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).*
This Supplement is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161, at the price code A08 ($8.00 domestic; $16.00 foreign).
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.
AVAILABILITY OF CITED PUBLICATIONS

IAA ENTRIES (A68-A78-10000 Series)

All publications abstracted in this Section are available from the Technical Information Service, American Institute of Aeronautics and Astronautics, Inc. (AIAA), as follows: Paper copies of accessions are available at $6.00 per document up to a maximum of 20 pages. The charge for each additional page is $0.25. Microfiche (1) of documents announced in IAA are available at the rate of $2.50 per microfiche on demand, and at the rate of $1.10 per microfiche for standing orders for all IAA microfiche. The price for the IAA microfiche by category is available at the rate of $1.25 per microfiche plus a $1.00 service charge per category per issue. Microfiche of all the current AIAA Meeting Papers are available on a standing order basis at the rate of $1.35 per microfiche.

Minimum air-mail postage to foreign countries is $1.00 and all foreign orders are shipped on payment of pro-forma invoices.

All inquiries and requests should be addressed to AIAA Technical Information Service. Please refer to the accession number when requesting publications.

STAR ENTRIES (N68-N78-10000 Series)

One or more sources from which a document announced in STAR is available to the public is ordinarily given on the last line of the citation. The most commonly indicated sources and their acronyms or abbreviations are listed below. If the publication is available from a source other than those listed, the publisher and his address will be displayed on the availability line or in combination with the corporate source line.

Avail: NTIS. Sold by the National Technical Information Service. Prices for hard copy (HC) and microfiche (MF) are indicated by a price code followed by the letters HC or MF in the STAR citation. Current values for the price codes are given in the tables on page vii.

Documents on microfiche are designated by a pound sign (#) following the accession number. The pound sign is used without regard to the source or quality of the microfiche.

Initially distributed microfiche under the NTIS SRIM (Selected Research in Microfiche) is available at greatly reduced unit prices. For this service and for information concerning subscription to NASA printed reports, consult the NTIS Subscription Section, Springfield, Va. 22161.

NOTE ON ORDERING DOCUMENTS: When ordering NASA publications (those followed by the * symbol), use the N accession number. NASA patent applications (only the specifications are offered) should be ordered by the U.S-Patent-Appl-SN number. Non-NASA publications (no asterisk) should be ordered by the AD, PB, or other report number shown on the last line of the citation, not by the N accession number. It is also advisable to cite the title and other bibliographic identification.

Avail: SOD (or GPO). Sold by the Superintendent of Documents, U.S. Government Printing Office, in hard copy. The current price and order number are given following the availability line. (NTIS will fill microfiche requests, at the standard $3.00 price, for those documents identified by a # symbol.)

(1) A microfiche is a transparent sheet of film, 105 by 148 mm in size, containing as many as 60 to 98 pages of information reduced to micro images (not to exceed 26.1 reduction).
Avail: NASA Public Document Rooms. Documents so indicated may be examined at or purchased from the National Aeronautics and Space Administration, Public Documents Room (Room 126), 600 Independence Ave., S.W., Washington, D.C. 20546, or public document rooms located at each of the NASA research centers, the NASA Space Technology Laboratories, and the NASA Pasadena Office at the Jet Propulsion Laboratory.

Avail: DOE Depository Libraries. Organizations in U.S. cities and abroad that maintain collections of Department of Energy reports, usually in microfiche form, are listed in Energy Research Abstracts. Services available from the DOE and its depositories are described in a booklet, DOE Technical Information Center - Its Functions and Services (TID-4660), which may be obtained without charge from the DOE Technical Information Center.

Avail: Univ. Microfilms. Documents so indicated are dissertations selected from Dissertation Abstracts and are sold by University Microfilms as xerographic copy (HC) and microfilm. All requests should cite the author and the Order Number as they appear in the citation.

Avail: USGS. Originals of many reports from the U.S. Geological Survey, which may contain color illustrations, or otherwise may not have the quality of illustrations preserved in the microfiche or facsimile reproduction, may be examined by the public at the libraries of the USGS field offices whose addresses are listed in this introduction. The libraries may be queried concerning the availability of specific documents and the possible utilization of local copying services, such as color reproduction.

Avail: HMSO. Publications of Her Majesty's Stationery Office are sold in the U.S. by Pendragon House, Inc. (PHI), Redwood City, California. The U.S. price (including a service and mailing charge) is given, or a conversion table may be obtained from PHI.

Avail: BLL (formerly NLL): British Library Lending Division, Boston Spa, Wetherby, Yorkshire, England. Photocopies available from this organization at the price shown. (If none is given, inquiry should be addressed to the BLL.)

Avail: ZLDI. Sold by the Zentralstelle für Luftfahrtdokumentation und -Information, Munich, Federal Republic of Germany, at the price shown in deutschmarks (DM).

Avail: Issuing Activity, or Corporate Author, or no indication of availability. Inquiries as to the availability of these documents should be addressed to the organization shown in the citation as the corporate author of the document.


Other availabilities: If the publication is available from a source other than the above, the publisher and his address will be displayed entirely on the availability line or in combination with the corporate author line.
ADDRESSES OF ORGANIZATIONS

American Institute of Aeronautics and Astronautics
Technical Information Service
750 Third Ave.
New York, N.Y. 10017

British Library Lending Division,
Boston Spa, Wetherby, Yorkshire, England

Commissioner of Patents and Trademarks
U.S. Patent and Trademark Office
Washington, D.C. 20231

Department of Energy
Technical Information Center
P.O. Box 62
Oak Ridge, Tennessee 37830

ESA-Information Retrieval Service
ESRIN
Via Galileo Galilei
00044 Frascati (Rome) Italy

Her Majesty's Stationery Office
P.O. Box 569, S.E. 1
London, England

NASA Scientific and Technical Information Facility
P.O. Box 8757
B. W. I. Airport, Maryland 21240

National Aeronautics and Space Administration
Scientific and Technical Information Branch (NST-41)
Washington, D.C. 20546

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Pendragon House, Inc.
899 Broadway Avenue
Redwood City, California 94063

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

University Microfilms
A Xerox Company
300 North Zeeb Road
Ann Arbor, Michigan 48106

University Microfilms, Ltd.
Tylers Green
London, England

U.S. Geological Survey
1033 General Services Administration Building
Washington, D.C. 20242

U.S. Geological Survey
601 E. Cedar Avenue
Flagstaff, Arizona 86002

U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

U.S. Geological Survey
Bldg. 25, Denver Federal Center
Denver, Colorado 80225

Zentralstelle fuer Luft Raumfahrt
Dokumentation U. Information
C/o Fachinformationszentrum E P M
Attn: Library
Kernforschungszentrum
7514 Eggenstein Leopoldsaffen
Federal Republic of Germany
NTIS PRICE SCHEDULES

Schedule A
STANDARD PAPER COPY PRICE SCHEDULE
(Effective October 1, 1977)

<table>
<thead>
<tr>
<th>Price Code</th>
<th>Page Range</th>
<th>North American Price</th>
<th>Foreign Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A01</td>
<td>Microfiche</td>
<td>$ 3.00</td>
<td>$ 4.50</td>
</tr>
<tr>
<td>A02</td>
<td>001-025</td>
<td>4.00</td>
<td>8.00</td>
</tr>
<tr>
<td>A03</td>
<td>026-050</td>
<td>4.50</td>
<td>9.00</td>
</tr>
<tr>
<td>A04</td>
<td>051-075</td>
<td>5.25</td>
<td>10.50</td>
</tr>
<tr>
<td>A05</td>
<td>076-100</td>
<td>6.00</td>
<td>12.00</td>
</tr>
<tr>
<td>A06</td>
<td>101-125</td>
<td>6.50</td>
<td>13.00</td>
</tr>
<tr>
<td>A07</td>
<td>126-150</td>
<td>7.25</td>
<td>14.50</td>
</tr>
<tr>
<td>A08</td>
<td>151-175</td>
<td>8.00</td>
<td>16.00</td>
</tr>
<tr>
<td>A09</td>
<td>176-200</td>
<td>9.00</td>
<td>18.00</td>
</tr>
<tr>
<td>A10</td>
<td>201-225</td>
<td>9.25</td>
<td>18.50</td>
</tr>
<tr>
<td>A11</td>
<td>226-250</td>
<td>9.50</td>
<td>19.00</td>
</tr>
<tr>
<td>A12</td>
<td>251-275</td>
<td>10.75</td>
<td>21.50</td>
</tr>
<tr>
<td>A13</td>
<td>276-300</td>
<td>11.00</td>
<td>22.00</td>
</tr>
<tr>
<td>A14</td>
<td>301-325</td>
<td>11.75</td>
<td>23.50</td>
</tr>
<tr>
<td>A15</td>
<td>326-350</td>
<td>12.00</td>
<td>24.00</td>
</tr>
<tr>
<td>A16</td>
<td>351-375</td>
<td>12.50</td>
<td>25.00</td>
</tr>
<tr>
<td>A17</td>
<td>376-400</td>
<td>13.00</td>
<td>26.00</td>
</tr>
<tr>
<td>A18</td>
<td>401-426</td>
<td>13.25</td>
<td>26.50</td>
</tr>
<tr>
<td>A19</td>
<td>426-450</td>
<td>14.00</td>
<td>28.00</td>
</tr>
<tr>
<td>A20</td>
<td>451-475</td>
<td>14.50</td>
<td>28.00</td>
</tr>
<tr>
<td>A21</td>
<td>476-500</td>
<td>15.00</td>
<td>30.00</td>
</tr>
<tr>
<td>A22</td>
<td>501-525</td>
<td>15.25</td>
<td>30.50</td>
</tr>
<tr>
<td>A23</td>
<td>526-550</td>
<td>15.50</td>
<td>31.00</td>
</tr>
<tr>
<td>A24</td>
<td>551-575</td>
<td>16.25</td>
<td>32.50</td>
</tr>
<tr>
<td>A25</td>
<td>576-600</td>
<td>16.50</td>
<td>33.00</td>
</tr>
<tr>
<td>A99</td>
<td>601-up</td>
<td>1/</td>
<td>2/</td>
</tr>
</tbody>
</table>

1/ Add $2.50 for each additional 100 page increment from 601 pages up.

2/ Add $5.00 for each additional 100 page increment from 601 pages up.

