rolls, which could be processed into beams once in space, is viewed as the most likely approach to the problem of large structure fabrication. D.M.W.

A78-42509 **Platform designed for numerous uses.** C. Covault. *Aviation Week and Space Technology,* vol. 108, June 19, 1978, p. 67, 68, 73.

An 82 x 31 meter GEO platform, expected to be operational by 1986, is described in terms of the antennas it will carry. It is noted that the platform is designed to be able to take over the function of more than a dozen communications and meteorological satellites now serving North America. Primary hardware on the platform includes: a 30 m dia C-band antenna capable of directing 37 spot beams to the 48 contiguous states and one beam each to Alaska, Hawaii, and Puerto Rico; one 12 m Ku-band antenna and 4 independently gimbaled Ku-band antennas of 4.5 m each, permitting direct-broadcast to earth receivers as small as 1.6 m; S- and K-band capability; and an L-band system for use both in conjunction with the Marisat, Marots, and Aerosat programs, and for direct broadcast links to mobile receivers, e.g. automobiles. The platform would be assembled on two external Shuttle tanks over the course of three Space Shuttle missions. D.M.W.

A78-51976 # **Geosynchronous information services platforms in the year 2000.** H. L. Wolbers and F. H. Shepphird (McDonnell Douglas Astronautics Co., Huntington Beach, Calif.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1636.* 11 p. 10 refs.

Economic, social, and political factors related to the development of space information-relay systems and communication services during the next two decades are discussed. Service requirements are projected to the year 2000 for typical preindustrial, industrial, and postindustrial societies. It is found that the growing demands for communication-related services can best be satisfied by developing larger, more sophisticated space systems, requiring orbital assembly and/or construction, in order to reduce the size, complexity, and cost of ground terminals. B.J

A78-51982 * # **Large space structures at the Marshall Space Flight Center.** J. K. Harrison and C. R. Darwin (NASA, Marshall Space Flight Center, Huntsville, Ala.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1650.* 18 p.

The Space Shuttle will provide a new capability for the construction in space of structures too large to be accommodated in the Shuttle bay. To understand and develop this new capability several construction methods and design approaches are being studied by MSFC and industry. This paper relates the general scope of these ongoing activities, the project aims and objectives, and a discussion of many design and equipment variables. Major design and construction variables, such as on-orbit or ground fabricated construction and type of materials to be used, are discussed relative to their status and applicability to various designs. Construction methods and options are reviewed and many of the support equipments under study or development are described. (Author)

A78-51993 # **Manned remote work stations.** C. A. Nathan (Grumman Aerospace Corp., Bethpage, N.Y.). *American Institute of Aeronautics and Astronautics, Conference on Large Space Platforms: Future Needs and Capabilities, Los Angeles, Calif., Sept. 27-29, 1978, Paper 78-1667.* 13 p. 7 refs.

The exploration and utilization of space has witnessed a continuous growth in spacecraft size and weight. Many applications are now envisioned which require ultralarge space structures for implementation. Due to the restrictions of payload and volume limitations of current and projected launch systems, space construction of these ultralarge structures is essential. The paper discusses the concepts and application of a key piece of construction equipment needed to support assembly of these large structures. The Manned Remote Work Station is a universal crew cabin to be used as a construction cherry picker, space crane turret, railed work station, or a free flyer. Concepts and requirements for this spacecraft are delineated for early applications in support of Shuttle operations, applications in support of a mid- to-late-1980s space construction base, and finally in support of constructing and maintaining a Solar Power Satellite system. (Author)

N68-27917# Air Force Systems Command, Wright-Patterson AFB, Ohio. Air Force Aero Propulsion Lab.
EXPANDABLE AND MODULAR STRUCTURES CONFERENCE
May 1967 723 p refs 3d Aerospace Conf. held Miami Beach, Fla., 16–18 May 1967
(AFAPL-TR-68-17; AD-668181)

The Aerospace Expandable and Modular Structures Conference serves as a forum in which leading authorities in structures technology advance new ideas and techniques for critical discussion. The objectives of the conference were (1) to present current research and development contributions in the fields of expandable and modular structures and, (2) through the exchange and evaluation of the most advanced concepts, to simulate further advances in structures technology.