Schedule E
EXCEPTION PRICE SCHEDULE
Paper Copy & Microfiche

<table>
<thead>
<tr>
<th>Price Code</th>
<th>North American Price</th>
<th>Foreign Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>E01</td>
<td>$ 3.25</td>
<td>$ 6.50</td>
</tr>
<tr>
<td>E02</td>
<td>4.75</td>
<td>9.50</td>
</tr>
<tr>
<td>E03</td>
<td>6.25</td>
<td>12.50</td>
</tr>
<tr>
<td>E04</td>
<td>7.50</td>
<td>15.00</td>
</tr>
<tr>
<td>E05</td>
<td>9.00</td>
<td>18.00</td>
</tr>
<tr>
<td>E06</td>
<td>10.50</td>
<td>21.00</td>
</tr>
<tr>
<td>E07</td>
<td>12.50</td>
<td>25.00</td>
</tr>
<tr>
<td>E08</td>
<td>15.00</td>
<td>30.00</td>
</tr>
<tr>
<td>E09</td>
<td>17.50</td>
<td>35.00</td>
</tr>
<tr>
<td>E10</td>
<td>20.00</td>
<td>40.00</td>
</tr>
<tr>
<td>E11</td>
<td>22.50</td>
<td>45.00</td>
</tr>
<tr>
<td>E12</td>
<td>25.00</td>
<td>50.00</td>
</tr>
<tr>
<td>E13</td>
<td>28.00</td>
<td>56.00</td>
</tr>
<tr>
<td>E14</td>
<td>31.00</td>
<td>62.00</td>
</tr>
<tr>
<td>E15</td>
<td>34.00</td>
<td>68.00</td>
</tr>
<tr>
<td>E16</td>
<td>37.00</td>
<td>74.00</td>
</tr>
<tr>
<td>E17</td>
<td>40.00</td>
<td>80.00</td>
</tr>
<tr>
<td>E18</td>
<td>45.00</td>
<td>90.00</td>
</tr>
<tr>
<td>E19</td>
<td>50.00</td>
<td>100.00</td>
</tr>
<tr>
<td>E20</td>
<td>60.00</td>
<td>120.00</td>
</tr>
<tr>
<td>E99</td>
<td>Write for quote</td>
<td></td>
</tr>
<tr>
<td>N01</td>
<td>28.00</td>
<td>40.00</td>
</tr>
</tbody>
</table>
## TABLE OF CONTENTS

### Subject Categories

Abstracts in this bibliography are grouped under the following categories:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>01 SYSTEMS</td>
<td>Includes mission requirements, focus missions, conceptual studies, technology planning, and systems integration.</td>
<td>1</td>
</tr>
<tr>
<td>02 INTERACTIVE ANALYSIS AND DESIGN</td>
<td>Includes computerized technology design and development programs, dynamic analysis techniques, thermal modeling, and math modeling.</td>
<td>7</td>
</tr>
<tr>
<td>03 STRUCTURAL CONCEPTS</td>
<td>Includes erectable structures (joints, struts, and columns), deployable platforms and booms, solar sail, deployable reflectors, space fabrication techniques and protrusion processing.</td>
<td>17</td>
</tr>
<tr>
<td>04 CONTROL SYSTEMS</td>
<td>Includes new attitude and control techniques, improved surface accuracy measurement and control techniques.</td>
<td>35</td>
</tr>
<tr>
<td>05 ELECTRONICS</td>
<td>Includes techniques for power and data distribution.</td>
<td>43</td>
</tr>
<tr>
<td>06 ADVANCED MATERIALS</td>
<td>Includes matrix composites, polyimide films and thermal control coatings, and space environmental effects on these materials.</td>
<td>47</td>
</tr>
<tr>
<td>07 ASSEMBLY CONCEPTS</td>
<td>Includes automated manipulator techniques, EVA, robot assembly, teleoperators, and equipment installation.</td>
<td>53</td>
</tr>
<tr>
<td>08 PROPULSION</td>
<td>Includes propulsion designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.</td>
<td>65</td>
</tr>
<tr>
<td>09 FLIGHT EXPERIMENTS</td>
<td>Includes controlled experiments requiring high vacuum and zero G environment.</td>
<td>69</td>
</tr>
<tr>
<td>10 GENERAL</td>
<td>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.</td>
<td>71</td>
</tr>
</tbody>
</table>

### SUBJECT INDEX

<table>
<thead>
<tr>
<th>Index</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PERSONAL AUTHOR INDEX</td>
<td>A-1</td>
</tr>
<tr>
<td>CORPORATE SOURCE INDEX</td>
<td>B-1</td>
</tr>
<tr>
<td>CONTRACT NUMBER INDEX</td>
<td>C-1</td>
</tr>
<tr>
<td>REPORT/ACCESSION NUMBER INDEX</td>
<td>D-1</td>
</tr>
</tbody>
</table>

viii
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
TECHNOLOGY FOR LARGE SPACE SYSTEMS

A Special Bibliography

APRIL 1979

01 SYSTEMS

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


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)


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.


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, GOES-3, Seasat, Tiros, Nimbus, ITPS, 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.


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

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)
01 SYSTEMS

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.


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.


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.


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 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, University, Lublin; Polskie Towarzystwo Astronautyczne, Katowice, Poland), J. Usowicz (Torun, University, Torun; Polskie Towarzystwo Astronautyczne, Warsaw, Poland), and Z. Papatrocy (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 dispersive 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, undesirable motion of the antenna, and antenna mechanical oscillations. M.L.


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)


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.


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 tests with such an antenna system would enable validation of performance prediction models. The 30-m-diam mesh deployable-defurdlable antenna experiment would be carried out with the shuttle. P.T.H.

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 observational 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.


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.


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.


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, space surveillance, search and rescue services, and thin-route communications to small terminals as proposed for experimental rural communications satellites.


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 high performance and 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)


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 antennas, 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.

ORBITAL SUPPORT NEEDS

Two of the four objectives in the entire study were discussed 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


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.


STUDY OF THE COMMONALITY OF SPACE VEHICLE APPLICATIONS TO FUTURE NATIONAL NEEDS (UNCLASSIFIED PORTION)

24 Mar. 1975 407 p ref

(Contract NASw-2727)

(ARR-76/17356-2) Avail: NTIS HC $11.00 CSCL 95C

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 2000. 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


MICROWAVE POWER TRANSMISSION SYSTEM STUDIES. VOLUME 3, SECTION 8: MECHANICAL SYSTEMS AND FLIGHT OPERATIONS


(Contract NAS2-17835)

(NASA-CR-134886-Vol-3; ER75-4368-Vol-3) Avail: NTIS HC $8.00 CSCL 108

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


(Contract NASw-2727)

(NASA-CR-148704; ATR-76/17356-1-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


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
The commonality of space vehicle applications to future national needs: (1) index of initiatives (civilian observation, communication, support), each initiative, time periods from 1980 to 2000; (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 technology, and far-term space projects applicable to each subcategory of functions to be fulfilled; (3) data sheets on size, weight and cost estimations; (4) table relating initiatives and desired goals (public service and humanistic, materialistic, scientific and intellectual); and (5) data on future implementation of these initiatives.

The methodology of alternate world future scenarios is utilized for selecting a plausible, though not advocated, set of future scenarios 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.

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.

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.
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.).


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 testing program is suggested.

A69-25500*

Minimizing Spacecraft Structure/Control-System Interaction


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 498, 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.

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. Guramnick (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 Can- tilever Beam


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 #


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.

A71-10941 #


The stability of in-plane bending of oscillations of long flexible members (STEM) 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)

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)


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 forms 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.


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.


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.


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)


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.


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)

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)


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)


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)


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.


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 frame and frame structures demonstrates the efficiency and accuracy of the method. (Author)


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.


First-generation dynamic-interaction problems are reviewed, including the wire whip antennas of the Explorer 1 spacecraft, the gravity-stabilized OVI-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.

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 both the 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)


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 found 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 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)


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 in-plane 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 orbital angular rate. (Author)


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.


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)


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 components 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)


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 antennas 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 plots 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
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.

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.

N71-36286* 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.

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 Sep. 1971 206 p refs

(Grant NGR-14-008-002)

(NASA-CP-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).

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 Sep. 1971 147 p refs

(Grant NGR-14-008-002)

(NASA-CP-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.


COMPENSATOR IMPROVEMENT WITH AN APPLICATION TO A LARGE SPACE VEHICLE

Jerrl R. Mitchell 30 Sep. 1971 32 p refs

(Contract NAS7-21377)

(NASA-CR-119858) 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.


RADIAL RIB ANTENNA SURFACE DEVIATION ANALYSIS PROGRAM

John V. Coyner, Jr. 15 Dec. 1971 70 p refs

(Contract NAS7-100)


A digital computer, 8080 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 goss are cut can be determined.

N72-16871* National Aeronautics and Space Administration.

Goddard Space Flight Center, Greenbelt, Md.

WAGGING TAIL VIBRATION ABSORBER


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.

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 p140-144

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
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 simulation of 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.


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 attitude 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. Coyer, Jr. 1 Oct. 1973 54 p refs (Contract NAS7-100)

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


The continuum mechanics dynamic 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 array motions 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.


A literature survey, theory, step-by-step procedure, data and examples relating to the thermal modeling 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 acceleration 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.


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. 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 system with a remote manipulator 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
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)

N77-20501# Grumman Aerospace Corp., Bethpage, N.Y.

APPLICATION OF NASTRAN TO LARGE STRUCTURES


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


(Contract ESTEC-2405/75-AK)

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


(Contract ESTEC-2405/75-AK)

For abstract, see N77-23188.


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/MB 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
spacecraft thermal design considerations is presented. Background information for heating rates and temperatures for certain typical large spacecraft structural elements are provided. Further, general design guidelines, and approaches available for more detailed thermal response analysis are discussed. 

Author

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

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


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 orbital 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

N78-24688# Aero-space 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 HPSCI) (ESA-CRIP) 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 accuracy of the results is determined 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 simulation 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. Bedley (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-F28-Vol-1) Avail: NTIS HC A09/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**


(Contract NASA-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.
03 STRUCTURAL CONCEPTS

Includes erectable structures (posts, 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 Congress, 18th, Belgrade, Yugoslavia, Sept. 1967.)

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.).

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.).

Members, $1.00; nonmembers, $1.50.

Discussion of a parametric study of six techniques for erecting 9 to 16-in., deployed-diameter spaceborne paraboloid 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 Aeroespacial, Madrid, Spain).
Edited by Michal Lunc.

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.).
Edited by Mical Lunc.

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 poly-ester 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 sheltered 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.).

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 diameter. 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.

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.).

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.


Because of the increased influence of structural 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.

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.).

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.).

Contracts 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.).

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形状稳定性, 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)
03 STRUCTURAL CONCEPTS

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.

CONTENTS:

PREFACE. D. F. Igielinski. 1 p.
FOREWORD, p. ii.
DEPLOYMENT TECHNIQUES DEVELOPED FOR LARGE AREA ROLL-OUT SOLAR ARRAYS. W. A. Hasbach (California Institute of Technology, Pasadena, Calif.), p. 1-1 to 1-12.

A MILLIMETER WAVE PARABOLIC ANTENNA FOR COMMUNICATIONS WITH A SYNCHRONOUS SATELLITE. R. J. Eby and G. I. Goldberg (Fairchild Hirfer Corp., Germantown, Md.), p. 2-1 to 2-12.

DESIGN OF AN EXPANDABLE SHELL FOR USE AS AN ORBITING MAINTENANCE SHELF. M. R. Keating (U.S. Air Force Academy, Colorado Springs, Colo.) and S. W. Johnson (USAF, Air University, Wright-Patterson AF, Ohio), p. 3-1 to 3-15. 10 refs.

STRUCTURAL DESIGN EXPERIENCE ON BERYLLIUM SOLAR ARRAY. F. W. McAffee (Boeing Co., Seattle, Wash.), p. 4-1 to 4-14. 8 refs.


DESIGN STUDY OF BODY FRAMES FOR THE SST. R. K. Robinson (Boeing Co., Seattle, Wash.), p. 6-1 to 6-9.

HAUL DAMAGE RESISTANT STRUCTURE. R. J. Bristow (Boeing Co., Seattle, Wash.), p. 7-1 to 7-14.

EXTENDED SERVICE LIFE WING DESIGN F-8 CRUSADER. J. M. Smith (LTV Aerospace Corp., Dallas, Tex.), p. 8-1 to 8-14.

RADIATIVE THERMAL PROTECTION SYSTEM DEVELOPMENT FOR MANEUVERABLE RE-ENTRY SPACECRAFT. W. E. Black (General Dynamics Corp., San Diego, Calif.), p. 9-1 to 9-14. 5 refs.

DESIGN OF A LOAD-BEARING REFRACTORY ALLOY CONTROL SURFACE FOR A HYPERSONIC FLIGHT VEHICLE. A. Varisco (Gurnean Aerospace Corp., Bethpage, N.Y.), p. 11-1 to 11-21.

DESIGN OF A LOW CONDUCTIVE LIGHT WEIGHT SUPPORT STRUT FOR CRYOGENIC PROPELLANT TANKS. E. H. Bock (General Dynamics Corp., San Diego, Calif.), p. 12-1 to 12-12.


TRENDS IN AUTOMATED STRUCTURAL DESIGN. R. N. Karnes and J. L. Tocher (Boeing Co., Renton, Wash.), p. 14-1 to 14-12. 9 refs.


THE BEADED DOUBLER MISSILE WING CONCEPT. R. Hardy, R. F. Jones (Boeing Co., Huntsville, Ala.), and J. R. Sandlin (U.S. Army, Missile Command, Redstone Arsenal, Ala.), p. 16-1 to 16-11.