N75-20468# Communications Research Centre, Ottawa (Ontario). Spacecraft Mechanics Directorate.
COMMUNICATIONS TECHNOLOGY SATELLITE DEPLOYED SOLAR ARRAY DYNAMICS TESTS
T. D. Harrison Jan. 1975 44 p refs
(CRC-1264) Avail: NTIS HC $3.75

A vibration test facility and a test program for the deployed dynamic testing of large flexible solar arrays are described. The results of tests conducted on an array from the Communications Technology Satellite Program are presented. The tests found 8 blanket resonances, 7 array resonances, and the damping coefficients--or the equivalent linear damping coefficients for the resonances that had a nonlinear damping coefficient--of 4 of the 7 array resonances. Also, it is observed that certain resonances are excited by subharmonic excitation. Author

N75-22504# European Space Research Organization, Paris (France).
LARGE STRUCTURES FOR MANNED SPACECRAFT: MATHEMATICAL ANALYSIS, DESIGN, CONSTRUCTION AND TESTS
Mar. 1974 618 p refs Partly in ENGLISH; partly in FRENCH Proc. of 3d Testing Symp., Frascati, Italy, 22-26 Oct. 1973
(ESRO-SP-99) Avail: NTIS HC $15.25

Results and findings on the various aspects relating to structural problems concerning large structures for manned spacecraft are presented. Selected studies are described in the fields of: (1) mathematical analysis (finite element methods, structure dynamic optimization, damping analysis, thermal distortion, NASTRAN analysis), (2) design (aircraft structural technology, reliability, low cost approaches, structural trade studies, reusable structures, mechanical properties of composite materials); (3) construction (machinery and tooling methods, bonding, jointing riveting, bolting, welding processes); and (4)tests (environmental fatigue, dynamic, mechanical, acoustic, and modal tests; nondestructive testing methods; data acquisition and processing techniques).

N75-22531 Lockheed Missiles and Space Co., Sunnyvale, Calif.
STRUCTURAL DYNAMIC TESTING CONSIDERATIONS FOR LARGE SPACE VEHICLES
R. J. Herzberg *In* ESRO Large Struct. for Manned Spacecraft Mar. 1974 p 429-439

The transition from the design and manufacture of relatively small satellites in the 100-300 kg range to large satellites weighing above 10,000 kg has been made. The structural dynamic testing program for the large vehicles differs significantly from those used successfully for the smaller spacecraft. Experiences in this area are discussed in survey format. The more significant differences, such as acoustic test philosophy and modal testing, are emphasized. Author (ESRO)

N75-23620*# Aerospace Corp., El Segundo, Calif.
MANNED SYSTEMS UTILIZATION ANAYLSIS. STUDY 2.1: SPACE SERVICING PILOT PROGRAM STUDY
R. R. Wolfe 30 Jan. 1975 54 p refs
(Contract NASw-2727)
(NASA-CR-142758; ATR-75(7361)-1) Avail: NTIS HC $4.25 CSCL 22A

Space servicing automated payloads was studied for potential cost benefits for future payload operations. Background information is provided on space servicing in general, and on a pilot flight test program in particular. An fight test is recommended to demonstrate space servicing. An overall program plan is provided which builds upon the pilot program through an interim servicing capability. A multipayload servicing concept for the time when the full capability tug becomes operational is presented. The space test program is specifically designed to provide low-cost booster vehicles and a flight test platform for several experiments on a single flight. L.R.B.