ECONOMICS OF STRUCTURAL ALLOWABLES. O. T. Ritchie and M. Musgrove (Boeing Co., Seattle, Wash.), p. 17-1 to 17-12.

LOCAL POSTBUCKLING STRENGTH OF FLAT TRUSS CORE SANDWICH PANELS. D. J. Dorr (McDonnell Douglas Corp., St. Louis, Mo.), p. 18-1 to 18-12. 10 refs.

DESIGN OF FITTINGS ON HONEYCOMB BASED ON ELASTIC FOUNDATION ANALYSIS. D. G. Cross (TRW Systems Group, Redondo Beach, Calif.) and M. J. Siegel (Southern California, University, Los Angeles, Calif.), p. 19-1 to 19-14.


DESIGN AND CONSTRUCTION OF AN ALUMINUM-BORON MISSILE ADAPTER. J. D. Forest (General Dynamics Corp., San Diego, Calif.), p. 21-1 to 21-11.

THE DESIGN OF JOINTS IN COMPOSITE MATERIALS. A. V. Hawley and M. Ashizawa (McDonnell Douglas Corp., Long Beach, Calif.), p. 22-1 to 22-11.


DESIGN AND ANALYTICAL STUDY OF COMPOSITE STRUCTURES. H. D. Neubert (General Dynamics Corp., San Diego, Calif.), p. 24-1 to 24-19.


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.

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.

Demonstration of the evolution of the configuration of STEM (storable tubular extendible member) boom, 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.

19
03 STRUCTURAL CONCEPTS


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 blanks, 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)


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.


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.


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.


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.


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 %-in. in diameter. An interleaved 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.


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)


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

Design data are derived for three categories of automatically deployable booms to meet several different types of space requirements. Boom categories are reeatable 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 that coiled lattice 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)


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)


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)


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, bellutes, and inflated cones are described. In considering rigidized cloth structures, the advantages of a honeycomb structure are cited, and the use of 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.


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

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)


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 efficiencies. Structural efficiencies are related to 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)


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 rebleak 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)


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.


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.


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 structural 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.


A technology development program is in progress to define a technology to define a light-weight, 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 undereway 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)


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 set to a lower limit below which bending mode frequencies may not lie.

M.L.


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/thermoset 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 'roll fabrication'. 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)


Space fabrication, as a major contributor to 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 large 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)


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 set to a lower limit below which bending mode frequencies may not lie.

M.L.


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 provision 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.


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 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 thin stock material that is stored on reels. An assembly jig would then be used to position a number of beam
03 STRUCTURAL CONCEPTS

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.


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.


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, multi-beam, 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.


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 a 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.


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.


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 metals for the retrograde orbit, and aluminum alloys. Selected for further study were AL2024T3 and AL2219-T62. In the area of fiber composites, thermoplastic matrix materials with graphite fibers were selected for future studies.

G.R.


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)


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 determine 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 emissive coating. The problem of maintaining the sail wrinkle-free is discussed.

J.M.B.


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.


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.


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 such 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.


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 structure to geosynchronous equatorial orbit (GEO) without high sensitivity to acceleration forces. As a teleoperator controlled device, being mated to the Orbiter, 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.


NASA-MSC 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 subsystems 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

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-to-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.


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. This 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.


An outline is presented of a plan which will lead to the establishment of an operational five gigawatt 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 blocks 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.


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.
FEASIBILITY DEVELOPMENT OF A SELF-DEPLOYING ELECTROMAGNETIC ENERGY FOCUSING REFLECTOR FOR SPACE OR TRANSPORTABLE GROUND BASED APPLICATIONS

William Korvin, Hossein Bahiman, and John Gates, AFSC Expandable and Modular Struct. Conf. May 1967

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 loading on a 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 bands), mechanical loading and deflection tests indicating 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 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 1.00 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.

UNFURLABLE ANTENNAS


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 an intermediate 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 1.00 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.

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)

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 4.4-foot-square sample panel.

INVESTIGATION OF A COILABLE LATTICE COLUMN

R. F. Crawford Washington NASA May 1969 31 p ref (Contract NAS7-427)

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 4.4-foot-square sample panel.

Author
03 STRUCTURAL CONCEPTS

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 CSLC 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 ISOSTABILIOIDS
(Contract NAS 7-427)
(NASA-CR-1444; ARC-R-299) Avail: CFSTI CSLC 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 CSLC 09E

CONTENTS:
1. TASK 1.0: MATERIAL AND FABRICATION TECHNIQUES 64 p
2. ANTENNA FEED DESIGN ASPECTS 32 p refs
3. TASK III DEPLOYMENT DYNAMICS 27 p
4. GIMBALED ANTENNA CONFIGURATION: 15 FOOT DIAMETER ANTENNA ON SIVB WORKSHOP 43 p
5. MANUFACTURING TECHNOLOGY 27 p
6. THERMAL ANALYSIS OF REFLECTOR 43 p

APPENDICES
7. PRE-VACUUM MESH REFLECTIVITY MEASUREMENTS 3 p
8. POST-VACUUM MESH REFLECTIVITY MEASUREMENTS 3 p
9. GENERAL DYNAMICS SPECIFICATION TWO BAR TRICOT KNIT FABRIC 15 p
10. APERTURE BLOCKAGE COMPUTER RUNS 37 p
11. ANTENNA REFLECTOR DEPLOYMENT DYNAMICS 109 p refs
12. THERMAL ANALYSIS 109 p

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 CSLC 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

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 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
Avail: NTIS CSLC 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
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-erecting antenna elements are designed to be packaged as low volume units to be deployed to an expanded operational shape.

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.

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.

An apparatus is described for preparing and placing mixtures of materials in the capsule for processing. 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.
03 STRUCTURAL CONCEPTS

EXPANDABLE SPACE FRAMES Patent

Alan H. Schoen, inventor (to NASA) Issued 11 Sep 1973

9 p. Filed 17 Dec 1970 Supersedes N71-28848 (09 - 16, p 2883)


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 joint. 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 joint in syrchnor, 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

FOLDABLE BOOM SYSTEMS STUDY. FIRST PHASE: INITIAL STUDIES Final Report


(Contract ESTEC-1130/70) 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)

N74-16154# Instituto Nacional de Tecnica Aeroespacial, Madrid (Spain)

DEPLOYABLE REFLECTOR DESIGN FOR KU-BAND OPERATION

B. C. Tankersley Sep. 1974 391 p refs

(Contract NAS7-11944) 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

N75-33741# Harris Corp., Melbourne, Fla.

DEPLOYABLE REFLECTOR DESIGN FOR KU-BAND OPERATION


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)

STUDY OF DEPLOYABLE ANTENNAS FOR SATELLITES Final Report


{Contract ESTEC-2070/73-HP; (MBB-URV-80-75; ESA-CRIP-645-A): Avail: NTIS HC $11.75

Deployable antenna designs 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.
DEVELOPMENT PLANNING FOR A LIGHTWEIGHT DEPLOYABLE 12 GHz ANTENNA

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.

A STRUT WITH INFINITELY ADJUSTABLE THERMAL EXPANSIVITY AND LENGTH

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 tubes for satellite hinges. An analysis is made of the stress applied to a general variety of structures and precision mechanisms where dimensional control of component elements in a dynamic thermal environment is required. Details, design, fabrication, and test of a developmental strut are discussed.

ANALYTICAL STUDIES ON FOLDABLE TUBES

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.

CONCEPTUAL APPROACH STUDY OF A 200 WATT PER KILOGRAM SOLAR ARRAY

Solar array candidate configurations (flexible rollup, flexible flat-pack, 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 x 10 to the 12th power/ particle/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.

APPLIED ROOT MOTIONS

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.

A STRAPDOWN TAPERED COLUMN CONCEPT FOR LARGE SPACE STRUCTURES

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 very limited payloads on 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.

RESPONSE OF LONG, FLEXIBLE CANTILEVER BEAMS TO APPLIED ROOT ROTATIONAL ACCELERATIONS

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.
STRUCTURAL CONCEPTS

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.


John F. McCarthy, Jr. and Oscar Orrienger May 1976 100 p refs

(Air Force, Contract F33615-75-C-5625)

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 structures. 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-1515352: NSS-GC-005008) 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 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 ERRECTABLE STRUCTURES - BUILDING BLOCK STRUCTURES STUDY Final Report


(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.
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.

N78-22146* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.

STRUCTURAL MEMBERS, METHOD AND APPARATUS Patent Application

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.

NASA

N78-33446* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

TELESCOPING COLUMNS Patent Application

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

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
CONTROL SYSTEMS

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

A89-35326#
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 26, 26, 1968, PROCEEDINGS.


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 (AVTOMATICHESKAI A SBORKA V KOSMOSO).
V. P. Legostaev and B. V. Raushenbakh.

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.


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.


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)


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 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 y-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.


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.


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 telescopes are also discussed.

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...

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.


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.
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)


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)


Certain space shuttle missions may require retrieval of passive swinging 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)


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.


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)


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.


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 precritical 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)


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)

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)


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.


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.


The control of structural vibrations in spacecraft presents severe problems to the ensureance 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)


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)


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)


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)


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 damper'. 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 modeled 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)

The role of the control system in large 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.


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

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 an attitude is desired, during rendezvous and docking maneuvers, during entry and reentry or atmospheric flight. The flexure modes of the spacecraft present a more difficult control problem. The pointing orientation is controlled by an on-off control system which contains a dead band. The large attitude angle excursion problem occurs during the injection into orbital flight when the acquisition of an 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. Sellapan 15 Nov. 1975 26 p. refs (Grant NSG-1181)

(NASA CR-145605) Available from 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.


THE ATTITUDE CONTROL OF THREE-AXIS STABILIZED SPACECRAFT WITH FLEXIBLE APPENDAGES, VOLUME 1 Final Report

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


THE ATTITUDE CONTROL OF THREE-AXIS STABILIZED SPACECRAFT WITH FLEXIBLE APPENDAGES, VOLUME 2, BOOK 1 Final Report

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


THE ATTITUDE CONTROL OF THREE-AXIS STABILIZED SPACECRAFT WITH FLEXIBLE APPENDAGES, VOLUME 2, BOOK 2 Final Report

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
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 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 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 conditions. Dynamic models are reviewed for spinning and non-spinning satellites. 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)

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 actuating 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. Flock 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 beams 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 beams 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.

**DYNAMICS AND CONTROL OF NON-RIGID SPACECRAFT**


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.

**GUIDANCE AND CONTROL PANEL**

Final Report on reduction of mission support cost by 50% through autonomous point and control, and a hundred-fold increase in human productivity in space through large-scale teleoperator applications.

**COMPARATIVE SYSTEMS STUDY OF MAGNETICALLY SUSPENDED FLYWHEELS**

Final Report presented for the investigation into flexure-satellite attitude spacecraft interaction due to two uniform beam arrays on a three axis stabilized spacecraft. 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 torque. 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)

**COMPARATIVE SYSTEMS STUDY OF MAGNETICALLY SUSPENDED FLYWHEELS**

Final Report presented for the investigation into flexure-satellite attitude spacecraft interaction due to two uniform beam arrays on a three axis stabilized spacecraft. 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 torque. 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)
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.

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 gimbaled momentum wheel (DGMW) using linear gimbals servo loops and a single gimbaled momentum wheel (SGMW), gimbaled about the roll axis, with either a linear or a stepper motor gimbals 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.

Attitude control techniques for the pointing and stabilization of a 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

N78-28162 Stanford Univ., Calif.

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 thrusters 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. Author

42
Includes techniques for power and data distribution.


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.


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.


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.

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 cavity loss mode, coupling coefficients, coupled modes; seven figures and two tables include numeric data.


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.


The first phase of the Multi-kw dc Power Distribution System Study 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 characteristics, and 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


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


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


 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)


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 characteristics, 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) physical 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.

**N75-27263** TRW Systems Group, Redondo Beach, Calif.

Research Study on Multi-kW DC Distribution System Final Report
E. A. Berkey and A. Krausz May 1975 126 p
(Contract NAS8-30778)
(NASA-CR-143898) 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.