N76-15500*# Astro Research Corp., Santa Barbara, Calif.
SURVEY OF FUTURE REQUIREMENTS FOR LARGE SPACE STRUCTURES Final Report
John M. Hedgepeth Washington NASA Jan. 1976 53 p refs
(Contract NAS1-13178)
(NASA-CR-2621) Avail: NTIS HC $4.50 CSCL 20K

The future requirements for large space structures were examined and the foundation for long range planning of technology development for such structures is provided. Attention is concentrated on a period after 1985 for actual use. Basic ground rule of the study was that applications be of significant importance and have promise of direct economic benefit to mankind. The inputs to the study came from visits to a large number of government and industrial organizations, written studies in current literature, and approximate analyses of potential applications. The paper identifies diverse space applications for large area structures in three general categories: (1) large surfaces for power, (2) large antenna to receive and transmit energy over the radio frequency bandwidth, and (3) space platforms to provide area for general utilizations. Author

N76-18004*# National Aeronautics and Space Administration, Washington, D.C.
OUTLOOK FOR SPACE Report to the NASA Administrator by the Outlook for Space Study Group
Jan. 1976 373 p refs
(NASA-SP-386) Avail: NTIS MF $2.25; SOD HC $4.40 CSCL 22A

Future space activities within the context of national needs were examined, and directions that the United States should take in the civilian use and exploration of space for the time period from 1980 to 2000 were identified. It was decided that the following activities should be pursued: (1) those related to the continuing struggle to improve the quality of life (food production and distribution, new energy sources, etc., (2) those meeting the need for intellectual challenge, for exploration, and for the knowledge by which man can better understand the universe and his relationship to it, (3) those related to research and development in areas applicable to future space systems and missions. A continuing emphasis should be placed on orienting the space program to the physical needs of mankind, to the quest of the mind and spirit, to the vitality of the nation and to the relationship between this nation and other nations of the world. Y.J.A.

N76-30243*# Aerospace Corp., El Segundo, Calif. Systems Engineering Operations.
ADVANCED SPACE PROGRAM STUDIES, OVERALL EXECUTIVE SUMMARY
Mar. 1976 48 p
(Contract NASw-2727)
(NASA-CR-148702; ATR-76(7379-01)-1) Avail: NTIS HC $4.00 CSCL 22A

Multidisciplined advanced planning studies were conducted that involve space operations and the associated system elements, identification of potential low cost system techniques, vehicle design, cost synthesis techniques, DoD technology forecasting, and the development of near and far term space initiatives with emphasis on domestic and military use commonality. Specific areas studied include: (1) manned systems utilization; (2) STS users; (3) vehicle cost/performance; (4) space vehicle applications to future national needs; (5) STS spin stabilized upper stage; and (6) technology assessment and forecast. J.M.S.

N76-30262*# Aerospace Corp., El Segundo, Calif.
STS USERS STUDY (STUDY 2.2). VOLUME 1: EXECUTIVE SUMMARY Final Report
Ernest I. Pritchard 1 Nov. 1975 26 p refs
(Contract NASw-2727)
(NASA-CR-148720; ATR-76(7362)-1-Vol-1) Avail: NTIS HC $4.00 CSCL 22B

The space transportation system (STS) and ancillary equipment user studies are presented. Space shuttle data and planning requirements needed by the STS user are discussed along with the potential for common usage of multi-mission support equipment by the military and other aerospace personnel. B.B.

N76-30263*# Aerospace Corp., El Segundo, Calif.
STS USERS STUDY (STUDY 2.2). VOLUME 2: STS USERS PLAN (USER DATA REQUIREMENTS) STUDY Final Report
E. I. Pritchard 1 Nov. 1975 378 p
(Contract NASw-2727)
(NASA-CR-148721; ATR-76(7362)-1-Vol-2) Avail: NTIS HC $10.75 CSCL 22B

Pre-flight scheduling and pre-flight requirements of the space transportation system are discussed. Payload safety requirements, shuttle flight manifests, and interface specifications are studied in detail. B.B.