**N76-13204** TRW Systems Group, Redondo Beach, Calif.

Research Study on Multi-kW DC Distribution System Final Report
E. A. Berkey Nov 1975 73 p refs
(Contract NAS8-3078)
(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.

**N76 22304** Messerschmitt-Boelkow-Blohm G.m.b.h., Ottheinbrunn (West Germany).

Electromagnetic Compatibility of AC Power Distribution Final Report
(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.

**N77-13910** National Aeronautics and Space Administration.

Langley Research Center, Langley Station, Va.

(Grant NsG-1186)

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.

**N77-13911** National Aeronautics and Space Administration.

Langley Research Center, Langley Station, Va.

(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.

**N77-13913** National Aeronautics and Space Administration.

Langley Research Center, Langley Station, Va.

(Grant NsG-1186)

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, flywheel (mechanical storage), satellite-to-ground transmission and reconversion systems, and regenerative fuel cells.

**N77-23317** AEG-Telefunken, Wedel (West Germany).

Power Supply Systems in the Multi-kW Power Range
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)**
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.

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 subject 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.
ADVANCED MATERIALS

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


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)


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)


The basic attractive 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.


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 presented. 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)


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)


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. This 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)


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 strain-to-tensile characteristics are affected, but only within a range acceptable for most applications. S.D.


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 metatized fluorocarbons. Directional reflectance properties of FEP are a function of charged particle energy and flux as well as total exposure influence and material characteristics. Data obtained on polyimides and polyimide-polyoxymethylene under high temperature radiation exposure conditions will be discussed in the context of near-sun solar sailing and rendezvousing. (Author)


The specimens tested in the experiments have 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. This 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)


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 blad, 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 nonlongated 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.


The use of fibre-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.


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
A79-33058


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, 110, and 140 C. The feasibility of controlling the mechanical properties by varying the fiber content is demonstrated.

A79-36430


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 spacecraft, e.g., stiffness and light weight, they are 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.

N68-17090#

General Dynamics/Convair, San Diego, Calif.

GRAVITY GRADIENT BOOM AND ANTENNA MATERIAL STUDY Final Report

H. R. Want 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 alloy-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.
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.

**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.


**SPACE MATERIALS HANDBOOK**


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.


**ORGANIC MATERIALS FOR STRUCTURAL APPLICATIONS**

R. E. Maun in Its Space Mater. Handbook 1969 p 355 382 refs Avail: CFSTI HC $10.00/MF $0.65 CSCL 11F

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.

**N71-16681**# Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena

**MATERIALS**


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


**DETERMINATION OF CONTAMINATION CHARACTER OF MATERIALS IN SPACE TECHNOLOGY TESTING**


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.


**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 UKASA (Contract ESTEC-1735P/22) (HSD-TP-7427; ESRO-C(R)(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.


**DESIGN, FABRICATION AND TEST OF GRAPHITE/EPOXY METERING TRUSS STRUCTURE COMPONENTS, PHASE 3**


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.

**N77-17151**# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt. Md.

**AN OUTGASING DATA COMPILATION OF SPACECRAFT MATERIALS**


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.

**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**


Polymide 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...
The polymer of interest is dissolved in a solvent which is soluble 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.

N78-32266*\(^*\) TRW Defense and Space Systems Group, Redondo Beach, Calif.

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.
07

ASSEMBLY CONCEPTS

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

A68-27391#

SATELLITES AND VEHICLES ASSEMBLED IN SPACE.


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 APPLI CATIONS.

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.


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 electron-optical portion consists of a triode-type gun. The gun has been successfully operated at 2 kw (20 kw and 100 ma). Weld penetration capabilities of the prototype gun are evaluated.

M.G.

A72-25049#


Members, $1.50; nonmembers, $2.00. Contracts No. NASA-NSF-27502; No. NAS9-27013.

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#


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#


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#


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.

A73-35317

**ASSEMBLY CONCEPTS**


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.

**A73-37301**


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 despins, 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.

**A73-37305**


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.

**A73-37307**


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**


The two viable approaches for accomplishing teleoperation include the Shuttle-Attached Teleoperator (SAT0) and the Free-Flying Teleoperator (FFTO). The SAT0 is more suitable for the close-in applications and the FFT0 better for the longer range missions. Advances made in the development of SAT0 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**


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**


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**


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,

The primary technology development areas for the AMS are in the extravehicular activity (EVA). Detailed descriptions are given of an system, and the mobility system. Four modes of EVA that are technology areas of primary concern in the case of the FFTO include enabling the Space Shuttle to perform the Shuttle and payload activity are discussed. Two general approaches to carrying out such tasks are cited, noting the unlikelihood of direct (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.


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.


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 control design of the AIO spacecraft, and the control of the AIO spacecraft, and the control of the AIO spacecraft. The presentation will conclude with some guidelines and recommendations for consideration by payload investigators in establishing concepts and designs utilizing EVA support.


A preliminary design of a manipulator system, applicable to a Free-Flying Teleoperator Spacecraft operating in conjunction with the Shuttle or Topg, 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.


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 mechanism concept. The kinematics of the manipulator and methods of controlling a satellite are discussed. Satellite equations of motion are provided, and analysis for use of FFTO is compulsory are indicated, and the FFTO contributions to the Shuttle missions are analyzed.


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 Vulken electron beam welding system.


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.


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.


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 role 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)


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, and 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)


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.


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)


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.


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)

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.


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.


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.


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.

A78-18870# 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: HCS $1.00; CFSTI: MF$0.65 CSCL $0.68

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

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 jointing 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 jointing; 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

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.


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.


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, 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

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 actuated 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

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

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 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.

N72-22890*# MB Associates, San Ramon, Calif.


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 stereoscopic 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.


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.


A simulator to generate the real time visual scenes required to perform man in the loop simulations 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.


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.


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.


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.


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 enclosure. 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

N75-29773*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex. 

CONCEPT DESIGN OF THE PAYLOAD HANDLING MANIPULATOR SYSTEM 


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 


The general use of robot manipulators is explained and the basics of their design and construction 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 


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 


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 

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). 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/retirement 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


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 57.75 CSCL 22A

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

N77-24769*# 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 largscale and small mass satellites was studied. Operations that may be performed by the STEV during the shuttle experiments are approximately.

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


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 A10/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 these 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 designed such that it includes a specific type of activity. Each SPS element may involve activities relating to any one or all of the generic processes. The processes are listed and examples of the requirements defined for a typical element are given.

Author


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
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

ANALYTICAL FORMULATION OF SELECTED ACTIVITIES OF THE REMOTE MANIPULATOR SYSTEM

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

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


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 programmatic are summarized. Conclusions and recommendations are given.

Author


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


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.

Author
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
08 PROPELLION

Includes propulsion designs utilizing solar sailing, solar electric, ion, and low thrust chemical concepts.


Description of one of the largest power systems placed into a synchronous orbit with a capability of providing over six million watts of electric power 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)


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. (Author)


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)
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.


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.


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.


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.


This study of advanced electric thruster systems 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).


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.

N59-28861* # Astro Research Corp., Santa Barbara, Calif.

HELIOGYRO SOLAR SAILER Summary Report

(NASA-CR-1329, ARC-R-297) Avail CFSTI CSCL 22B

Studies have been performed on the feasibility of a large sail-sail vehicle using long, narrow blades and operating in the manner of a helicopter rotor. This vehicle, the Heligyro, is superior to other propulsion and attitude-control systems for many missions requiring large total impulse and long flight times. A conceptual configuration has been evolved in which the thin aluminumized film blades are unrolled from spools during deployment. Centrifugal forces are used for stiffening the long, narrow sail. 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 longitudinal 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 Heligyro 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.
THE ADVANTAGES OF THE HIGH VOLTAGE SOLAR ARRAY FOR ELECTRIC PROPULSION

(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

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.

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.

National Aeronautics and Space Administration.
ElectroN bombardment propulsion system characteristics for large space systems
(NASA-TM-X-73554; E-8992) Avail NTIS HC A03/MF A01 CSCL 21C

The results of an analysis 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

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-D57239; Rept-709-01-CR; WGRC-77-4764) Avail NTIS HC A04/MF A01 CSCL 22A

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 must 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.

National Aeronautics and Space Administration.
NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY SUMMER WORKSHOP, VOLUME 5: PROPULSION TECHNOLOGY PANEL 1 Final Report
09 FLIGHT EXPERIMENTS

Includes controlled experiments requiring high vacuum and zero G environment.


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)


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 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, 13 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 gimbaled 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.

Recommendation of an on-orbit payload handling concept for the Space Shuttle is traced back to tradeoffs involving both docking (Space Station rescue 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)


Study of the actual behavior in relative weightlessness of aerospace 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 ±0.1 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.)


The avionics system for 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 multiplexor/demultiplexor and the CRT display system. (B.J.)


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.


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.)


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.)


This 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 freedom in terms of costs. Present and future interrelationships among manage-
ment 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.


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 space habitation. 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 a solar power satellite design, proj ected requirements, frequencies, experiment autonomy, and assembly and checkout are analyzed. J.M.B.


It is predicted that in the 1990s there will be a small number of 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 communications, 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.


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.


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-flier 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 debossing 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.


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.


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.


A proposal to test the large structures fabrication capability of the SLS 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.


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...


N75-20468# Communications Research Centre, Ottawa (Ontario). Spacecraft Mechanics Directorate.

N75-22504# European Space Research Organization, Paris (France).

N75-22531# Lockheed Missiles and Space Co., Sunnyvale, Calif.

N75-23620*# Aerospace Corp., El Segundo, Calif.

10 GENERAL


EXPANDABLE AND MODULAR STRUCTURES CONFERENCE

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.

The exploration and utilization of space has witnessed a 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)
10 GENERAL

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 flight 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.


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


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.


Multidisciplined advanced planning studies were conducted which 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.


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.


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.


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/installed/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


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.

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.

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

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.

N77-28152# Grumman Aerospace Corp., Bethpage, N.Y.

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.

Author

N77-28153# Grumman Aerospace Corp., Bethpage, N.Y.

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# Analytica and Computational Mathematics, Zurich (Switzerland).
AN ANALYTICAL SATELLITE ORBIT PREDICTOR (ASOP)


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


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
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 canonical program for the 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 (GRA)

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.
SUBJECT INDEX

TECHNOLOGY FOR LARGE SPACE SYSTEMS/A Special Bibliography

A

ABSORBERS (MATERIALS)
- MT SOLAR ENERGY ABSORBERS
- AC (CURREIT)
- ACCEPTABILITY
- ESTABRISERS (HATEBIALS)
- ACCUHULITORS

The title or Notation of Content (NOC) are used to provide a description of the subject matter. When the title is insufficiently descriptive of the document content, a title extension is added, separated from the title by three hyphens. The STAR or IAA accession number is included in each entry to assist the user in locating the abstract in the abstract section of this issue. If applicable a report number is also included as an aid in identifying the document. The page and accession numbers are located beneath and to the right of the title. Under any one subject heading the accession numbers are arranged in sequence with the accession numbers appearing first.