N76-31258*# McDonnell-Douglas Astronautics Co., Huntington Beach, Calif.
INDUSTRY WORKSHOP ON LARGE SPACE STRUCTURES: EXECUTIVE SUMMARY
Ellis Katz Washington NASA Sep. 1976 16 p
(Contract NAS1-12436)
(NASA-CR-2709) Avail: NTIS HC $3.50 CSCL 22B

A NASA-sponsored Industry Workshop on Large Space Structures was convened at Langley Research Center on 24-26 February 1976. A number of structures specialists from seven major aerospace companies participated. Predictions about the future structures to be fabricated/assembled/erected in space are presented along with a composite appraisal of what the Aerospace Industry views as the critical structural technology developments needed to support NASA space missions in the 1985-2000 time frame. Author

N77-13916*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICAL AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 7: MATERIALS PANEL Final Report
Aug. 1975 170 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73967) Avail: NTIS HC A08/MF A01 CSCL 11G

Materials technology requirements pertinent to structures, power, and propulsion for future space missions are identified along with candidate space flight experiments. Most requirements are mission driven, only four (all relating to space processing of materials) are considered to be opportunity driven. Exploitation of the space environment in performing basic research to improve the understanding of materials phenomena (such as solidification) and manufacturing and assembly in space to support missions such as solar energy stations which require the forming, erection, joining, and repair of structures in space are among the topics discussed. J.M.S.

N77-13917*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY SUMMER WORKSHOP. VOLUME 8: THERMAL CONTROL PANEL Final Report
Aug. 1975 170 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73968) Avail: NTIS HC A08/MF A01 CSCL 20D

Technology deficiencies in the area of thermal control for future space missions are identified with emphasis on large space structures and cold controlled environments. Thermal control surfaces, heat pipes, and contamination are considered along with cryogenics, insulation, and design techniques. Major directions forecast for thermal control technology development and space experiments are: (1) extend the useful lifetime of cryogenic systems for space, (2) reduce temperature gradients, and (3) improve temperature stability. J.M.S.

N77-13921*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY SUMMER WORKSHOP. EXECUTIVE SUMMARY
Aug. 1975 92 p Conducted at Madison College, Harrisonburg, Va., 3-16 Aug. 1975 Prepared jointly with Old Dominion Univ., Norfolk, Va. 11 Vol.
(Grant NsG-1186)
(NASA-TM-X-73960) Avail: NTIS HC A05/MF A01 CSCL 05B

Research and technology investigations are identified in eleven discipline technologies which require or which could significantly benefit from an in-space experiment, systems demonstrations, or component test using the Space Transportation System. Synopses of the eleven technology panels reports are presented. J.M.S.

N77-21107*# National Aeronautics and Space Administration. Langley Research Center, Langley Station, Va.
OAST SPACE THEME WORKSHOP 1976
Stanley R. Sadin Washington Apr. 1977 236 p refs Conf. held at Hampton, Va., 26-30 Apr. 1976
(Contract NASw-2973)
(NASA-TM-X-3486) Avail: NTIS HC A16/MF A01 CSCL 22A

Papers that provide a technical foundation including research and technology base candidates for each of six space themes - space power, space industrialization, search for extraterrestrial intelligence, exploration of the solar system, global service, and advanced transportation systems - are presented. The material is mainly intended for further use by workshop participants and NASA elements concerned with space research and technology. While the data presented do not represent official plans or positions, they are part of the process of evolving such plans and positions. The information contained reflects the efforts of workshop participants and should be an aid in the successful implementation and execution of the Agency's near- and far-term advanced technology program. Author

N77-23138*# Grumman Aerospace Corp., Bethpage, N.Y.
ORBITAL CONSTRUCTION DEMONSTRATION STUDY. EXECUTIVE SUMMARY Final Report
Dec. 1976 44 p
(Contract NAS9-14916)
(NASA-CR-151359) Avail: NTIS HC A03/MF A01 CSCL 22A

The supported construction base concept (no permanent habitation quarters) was explored. The studies concentrated on: (1) representative large structures that can only be tested in space, (2) definition of initial construction base (add-on to cover applications of facility), and (3) programmatic issues of schedule and cost, and mission plans. Author