AERODYNAMIC FORCES
- NT AERODYNAMIC DRAG

AEROSPACE ENGINEERING

- Heating and stress distribution of foldable tubular connecting element, discussing application to space extensible reticular column
- Space environment effect on adhesives and reinforcement techniques
- High vacuum effects on materials for use in space structures
- Application of shuttle EVA systems to payloads. Volume 1: EVA systems and operational modes description
- Application of shuttle EVA systems to payloads. Volume 2: Full-scale testing and training
- Application of shuttle EVA systems to payloads. Volume 3: Technical handbook
- Application of optimal and adaptive algorithm control to the system robot-manipulator in cosine space
- Space environment effect on adhesives and reinforced plastics
- Space environment effects on materials for spacecraft structures
- Space environment effects on reinforced plastic materials for spacecraft structures
- NASA Office of Aeronautics and Space Technology Summer Workshop, Executive summary --- in-space research utilizing the Space Transportation System
- AEROSPACE SYSTEMS

AEROSPACE TECHNOLOGY TRANSFER

- Future space systems /A survey of the next 25 years/
Equations of motion for a rotating flexible structure --- influence on spacecraft appendages

The dynamics of spin stabilized spacecraft with movable appendages, part 2

The attitude control of three-axis stabilized spacecraft with flexible appendages, volume 1

The attitude control of three-axis stabilized spacecraft with flexible appendages, volume 2, book 1

The attitude control of three-axis stabilized spacecraft with flexible appendages, volume 2, book 2

Optimal control of spin stabilized spacecraft with telescoping appendages

Three-axis control of spacecraft with large flexible appendages

The dynamics of spin stabilized spacecraft with movable appendages, part 2

Attitude control of three-axes stabilized spacecraft with flexible appendages, volume 1

Attitude control of three-axes stabilized spacecraft with flexible appendages, volume 2

Approximation

Automated control

Attitude control

Artificial satellites

Automatic control

Assessments

AVIATION TECHNOLOGY ASSESSMENT

Astronomy

Automated control

Atmospheric maneuvering equipment

Astronomy performance

Astronauts

Astronomical telescopes

Attitude and orbit control

Audio-visual

Automated control

Automatic control

Astronauts

Astronomy performance

Astronomical telescopes

Attitude control

Artificial satellites

The dynamics of spin stabilized spacecraft with movable appendages, part 2

A digital computer program for the dynamic interaction simulation of controls and structure

A space platform support experimental program with deployable 30 ft parabolic antenna

A parametric study

A new concept for an energy conversion system with controllable light output

A digital computer program for the dynamic interaction simulation of controls and structure

A parametric study

Aerospace structures

Area tube arrays

AFTI (Impact Prediction) approximation

Approximation

Attachment

Attachment methods for thermal control composite system comprised of optical solar reflectors and multilayer insulation to minimize heating from incident solar energy

Attachment stability of a flexible solar electric spacecraft - A parametric study

Attachment control of a spinning flexible spacecraft

Three-axis attitude control for solar-powered electric propulsion spacecraft

A singularity free analytical solution of artificial satellite motion with drag

Satellite performance system LEO vs GEO assembly issues --- construction in Low Earth Orbits vs Geosynchronous Orbits

Satellite assembly

Satellite orbit assembly

Satellite assemblers

Satellite antennas

Satellite antennas

Satellite assemblies

Satellite assemblies

Satellite control system design for space vehicle

A digital computer program for the dynamic interaction simulation of controls and structure (DISCCS), volume 1

A space platform support experimental program with deployable 30 ft parabolic antenna

A digital computer program for the dynamic interaction simulation of controls and structure

A space platform support experimental program with deployable 30 ft parabolic antenna

A new concept for an energy conversion system with controllable light output

A digital computer program for the dynamic interaction simulation of controls and structure
AUTOMATIC DATA PROCESSING

MT TIME OPTIMAL CONTROL
Automatically controlled rendezvous and docking for orbital assembly of spacecraft, deriving motion equations for mass centers p0035 A70-19481
Automatically controlled rendezvous and docking for orbital assembly of spacecraft, deriving motion equations for mass centers p0035 A70-32726

AUTOMATIC CONTROL OF THE SURFACE SHAPE OF LARGE SPACE RADIO TELESCOPES [IAA PAPER 77-194] p0037 A77-51470
Pointing and control technology needs for future automated space systems [AIAA PAPER 78-16871] p0039 A78-52748

AUTOMATION
Automated fabrication of structural elements [AAS 77-201] p0024 A78-36703
Ox lattice for space robots and automation p0057 A78-49164


AUXILIARY POWER SOURCES
MT SOLAR AUXILIARY POWER UNITS
MT SPACE POWER REACTORS

AUTONOMOUS ROCKET IMPACT PREDICTORS
U DATA PROCESSING
U COMPUTERIZED SIMULATION

AUTOSYMMETRIC BODIES
Differential equations for compression loaded axisymmetric cylindrical structures [NASA-CS-1848] p0028 N60-38789
Axisymmetric filamentary structures [NASA-CS-1518] p0028 N70-27128

BANDWIDTH
MT BROADBAND

BANDWIDTH APPROXIMATION
U ELECTRICAL PROPERTIES
U SURFACE PROPERTIES

BART CENTER
U CENTER OF GRAVITY

BATTERIES
U ELECTRICAL BATTERIES

BEAMS (SUPPORTS)
MT CANTILEVER BEAMS

BEARINGS
Handbook for the thermal modeling of space mechanisms by the nodal network method [YEWG-CH-219] p0012 N76-26398

BENDING MOMENTS
In-plane and lateral displacements triangular elements represented by cubic and quintic polynomials for folded plate structural analysis p0008 A73-39585

BENDING THEORY
Inflation effect on circular cylindrical cantilever beam subsequent response to bending loads, using theory of small deflections superimposed on large deformations p0007 A69-41881

BENDING VIBRATION
Flexible Storable Tubular Extendible Member /STEM/ In-plane bending vibrations under solar heating p0007 A71-10941

BINARY SYSTEMS (DIGITAL)
U DIGITAL SYSTEMS

BINDERS (ADHESIVES)
U ADHESIVES

BIOMEDICAL ENGINEERING
MT BIOMEDICAL ENGINEERING

BIOINSTRUMENTATION
Engineering problems survey on teleoperator control systems [NASA-SP-5070] p0058 N69-21478

BIOMECHANICAL EFFECTS
Aerospace environment and effects on materials, spacecraft material selection, and biological interaction with spacecraft materials - handbook [NASA SP-3051] p0050 N70-21226

BOOMS (EQUIPMENT)
Wire screen deployable boom concept for avoiding thermal bending of slender tubes problem in applications to gravity gradient stabilization and antennas of spacecraft p0010 A69-18350

Erectable metal booms and meshed structural analysis, design and mounting and deployment techniques for space applications p0010 A69-35548

Deployable STEM /storable tubular extendible member/ booms for aerospace gravity gradient stabilization, noting interlocked BI-STEM p0019 A70-14725

Thermal coated extendable booms for space applications, describing construction and vacuum metallizing technique p0047 A70-27266

Spacecraft boom design and performance, including Russian spacecraft photographs p0020 A70-34137

Thermal and mechanical properties of materials for spacecraft booms design p0020 A70-34138

Closed tubular extendible boom /Multiple Applications Storable Tube/ design, fabrication and applications, including stress factors and materials p0020 A70-34142

Space erectable boom with interlocked seams, perforations and coatings to provide torsional rigidity and thermal stability p0020 A70-34143

Spacecraft deployable booms, discussing structural design, self loading, weight, storage volume and thermal stability requirements [AIAA PAPER 71-396] p0020 A71-25272

Analysis of thickness tapered booms for space applications p0008 A74-21398

Some choices for design of deployable solar arrays p0022 A74-26419

Thermal stabilization of gravity gradient boom rods p0035 A74-8216

Vibrations of space booms under centrifugal force field p0036 A75-15191

Some boomer choices for design of deployable solar arrays p0022 A75-23020

The booms and mechanisms of Geos p0025 A78-45869

Rigidized woven screen material study for gravity gradient boom and antenna [NASA-CS-92680] p0049 N68-17090

Extended boom devices for orbital maintenance and safety of space shuttle p0026 N70-39609

NASPAC computer program used to calculate lateral deflections of weak spacecraft antenna booms to determine stiffness at small strains p0011 N71-36256


General purpose manipulator system, transferable between space station and shuttle, for assembly, docking, maintenance, cargo handling, and spacecraft retrieval - management summary [NASA-CS-115480] p0058 N72-22886

Thermal distortion and static bending plus twist measurements on deployable boom structures for spacecraft p0011 N72-25789
Foldable boom systems study. Second phase: Definition and development [ESRO-CR-211] p0030 W75-20461
Conceptual analyses of extensible booms to support a solar sail [NASA-CR-155615] p0032 W78-17124
BORON
Mechanical of a boron-reinforced composite material radiation-induced of its epoxy matrix p0047 A74-26644
BROADBAND
Optimization of the design parameters for a wide-band radiometric system [NASA-TM-78662] p0014 W76-18117
BUCKLING
WT ELASTIC BUCKLING BUILDING MATERIALS U CONSTRUCTION MATERIALS BUILDING STRUCTURES U BUILDINGS BUILDINGS
Apparatus and method of assembling building blocks by folding pre-cut flat sheets of material during on-site construction [NASA-CASE-MSC-12233-1] p0029 W72-25454
CANTILEVER BEAMS
Inflation effect on circular cylindrical cantilever beam subsequent response to bending loads, using theory of small deformations superimposed on large deformations p0007 A69-41881
Dynamical characteristics associated with deploying, orbiting, beam-type appendages [AIAA PAPER 78-1399] p0010 A76-45669
Pneumatic cantilever beams and platform for space erectable structure [NASA-CASE-XIA-07371] p0029 W71-21085
Response of long, flexible cantilever beams applied root motions --- spacecraft structures p0031 W77-10276
CANTILEVER MEMBERS
WT CANTILEVER BEAMS
CARBON FIBER REINFORCED PLASTICS
The potential application of carbon fibres to spacecraft. An appreciation of the design of carbon fibre rigid solar panels for spacecraft. p0047 A73-39411
Improved mechanical properties of composites reinforced with neutron-irradiated carbon fibers. p0047 A73-39412
Curved, tapered, circular cross section graphite/epoxy antenna ribs p0047 A74-24881
Developments of a unique graphite/epoxy antenna subreflector --- for furlable space antennas p0022 A74-34918
Advanced lightweight rigid solar arrays based on carbon fibre technology [IAF PAPER 74-085] p0022 A75-13717
Behaviour of carbon fibre composites under simulated space environment --- radiation effects on solar array materials p0047 A75-28190
Reliability of composite zero-expansion structures for use in orbital environment --- spacecraft antenna reflectors p0048 A76-16569
A statistical evaluation of a space stable optical support structure p0025 A78-89546
Study on the use of carbon fibre reinforced plastics in satellite structures, phase I. [ESR-TP-7-7427] p0025 W78-17797
CARGO
Attached manipulator system for simulating and demonstrating space shuttle manipulator cargo handling operations under weightless conditions [NASA-CR-133964] p0059 W73-27176
CARRIER ROCKETS U LAUNCH VEHICLES
CARTRIDGE ACTUATED DEVICES U ACTUATORS
CAVITY RESONATORS
Steady-state losses of optical fibers and fiber resonators p0044 A77-16626
CELESTIAL BODIES
WT METEOROIDS
WT SOLAR SYSTEM CENTER OF GRAVITY
Automatically controlled rendezvous and docking for orbital assembly of spacecraft, deriving motion equations for mass centers p0035 A70-19481
Automatically controlled rendezvous and docking for orbital assembly of spacecraft, deriving motion equations for mass centers p0035 A70-32726
CENTRIFUGAL FORCE Vibrations of space booms under centrifugal force field p0036 A75-15191
CHEMICAL PROTECTIVE COATINGS U PROTECTIVE COATINGS
CFRP
CARBON FIBER REINFORCED PLASTICS
CHARACTERISTIC EQUATIONS U EIGENVALUES
CHARACTERISTIC FUNCTIONS U EIGENVALUES
CHANGED PARTICLES
WT SOLAR ELECTRONS
CHECKOUT EQUIPMENT U TEST EQUIPMENT
CHEMICAL ELEMENTS WT BORON
CHEMICAL ENGINEERING
Expandable and modular structures for support on manned space missions, reviewing inflatable, chemically rigidizable, unfurlable and elastic recovery structures p0017 A68-42789
CIRCUIT RELIABILITY
Solid state reset power controllers for 120 VDC power systems --- for aerospace application p0043 A76-31510
CIRCUITS
WT POWER SUPPLY CIRCUITS WT SWITCHING CIRCUITS WT TRANSISTOR CIRCUITS
CIRCULAR CYLINDERS
Inflation effect on circular cylindrical cantilever beam subsequent response to bending loads, using theory of small deformations superimposed on large deformations p0007 A69-41881
CIRCULAR POLARIZATION
Calculation techniques to determine circularly polarized patterns of erectable spacecraft high gain antennas [NASA-CR-99137] p0010 A69-15726
CIRCULAR TUBES
Bending and stress distribution of foldable tubular connecting element, discussing application to space extendible reticular column p0017 A68-18019
CISLOMAR SPACE
Propulsion options for orbital transfers in cis-lunar space p0065 A78-27931
CLOSED CIRCUIT TELEVISION
On-orbit payload handling for space shuttles, including manipulator arms for drawing docking vehicles together, closed circuit TV and airlocking [AIAA PAPER 71-8111] p0071 A71-35927
CLOSED ECOLOGICAL SYSTEMS
Summary of problems of greatest urgency --- space colonies p0072 A77-35825
Aerospace environment and effects on materials, spacecraft material selection, and biological interaction with spacecraft materials - handbook [NASA-SP-3081] p0059 A70-21226
CLOSED LOOP SYSTEMS U FEEDBACK CONTROL
COATING
WT ELECTROPLATING WT METALLIZING

A-5
COATINGS
NT ELECTROPLATING
NT METALLIZING
NT PROTECTIVE COATINGS
NT THERMAL CONTROL COATINGS
COLUMNS (SUPPORTS)
Structural stability of lattice columns of
longerons and helical braces
Structural stiffness, strength and dynamic
characteristics of large tetrahedral space truss
structures [NASA-TE-794001] p0013 N77-19847
Lightweight structural columns --- for truss
structures [NASA-CASE-LAR-12095-1] p0032 N77-27342
Telecoping columns --- parabolic antenna support
[NASA-CASE-LAR-12195-1] p0033 N78-33446
Structural efficiency of long lightly loaded truss
and inordin columns for space applications
COMMAND AND CONTROL
Large active retrodirective arrays for space
COMMAND-CONTROL
U COMMAND AND CONTROL
COMMERCIALITY (ECONOMY)
Study of the commonality of space vehicle
applications to future national needs
(unclassified portion) [ATR-75(7365)-2] p0004 N76-14974
COMMUNICATING
NT INFORMATION DISSEMINATION
NT INTERPLANETARY COMMUNICATION
COMMUNICATION CABLES
NT OPTICAL WAVESIGNS
NT WAVESIGNS
COMMUNICATION EQUIPMENT
NT CLOSED CIRCUIT TELEVISION
Assembly in space of large communication structures
COMMUNICATION SATELLITES
NT COMMUNICATIONS TECHNOLOGY SATellite
Anticipated developments in communications
satellite technology [AR-4000044] p0001 A74-23086
Behaviour of carbon fibre composites under
simulated space environment --- radiation
effects on solar array materials [ATR-75(7365)-2] p0007 A75-29190
Space: A resource for earth - An AIAA review ---
Book [NASA-TP-77-32440] p0001 A77-32440
New themes for space: Mankind’s future needs and
aspirations; Proceedings of the Centennial
Space Symposium, Washington, D.C., October 6-8,
1976 [NASA-TP-77-32440] p0001 A77-32440
Orbital antenna bars --- geosynchronous platforms
replacing satellites [NASA-TP-77-12726] p0002 A77-47268
Past experience - Basis for future advanced power
systems for communications satellites [JAF PAPER 77-227] p0048 A77-51390
Communication satellite technologies in the early
twenty-first century - A projection into the
post Intelsat-V era [JAF PAPER 77-334] p0002 A77-51395
Impact of shuttle on technology and utility of
national and regional communications satellites
[JAF PAPER 77-138] p0002 A77-51399
Design considerations for multi-beam communication
satellite’s antennas [JAF PAPER 77-41] p0023 A77-51402
On the active and passive CETI from earth
satellite orbit --- communication with
extraterrestrial intelligence [JAF PAPER A-77-68] p0002 A77-51524
A flexible passive space array with
springs [JAF PAPER 77-12095] p0037 A78-12095
Future communications concepts. I - The
Large communication-satellite antennas
[AD-A029014] p0049 N77-47263
Advanced lightweight solar array technology ---
for communication satellites [AIAA 78-533] p0024 A78-32883
The GAP concept extended --- Orbital Antenna Park
[AIAA 78-546] p0003 A78-32891
A future for large space antennas
[AIAA 78-588] p0003 A78-32928
Large space erectable antenna stiffness requirements
[AIAA 78-590] p0003 A78-32929
Considerations on the use of graphite-reinforced
plastics for space erectable antennas
[AIAA 78-591] p0004 A78-32930
Assembly in space of large communication structures
[AIS 77-259] p0003 A78-36723
Platform designed for numerous uses --- in
geostationary orbit
[AGI 78-42599] p0002 A78-42599
An institutional plan for multipurpose space
platforms [NASA-78-15263]
Geosynchronous information services platforms in
the year 2000 [AIAA PAPER 78-1636] p0073 A76-51976
Orbital servicing of space platforms
[AIAA PAPER 78-1659] p0025 A76-51986
The continuum mechanics dynamic study of a
satellite with flexible solar panels
[SPAR-8558] p0012 N78-17622
Preliminary design of a composite structure for an
Air Force space application
[NASA-TP-77-17126] p0032 N77-17126
COMMUNICATION SYSTEMS
U TELECOMMUNICATION
COMMUNICATIONS TECHNOLOGY SATELLITE
Communications technology satellite deployed solar
array dynamics tests [CRC-1264] p0003 A77-20468
COMPENSATORS
Compensator improvement program with application
to large space vehicles and tables noting
relative stability versus frequency response
COMPLIANCE (ELASTICITY)
U MODULE OF ELASTICITY
COMPONENT RELIABILITY
Highlights of the long-life assurance study ---
achievement of ten year service life in selected
aerospace vehicle components [NASA-TP-78-19129]
COMPOSITE MATERIALS
NT CARBON FIBER REINFORCED PLASTICS
NT GLASS FIBER REINFORCED PLASTICS
NT GRAPHITE-EPOXY COMPOSITE MATERIALS
NT LAMINATES
NT REINFORCED PLASTICS
Designing with fibre reinforced materials;
September 27, 28, 1977 [NASA-TP-78-17251]
Therally inert composite hardware applications
for spacecraft [NASA-TP-78-36430]
Filamentary composite materials reviewed for
potential applications in spacecraft structures
Radiation and temperature effects on composite
structures in Pegasus satellite
Thermal vacuum environment tests of materials used
in space technology to determine effect of
ultraviolet radiation on contaminant properties
[NASA-CR-12327] p0050 N75-19556
NASA Office of Aeronautical and Space Technology
Secretary Workshop, Volume 7: Materials panel
[NASA-TP-77-13916] p0004 A77-13916
COMPOSITE STRUCTURES
NT LAMINATES
Advanced lightweight rigid solar arrays based on
carbon fibre technology [JAF PAPER 78-127] p0022 A75-13717
Fabrication and assembly of large composite
structures in space [JAF PAPER 77-643] p0023 A78-32665
Orbit fabrication and assembly of composite
structures [JAF PAPER 78-1659] p0026 A78-52783
Attachment methods for thermal control composite
system comprised of optical solar reflectors and
multilayer insulation to minimize heating from
CONICAL SHELLS

FUTURE SPACE PROGRAMS

[SPACEX-24-215] p0076-78-25157

CONICAL SHELLS

Family of rigid shell Coppacone structures self deployable from foldable configurations of conical shell frusta

[AIAA PAPER 68-359] p0017-68-26311

CONNECTIONS

U JOINTS (JUNCTIONS)

Foldable tubular connection application to expanded lattice structure, analyzing cross sectional distortions

[78-16870] p0018-69-17698

CONNECTIONS (ELECTRIC)

U ELECTRIC CONNECTORS

Construction materials

Apparatus and method of assembling building blocks by folding pre-cut flat sheets of material during on-site construction


Thermal vacuum environment tests of materials used in space technology to determine effect of ultraviolet radiation on contaminative properties


CONTINUUM MECHANICS

Continuous models for static and dynamic analysis of repetitive lattices

[AIAA 77-416] p0008-77-25760

The continuum mechanics dynamic study of a satellite with flexible solar panels

[SPAC-6-555] p0012-74-17622

CONTINUOUS

Continuous modeling of three-dimensional truss-like space structures

[AIAA 78-44991] p0009-78-25500

CONTROL DEVICES

U CONTROL EQUIPMENT

SPACECRAFT DESIGN

TELEOPERATORS

Spacecraft design for minimization of structure interaction with control system, noting susceptibility of extendible booms to solar environment

[AIAA 78-25500] p0007-69-17698

Experimental evaluation of remote manipulator systems.

[AIAA 77-37305] p0055-69-17698

Variable ratio mixed-mode bilateral master-slave control system for satellite remote manipulator system

[NASA-CSP-652-12235-1] p0060-75-25794

Earth orbital teleoperator manipulator system

[AIAA 78-2586] p0061-77-25787

End effector device --- for manipulators


CONTROL SIMULATION

Teleoperator manipulator for payload handling in space shuttle, noting design features and simulations of master-slave control system

[AIAA PAPER 72-238] p0053-72-25975

Discrete time attitude control of spacecraft containing low frequency lightly damped structural modes

[AIAA 76-2562] p0008-76-26307

Multibody flexible spacecraft integrated analysis - Structure, dynamics, and control

[AIAA 78-31888] p0009-78-25500

CONTROL THEORY

Active control of flexible systems

[AIAA 78-12096] p0037-78-25500

Optimal digital control of large space structures

[AIAA PAPER 78-105] p0039-78-44380

An application of modern control theory to an elastic spacecraft

[AIAA 76-25317] p0040-76-25317

CONTROLLERS

MT SERVOMECHANISMS

Synthesis of active on-board controllers for vibratory systems with rigid body-modes

[AIAA 76-25324] p0040-76-25317

CORONAS

MT SOLAR CORONA

COMPUTATIONAL RADIATION

MT SOLAR ELECTROMAGNETISM

COST EFFECTIVENESS

The CAP concept extended --- Orbital Antenna Farm

[AIAA 78-546] p0003-78-32891

Size, performance and cost trades of large solar electric propulsion systems

[AIAA PAPER 78-697] p0066-78-37440

COST REDUCTION

Integrating Shuttle payloads

[AIAA 77-31832] p0071-77-31832

COUPLED MODES

Steady-state losses of optical fibers and fiber resonators

[77-16826] p0004-77-16826

COUPLING

MT OPTICAL COUPLING

CRACK PROPAGATION

Investigating mesh materials for deployable antennas, radiation tolerance of solar array components, and crack propagation threshold for isopropanol and titanium alloy

[AIAA 71-16891] p0050-71-16891

CRANES

A crane for construction in space

[AIAA PAPER 78-16656] p0026-78-51992

CREW STATIONS

MT CREW OFFICE STATIONS

CREW WORK STATIONS

N manned remote work stations --- for ultralarge space structure orbital assembly

[AIAA PAPER 78-16677] p0073-78-51993

CROSSING U FOLDING CRITERIA

MT STRUCTURAL DESIGN CRITERIA

Critical loading

A new optimality criterion method for large scale structures

[AIAA 78-870] p0009-78-29781

CRITICAL STRESSES

U CRITICAL LOADING

CRYSTALIZATION

Some results of studies in space technology in the USSR --- orbital fabrication, repair and maintenance

[AIAA 76-36475] p0055-76-36475

CYBERNETICS

Research study on multi-KW DC distribution system

[AIAA 76-16204] p0045-76-16204

CYLINDRICAL AFTERBODIES

U CYLINDRICAL BODIES

CYLINDRICAL BODIES

Differential equations for compression loaded axisymmetric cylindrical structures

[AIAA 14444] p0028-69-38781

CYLINDRICAL BODIES

U CYLINDRICAL BODIES

DAMAGING DATA ANALYSIS

U DATA PROCESSING

DAMPING

MT VIBRATION DAMPING

MT VISCOUS DAMPING

DATA ACQUISITION

NASA Office of Aeronautics and Space Technology Summer Workshop, Volume 3: Sensing and data acquisitions panel