N77-28151*# Grumman Aerospace Corp., Bethpage, N.Y.
ORBITAL CONSTRUCTION DEMONSTRATION STUDY. VOLUME 1: EXECUTIVE SUMMARY Final Report
Jun. 1977 67 p
(Contract NAS9-14916)
(NASA-CR-151465; NSS-OC-RP012-Vol-1) Avail: NTIS HC A04/MF A01 CSCL 22A

A conceptual design and program plan for an Orbital Construction Demonstration Article (OCDA), that can be used for technology growth and verification, and as the construction facility for a variety of large structures is presented. The OCDA design includes a large work platform, a rotating manipulator boom, a 250 kw solar array, and a core module of subsystems with a total mass of 37,093 kg, that can be assembled in three shuttle flights. An analysis of OCDA continued utility potential indicates that a shuttle tended platform with 250 kW of power can effectively be used to construct highly beneficial antenna systems and large demonstration articles that advance solar power satellite technologies. The construction of 100 m parabolic reflectors for use as a radiometer for measuring soil moisture and water salinity was found to be within the capabilities of OCDA concept. With 252 fixed beams for high population centers, and 16 scanning beams for rural areas, the antenna has the potential to significantly improve U.S. space based communications systems. The OCDA, that is slightly increased in size, was found adequate to build a large 2 MW solar array which, when coupled to a transmit antenna, demonstrate power transfer from space to ground. Author

N77-28152*# Grumman Aerospace Corp., Bethpage, N.Y.
ORBITAL CONSTRUCTION DEMONSTRATION STUDY. VOLUME 2: TECHNICAL Final Report
Jun. 1977 342 p refs
(Contract NAS9-14916)
(NASA-CR-151467; NSS-OC-RP012-Vol-2) Avail: NTIS HC A15/MF A01 CSCL 22A

The following items are discussed in reference to OCDA requirements; (1) flight mechanics and control, (2) effects of sun angle, (3) disturbance torques, (4) control system requirements, (5) OCDA orbit decay profile, and (6) aerodynamic drag forces. Structural design requirements are also given as well as basic design definition. B.B.

N77-28153*# Grumman Aerospace Corp., Bethpage, N.Y.
ORBITAL CONSTRUCTION DEMONSTRATION STUDY. VOLUME 3: REQUIREMENTS DOCUMENT Final Report
Jun. 1977 96 p refs
(Contract NAS9-14916)
(NASA-CR-151466; NSS-OC-RP012-Vol-3) Avail: NTIS HC A05/MF A01 CSCL 22A

A comprehensive set of requirements that defines the objective, scope and configuration of the orbital test facility needed to demonstrate the necessary automated fabrication, construction and assembly technology is provided. In addition to the requirements for the orbital demonstration facility, a detailed list of experiment requirements is included for various areas of technology. Author

N78-14066*# Analytical and Computational Mathematics, Zurich (Switzerland).
AN ANALYTICAL SATELLITE ORBIT PREDICTOR (ASOP)
Stephan E. Starke Oct. 1977 105 p refs
(Contract NAS9-15171)
(NASA-CR-151583; JSC-13094; Rept-77-FM-50) Avail: NTIS HC A06/MF A01 CSCL 22A

The documentation and user's guide for the Analytical Satellite Orbit Predictor (ASOP) computer program is presented. The ASOP is based on mathematical methods that represent a new state-of-the-art for rapid orbit computation techniques. It is intended to be used for computation of near-earth orbits including those of the shuttle/orbiter and its payloads. Author

N78-15136*# Analytical and Computational Mathematics, Inc., Houston, Tex.
AN ATMOSPHERIC DENSITY MODEL FOR APPLICATION IN ANALYTICAL SATELLITE THEORIES
A. C. Mueller Nov. 1977 61 p refs
(Contract NAS9-15171)
(NASA-CR-151605; ACM-TR-107) Avail: NTIS HC A04/MF A01 CSCL 22A

An atmospheric density model is developed and the implications of the model on the analytical drag theory are discussed. The ballistic number and coefficient of drag are assumed constant. Author

N78-15147*# Analytical and Computational Mathematics, Inc., Houston, Tex.