[AIAA 73-13911] p0045-73-13911

An outstanding data compilation of spacecraft materials

[AIAA 10198] p0050-78-17151

Microprocessor-based data acquisition system incorporating a floating-point arithmetic unit for complex mathematical computations

[AIAA 77-25786] p0062-77-25786

DATA ADAPTIVE EVALUATOR/MONITOR

U DATA PROCESSING

DATA ANALYSIS

U DATA PROCESSING

D

A-8
DATA HANDLING SYSTEMS
U DATA SYSTEMS
DATA PROCESSING
NASA Office of Aeronautics and Space Technology
Summer Workshop. Volume 1: Data processing and
transfer panel
[NASA-CR-77-13961] p0045 N77-13910
DATA PROCESSING EQUIPMENT
U AIRBORNE/SPACEBORNE COMPUTERS
U DIGITAL COMPUTERS
U MICROPROCESSORS
DATA READOUT SYSTEMS
U DATA SYSTEMS
U DISPLAY DEVICES
DATA SYSTEMS
A highly reliable data handling and control system
of a spaceborne power unit
[IAPF PAPER 77-138] p0044 A77-51441
DC (CURRENT)
U DIRECT CURRENT
DEADWEIGHT
U STATIC LOADS
DEBRIS
U SPACE DEBRIS
DEFLATING
U INFLATABLE STRUCTURES
DEFLECTION
NASTran computer program used to calculate lateral
deflections of weak spacecraft antenna boom
to determine stiffness at small strains
p0011 N71-36256
DEFORMATION
U ELASTIC BUCKLING
DENSITY (MATERIALS)
U ATMOSPHERIC DENSITY
DENSITY (NUMBER/VOLUME)
U ELECTRON DENSITY PROFILES
DEPLOYMENT
Dynamical characteristics associated with
deploying, orbiting, beam-type appendages
[AIAA PAPER 76-1048] p0030 A76-26827
Study of deployable antennas for satellites
[EDR-TR-V-80-75] p0030 N76-12233
Development planning for a lightweight deployable
12 GHz antenna
p0031 N76-12240
SAS-C solar array development dynamics
[AD-A022713] p0031 N76-33710
DEFINITION
U ELECTROPLATING
DESIGN ANALYSIS
Ion thruster design and analysis
[AIAA PAPER 76-1048] p0065 A77-15106
Orbital construction demonstration study. Volume
1: Executive summary
[NASA-CR-15445] p0075 N77-28151
Orbital construction demonstration study. Volume
2: Technical
[NASA-CR-15467] p0075 N77-28152
Conceptual analyses of extensible booms to support
a solar sail
[NASA-CR-155615] p0032 N76-17124
DESIGN OF EXPERIMENTS
U EXPERIMENTAL DESIGN
DETERMINATION
U CRYSTALLIZATION
DIGITAL COMPUTERS
Compensator improvement program with application
to large space vehicles and tables noting
relative stability versus frequency response
DIGITAL SIMULATION
Attitude control of a spinning flexspacecraft
p0035 A76-33345
Discrete time attitude control of spacecraft
containing low frequency lightly damped
structural modes
[AD-A022713] p0008 A76-26607
DIGITAL SYSTEMS
Optical digital control of large space structures
p0038 A78-44380
DIMENSIONAL STABILITY
U STRUCTURAL STABILITY
DIRECT CURRENT
Powerplexor for distribution of dc power levels to
loads which require different voltages
Multi-kw dc power distribution system study program
DRG
U AERODYNAMIC DRAG
U SOLAR DRAG
U ATTITUDE STABILITY
U ORBITAL DRAG
U SPACECRAFT STABILITY
Research study on multi-kW-DC distribution system
[NASA-CR-143896] p0045 N75-27263
DIRECT POWER GENERATORS
U SOLAR CELLS
U THERMOELECTRIC GENERATORS
DIRECTIONAL ANTENNAS
U PARABOLIC ANTENNAS
U TWO REFLECTOR ANTENNAS
DISPLAYS
U PARABOLIC REFLECTORS
DISPLAY DEVICES
Experimental evaluation of remote manipulator
systems
p0054 A73-37305
DISPLAY SYSTEMS
U DISPLAY DEVICES
DISTORTION
Thermal distortion and static bending plus twist
measurements on deployable boom structures for
spacecraft
p0011 N72-25789
DISTRIBUTION (PROPERTY)
U ANTENNA RADIATION PATTERNS
U CURRENT DISTRIBUTION
U ELECTRON DENSITY PROFILES
U ENERGY DISTRIBUTION
U STRESS CONCENTRATION
U TEMPERATURE DISTRIBUTION
DISTURBANCE THEORY
U PERTURBATION THEORY
DOCKING
U SPACECRAFT DOCKING
DOCUMENTS
U HANDBOOKS
U USER MANUALS (COMPUTER PROGRAMS)
DOMESTIC SATELLITE COMMUNICATIONS SYSTEMS
Impact of shuttle on technology and utility of
national and regional communications satellites
[IAPF PAPER 77-36] p0002 A77-51399
Future communications concepts. I - The
switchboard-in-the-sky
p0003 A78-26827
Switchboard in the sky --- antenna platform for
domestic satellite communications systems
p0044 A78-37243
DRAG
U AERODYNAMIC DRAG
U SATELLITE DRAG
An atmospheric density model for application in
analytical satellite theories
DEADWEIGHT
U DEBRIS
U SPACE DEBRIS
DEFLATING
U DEPLOYMENT
DEFLECTION
DEFLECTION
METRIC (DIMENSIONS)
U WEIGHT (MATERIALS)
DIRECT CURRENT
U DEPLOYMENT
DEFLECTION
METRIC (DIMENSIONS)
U WEIGHT (MATERIALS)
DIRECT CURRENT
U DEPLOYMENT
DEFLECTION
METRIC (DIMENSIONS)
U WEIGHT (MATERIALS)
DYNAMIC PROPERTIES

- Analysis
  - [AIAA Paper 71-400] p0021 A71-25276
- Model verification of large structural systems — space shuttle model response
  - [NASA-CR-150811] p0015 N78-31464

DYNAMIC PROPERTIES

U DYNAMIC CHARACTERISTICS

- Dynamic response
  - Multiflexible spacecraft integrated analysis
    - Structures, dynamics, and control
  - [NASA-CR-145320] p0009 A78-12108
- Dynamics and control of non-rigid space vehicles
  - Conferences held at Frascati, Italy, 24-26 May 1976
  - p0039 N76-28297
- Dynamics and control of non-rigid spacecraft
  - Conference held at Frascati, Italy, 24-26 May 1976
  - [ESA-SP-117] p0041 N77-10142
- Response of long, flexible cantilever beams
  - Applied root motions — spacecraft structures
  - p0031 N77-10276
- Mathematical methods in flexible spacecraft dynamics, volume 1
  - [ISS/SS-766-VOL-1] p0013 N77-23188
- Mathematical methods in flexible spacecraft dynamics, volume 2
  - [ISS/SS-766-VOL-2] p0013 N77-23189
- The dynamics and control of large flexible space structures
  - Part A: Discrete model and modal control

DYNAMIC STABILITY

- NT ATTITUDE STABILITY
- NT MOTION STABILITY
- NT SPACECRAFT STABILITY

DYNAMIC STRUCTURAL ANALYSIS

- Damping augmentation for large space structures
  - [AIAA Paper 78-440] p0073 N75-22531
- Simulation, analysis, and evaluation of dynamic load interactions between solar arrays and space station resulting from orbital perturbations
- Integrated dynamic analysis simulation of space stations with controllable solar arrays
  - [NASA-CR-112145] p0012 N72-32849
- The continuum mechanics dynamic study of a satellite with flexible solar panels
  - [SPAB-8-551] p0012 N74-17622
- Structural dynamic testing considerations for large space vehicles
  - p0073 N75-22531
- A semi-automatic modal-survey test technique for complex aircraft and spacecraft structures
  - p0012 N75-22539
- Microwave power transmission system studies:
  - Volume 3, section 9: Mechanical systems and flight operations
- Finite element dynamic analysis of large dimensional flexible solar arrays: Necessity of modal truncation for the simulation of spacecraft control manoeuvres
  - p0013 N76-28306
- Response of long, flexible cantilever beams
  - Applied root motions — spacecraft structures
  - p0031 N77-10276
- A Rayleigh-Ritz approach to the synthesis of large structures with rotating flexible components
  - p0013 N77-10280
- Structural stiffness, strength and dynamic characteristics of large tetrahedral space truss structures
  - [NASA-M-17001] p0013 N77-19987
- The dynamics and control of large flexible space structures. Part A: Discrete model and modal control
- Model verification of large structural systems — space shuttle model response
  - [NASA-CR-150811] p0015 N78-31464

DYNAMIC TESTS

- Control system technology and tradeoffs for large space structures
  - [AIAA Paper 78-1661] p0039 A78-52747
- Communications technology satellite deployed solar array dynamics tests
  - [CSC-1264] p0073 N75-20468

SUBJECT INDEX

EARTH ORBITS

- Earth orbital teleoperator manipulator system evaluation program
  - [NASA-CR-150811] p0061 N77-25787
- Information services platforms at geosynchronous earth orbit: A requirements analysis
- A fine pointing control for a large spinning spacecraft in earth orbit
  - p0042 N78-26162

EARTH RESOURCES

- Space: A resource for earth — An AIAA review
  - Book
  - p0001 A77-32440

EARTH RESOURCES TECHNOLOGY SATELLITES

U LANDSAT SATELLITES

U NAVIGATION SATELLITES

U Synchronous Satellites

ECONOMIC ANALYSIS

- Economics of ion propulsion for large space systems
  - [AIAA Paper 78-16861] p0066 N78-37441
- Solar electric propulsion and interorbital transportation
  - [AAS 77-221] p0066 N78-43879

EFFECTIVENESS

- NT COST EFFECTIVENESS
- NT SYSTEM EFFECTIVENESS

EFFICACIOUS

- NT CONTROL EQUIPMENT

EIGENVALUES

- Flexible spacecraft control design using pole allocation technique
  - [AIAA Paper 77-10971] p0037 A77-42817
- Damping augmentation for large space structures
  - [AIAA 78-440] p0037 A78-29797

ELASTIC BUCKLING

- Post buckling behaviour of thin-walled members — of folded flat plates
  - p0008 A75-15084

ELASTIC DEFORMATION

- NT ELASTIC BUCKLING
- NT ELASTIC MODULUS
- NT MODULUS OF ELASTICITY
- NT ELASTIC PROPERTIES
- NT ELASTOPLASTICITY
- NT MODULUS OF ELASTICITY

- NT ELASTOPLASTICITY
- NT ELASTIC PROPERTIES
- NT ELASTOPLASTICITY
- NT MODULUS OF ELASTICITY
- NT ELASTOPLASTICITY
- NT MODULUS OF ELASTICITY

- NT MODULUS OF ELASTICITY
- NT ELASTIC PROPERTIES

ELECTRIC APPLIANCES

U NT ELECTRIC EQUIPMENT

ELECTRIC BATTERIES

- Solar/battery space station power plants combined with nuclear configurations, discussing rectified alternator current, direct energy transfer, and high voltage dc sources
  - p0043 A73-26008
- A 25 kW solar array/battery design for an earth orbiting space station
  - p0043 A73-26010

ELECTRIC CONNECTORS

- The installation of systems on large space structures
  - [AIAA Paper 76-1661] p0044 A78-51988

ELECTRIC CURRENT

- NT ALTERNATING CURRENT
- NT DIRECT CURRENT

ELECTRIC EQUIPMENT

- Design, development, and evaluation of roll-up solar array rated at thirty watts per pound
  - [NASA-CR-158196] p0029 N72-32070