A SINGULARITY FREE ANALYTICAL SOLUTION OF ARTIFICIAL SATELLITE MOTION WITH DRAG

G. Scheifele, A. C. Mueller, and S. Starke Mar. 1977 71 p refs
(Contract NAS9-15171)
(NASA-CR-151601; ACM-TR-103) Avail: NTIS HC A04/MF A01 CSCL 22A

The connection between the existing Delaunay-Similar and Poincare-Similar satellite theories in the true anomaly version is outlined for the J(2) perturbation and the new drag approach. An overall description of the concept of the approach is given while the necessary expansions and the procedure to arrive at the computer program for the canonical forces are delineated. The procedure for the analytical integration of these developed equations is described. In addition, some numerical results are given. The computer program for the algebraic multiplication of the Fourier series which creates the FORTRAN coding in an automatic manner is described and documented. Author

N78-15157*# Analytical and Computational Mathematics, Inc., Houston, Tex.

A COMPARATIVE STUDY OF THE UNIFIED SYSTEM FOR ORBIT COMPUTATION AND THE FLIGHT DESIGN SYSTEM

Werner Maag Nov. 1977 53 p refs
(Contract NAS9-15171)
(NASA-CR-151606; ACM-TR-108) Avail: NTIS HC A04/MF A01 CSCL 22A

The Flight Design System (FDS) and the Unified System for Orbit Computation (USOC) are compared and described in relation to mission planning for the shuttle transportation system (STS). The FDS is designed to meet the requirements of a standardized production tool and the USOC is designed for rapid generation of particular application programs. The main emphasis in USOC is put on adaptability to new types of missions. It is concluded that a software system having a USOC-like structure, adapted to the specific needs of MPAD, would be appropriate to support planning tasks in the area unique to STS missions. J.M.S.

N78-23114*# National Aeronautics and Space Administration, Washington, D. C.

OAST SPACE SYSTEMS STUDIES REVIEW MEETING

Stanley R. Sadin 1978 415 p Meeting held at Washington, D. C., 11-12 Jan. 1978
(NASA-TM-79446) Avail: NTIS HC A18/MF A01 CSCL 22A

The agenda from the OAST review meeting is presented. Some of the following topics were reviewed in detail: (1) space utilization; (2) space transportation and (3) science and exploration. B.B.

N78-26157# Committee on Science and Tec.inology (U. S. House).

FUTURE SPACE PROGRAMS

Washington GPO 1978 991 p refs Hearings before Comm. on Sci. and Technol., 95th Congr., 2d Sess., No. 63, 24-26 Jan. 1978
(GPO-24-215) Avail: Comm. on Sci. and Technol.

Testimony delivered and statements submitted in support of a national program for space utilization are presented. Activities discussed include scientific exploration, space industrialization, and human habitation and space settlement. The development of solar power statellites and NASA's role in future space programs are also discussed. A.R.H.

N78-32849# Ballistic Research Labs., Aberdeen Proving Ground, Md.

ANALYSIS OF TRANSMISSION-LINE ACCELERATOR CONCEPTS Final Report, Nov. 1976 - Sep. 1977

J. K. Temperley and D. Eccleshall May 1978 58 p refs
(DA Proj. 1T1-61101-A-91A)
(AD-A056364; AD-E430056; ARBRL-TR-02067) Avail: NTIS HC A04/MF A01 CSCL 20/7

An analysis is presented of charged transmission-line configurations for use in high-current accelerators Basic drawbacks of the symmetric radial-pulse-line design are identified. The concept of using asymmetric pairs of transmission lines of various geometries is introduced. Conditions for maximum efficiency and maximum energy transfer to the beam load are derived for ideal constant-impedance lines. It is shown that, in the lossless-line approximation, asymmetric line-pair configurations exist with which both a high accelerating voltage per stage and nominal unit efficiency can be achieved. A recirculating accelerator is described, in which advantage is taken of a repetitive voltage waveform present in the transmission-line cavities to repeatedly accelerate a current pulse which is recirculated through the accelerator. Expressions for the open-circuit output voltage, accelerating voltage per stage, and efficiency of energy transfer to the beam are derived for this case also. It is shown that, with proper choice of parameters, this type of design again affords the possibility of nominal unit efficiency for energy transfer to the beam. Author (GRA)

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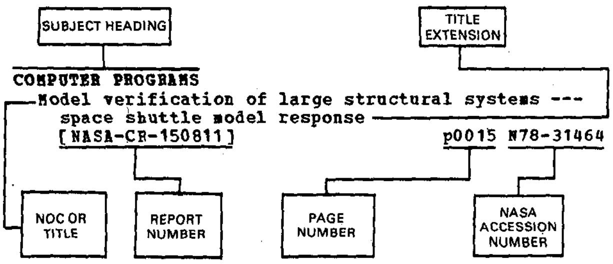

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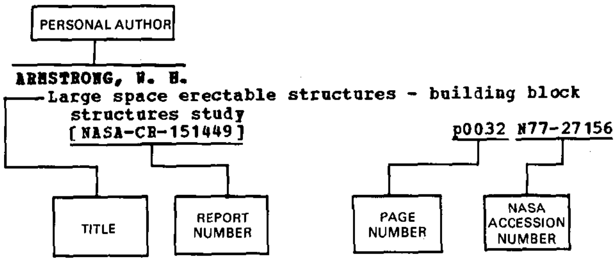

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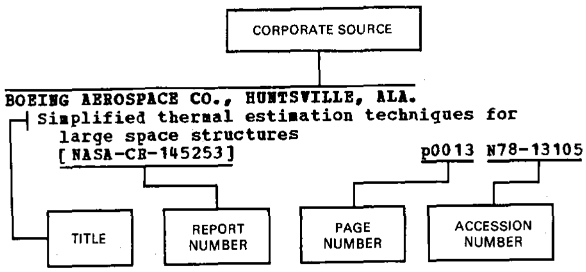

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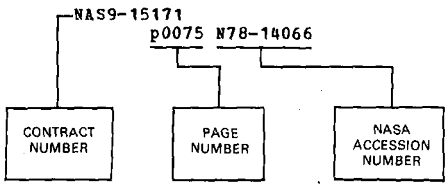

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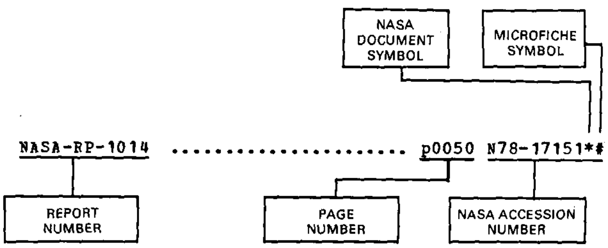

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
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4. Title and Subtitle	5. Report Date
TECHNOLOGY FOR LARGE SPACE SYSTEMS A Special Bibliography	April 1979
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
9. Performing Organization Name and Address National Aeronautics and Space Administration Washington, D. C. 20546	10. Work Unit No.
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15. Supplementary Notes

Report prepared, in part, by the LSST Program Office, Langley Research Center, Hampton, Virginia.

16. Abstract

This bibliography lists 460 reports, articles, and other documents introduced into the NASA scientific and technical information system between January 1, 1968 and December 31, 1978. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design in the area of the Large Space Systems Technology (LSST) Program. Subject matter is grouped according to systems, interactive analysis and design, structural concepts, control systems, electronics, advanced materials, assembly concepts, propulsion, and flight experiments.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Folding Structures Orbital Space Stations Space Erectable Structures Spacecraft Structures	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
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