ELECTRIC GENERATORS

U NT SOLAR AUXILIARY POWER UNITS

A-10
ENVIROMENTS

Space environment effects on reinforced plastic materials for spacecraft structures p0050 N70-21237
Thermal vacuum environment tests of materials used in space technology to determine effect of ultraviolet radiation on contaminative properties [NASA-CR-122374] p0050 W75-19556

ENVIRONMENTS
MT AEROSPACE ENVIRONMENTS
MT CISTLUNAR SPACE
MT THERMAL ENVIRONMENTS

EPOXIDES

U EPOXY COMPOUNDS

EPOXY RESINS

Improved mechanical properties of composites reinforced with neutron-irradiated carbon fibers. p0047 A74-85143
Curved, tapered, circular cross section graphite/epoxy antenna ribs p0047 A74-28881
Mechanical of a bore-nrom reset composite material radiation-induced of its epoxy matrix p0037 A74-26648
Investigation of the physical-mechanical properties and supramolecular structure of epoxy resins exposed to UV radiation under atmospheric conditions p0047 A75-21365

EQUATIONS OF MOTION

Dynamical equations of spacecraft with controlled flexible appendages using finite element approach [AIAA PAPER 74-1261] p0036 A75-11105
Equations of motion for a rotating flexible structure --- influence on spacecraft appendages p0009 A70-1203
SAS-C solar array development dynamics [ADV-DO27073] p0031 W76-33743
RMS massless arm dynamics capability in the SVDS --- equation of motion [NASA-CR-151458] p0061 W77-27162

EQUIPMENT SPECIFICATIONS


ERGONOMICS

U HUMAN FACTORS ENGINEERING

U LANDSAT SATELLITES

ESA SATELLITES

MT GEOSS SATELLITES (ESA)

ESTIMATING

MT ORBITAL POSITION ESTIMATION

EUCLIDEAN GEOMETRY

MT POLYHEDRONS

MT TRUFPOLYHEDRONS

FLEXION

U ORBIT PERTURBATION

EXHAUST FLOW SIMULATION

MT FLIGHT SIMULATION

EXPANDABLE STRUCTURES

MT INFLATABLE STRUCTURES

Expandable and modular structures for support on ranked space missions, reviewing inflatable, chemically rigidizable, unfurlable and elastic recovery structures p0017 A69-42789
Foldable tubular connection application to expandable lattice structure, analyzing cross sectional distortions p0018 A69-17608

A-12

SUBJECT INDEX

Deployable STEM / storable tubular extendible member / booms for aerospace gravity gradient stabilization, noting interlocked BI-STEM p0007 A70-30762
Optimal overlap design of the various tubular extendible spacecraft structures under solar heating in zero-g environment p0019 A70-14725
Storable tubular extendible member / STEM/, discussing advantages of BI-STEM for erecting unfurlable structures in space p0020 A70-34141
Flexible Storable Tubular Extendible Member / STEM/ in-plane bending vibrations under solar heating p0007 A71-10941
Spacecraft deployable boom, discussing structural design, self loading, weight, storage volume and thermal stability requirements p0020 A71-25272
Lightweight parabolic antenna model with inflated Mylar tube torus and central mast interconnected by wires, discussing construction, performance tests and tradeoffs p0021 A71-25273
Space deployed expandable structures, discussing vehicular and environmental constraint effects on design, large structure requirements, and applications p0021 A73-18905
Rigidized woven screen material study for gravity gradient boom and antenna [NASA-CR-93837] p0026 W68-20267
Large space parabolic expandable truss antenna experiment [NASA-CR-93833] p0026 W68-20304
Parabolic expandable truss antenna experiment design for Apollo applications program p0026 W68-20304
Expandable and Modular Structures Conference [AFAPL-TR-68-17] p0073 W68-27917
Zero gravity simulation methods and applications in design and procedures determination for D-021 and 0-023 space structure experiments p0069 W68-27931
Development of expandable structures concepts for application to structures used in space missions - Part 2 [NASA-CR-1735] p0011 W71-37537
Expandable space frames with high expansion to collapse ratio [NASA-CASE-lRC-10365-1] p0030 W73-32749

EXPANSION

MT THERMAL EXPANSION

EXPERIMENTAL DESIGN

Design of satellite flexibility experiments --- appendage effects on attitude control [JSPA PAPER 74-003] p0008 A75-13627

EXPLORATION

MT SPACE EXPLORATION

EXTRAGALACTIC LIGHT

U EXTRATERRESTRIAL RADIATION

EXTRATERRESTRIAL COMMUNICATION

Searching for extraterrestrial intelligence - The ultimate exploration p0002 A77-46747
On the active and passive CEV from earth satellite orbit --- communication with extraterrestrial intelligence [JSPA PAPER A-77-48] p0002 A77-51524
Searching for extraterrestrial life - The SFI gamble p0003 A78-16768
Extraterrestrial intelligence - An observational approach p0003 A78-22524

EXTRATERRESTRIAL ENVIRONMENTS

MT CISTLUNAR SPACE

EXTRATERRESTRIAL LIFE

NASA contemplates radio Search for Extra-terrestrial Intelligence p0001 A76-45888
Searching for extraterrestrial intelligence - The ultimate exploration p0002 A77-46747
Antenna concepts for interstellar search systems p0002 A78-13323
Searching for extraterrestrial life - The SFI gamble p0003 A78-16768
The dynamics of flexible bodies --- aircraft and space vehicles motion p0036 A76-46286
Evaluation of rotor-induced gyroscopic coupling on the natural modes of large flexible spacecraft [AIAA 77-1096] p0089 A77-42801
Flexible spacecraft flexible appendage rigidity [AIAA 77-1097] p0023 A77-42802
Flexible spacecraft control design using pole allocation technique [AIAA PAPER 77-1097] p0037 A77-42817
Active control of flexible systems p0037 A78-12096
An active modal control system philosophy for a class of large space structures p0037 A78-12099
Equations of motion for a rotating flexible structure --- influence on spacecraft appendages p0099 A78-12103
Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control p0099 A78-12108
Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control p0099 A78-31688
The new generation of dynamic interaction problems --- for attitude control [AIAA PAPER 78-101] p0099 A78-44376
Dynamics of a "flexible body in orbit" [AIAA PAPER 78-1418] p0100 A78-45682
Dynamics and control of large spinning spacecraft [AIAA PAPER 79-1921] p0108 A78-45684
Feedback control of flexible systems p0138 A78-49256
Control of large space structures via singular perturbation optimal control [AIAA PAPER 78-1690] p0138 A78-52002
Mathematical composition, weight, size, and unfolding factors entering into design of inflatable space station structures [NASA-CR-92596] p0138 A78-52002
The attitude control of three-axis stabilized spacecraft with flexible appendages, volume 1 --- equations of motion and control system design and synthesis [ISS/SS-695-VOL-1] p0330 A76-15239
An application of modern control theory to an elastic spacecraft p0340 A76-28317
Three axis control of spacecraft with large flexible appendages p0340 A76-28323
Comparative systems study of magnetically suspended flywheels --- for stationary satellites with flexible appendages [BNFT-FB-8-76-20] p0441 A77-23166
Mathematical methods in flexible spacecraft dynamics, volume 1 [ISS/SS-766-VOL-1] p0413 A77-23188
Mathematical methods in flexible spacecraft dynamics, volume 2 [ISS/SS-766-VOL-2] p0413 A77-23188
Attitude control of three-axes stabilized spacecraft with flexible appendages, volume 1 [ISS/SS-783-VOL-1] p0441 A77-23189
Attitude control of three-axes stabilized spacecraft with flexible appendages, volume 2 [ISS/SS-783-VOL-2] p0441 A77-23199
Comparative systems study of magnetically suspended flywheels --- for stationary satellites with flexible appendages [ISS-FT-393] p0441 A77-33245
FLIGHT COMPUTERS
U AEROBRE/SPACEBORNE COMPUTERS
FLIGHT CONTROL
MT POINTING CONTROL SYSTEMS
FLIGHT MECHANICS
Microwave power transmission system studies.
HABDBOOKS

HANDBOOKS

MT USER MANUALS (COMPUTER PROGRAMS)
aerospace environment and effects on materials, spacecraft material selection, and biological interaction with spacecraft materials - handbook [NASA-SF-3051] p0050 N70-21226

HANDLING EQUIPMENT

MT CRANES
HEAT EFFECTS
U TEMPERATURE EFFECTS
HEAT REGULATION
U TEMPERATURE CONTROL
HEATING
MT SOLAR HEATING
HELICAL WINDINGS
HELICAL WINDINGS
HELICOPTER AIRCRAFT
Large solar sail vehicle to operate in manner of helicopter rotor [NASA-CR-1229] p0066 N69-28861
HELICOPTER MILITARY AIRCRAFT
U HELICOPTER AIRCRAFT
HELIOCENTRIC ORBITS
U SOLAR ORBITS
HERMES SATELLITE
U COMMUNICATIONS TECHNOLOGY SATELLITE
HIGH VOLTAGES
Spacecraft-generated plasma interaction with high voltage solar array [AIAA PAPER 78-671] p0045 A78-32751
High voltage solar array for ion thruster electric propulsion system [NASA-TM-X-71862] p0067 N73-33002
HINGED MOTOR BLADES
U HINGES
HINGERS
Analytical studies on foldable tubes --- for satellite hinges, noting prestressing [NASA-CR-763] p0031 N76-24635
HOMANN TRAJECTORIES
U TRANSFER ORBITS
HOMANN TRANSFER ORBITS
U TRANSFER ORBITS
HOLOGRAPHY
Holographic structural control for large space reflectors and radio telescopes p0035 A74-36663
HUMAN ENGINEERING
U HUMAN FACTORS ENGINEERING
HUMAN FACTORS ENGINEERING
Zero gravity simulation methods and applications in design and procedures determination for D-021 and D-022 space craft experiments p0069 N69-27911
HUMAN PERFORMANCE
MT ASTRONAUT PERFORMANCE
MT OPERATOR PERFORMANCE
HYDRAULIC ACTUATORS
U ACTUATORS
IMAGERY
U BLOGOGRAPHiY
INDUSTRIES
Space industrialization [GEO-95-159] p0005 N78-20149
INERTIAL MOUNTS
U RIGID STRUCTURES
INERTIAL WHEELS
U REACTION WHEELS
INERTIAL REFERENCE SYSTEMS
The dynamics of flexible bodies --- aircraft and space vehicles motion p0036 A76-46286
INFLATABLE DEVICES
U INFLATABLE STRUCTURES
INFLATABLE STRUCTURES
Expandable and modular structures for support on manned space missions, reviewing inflatable, chemically rigidizable, unfurlable and elastic recovery structures p0017 A69-42789

SUBJECT INDEX

The SETI project - the search for extraterrestrial intelligence p0036 A76-46286
The SETI project - the search for extraterrestrial intelligence - The SETI gable p0003 A76-16768
ION ENGINES
MT MERCURY ION ENGINES
Thermal control of the solar electric propulsion stage [AIAA PAPER 73-11116] p0065 A74-10563
Ion thruster design and analysis [AIAA PAPER 76-10489] p0065 A77-15106
ION PROPULSION
Economics of ion propulsion for large space systems [AIAA PAPER 78-698] p0066 A78-37441
High voltage solar array for ion thruster electric propulsion system [NASA-TM-X-71862] p0067 N73-33002
Electron bombardment propulsion system characteristics for large space systems [NASA-TM-X-73561] p0067 N77-11106
IONIC PROPELLANTS
U ION ENGINES
IONIZING RADIATION
MT ULTRAVIOLET RADIATION
Effect of ionizing radiation on mechanical properties of glass-fiber-filled polyethylene p0049 A78-33058
IP (IMPACT PROTECTION)
U COMPUTERIZED SIMULATION
IRRADIATION
MT NEUTRON IRRADIATION
LISTING MODEL
U MATHEMATICAL MODELS

A-16
Structural and assembly concepts for large erectable space systems

[AAS 77-205]
p0024 A78-36706

Economics of ion propulsion for large space systems

[AIAA PAPER 78-698]
p0066 A78-37441

Structure assembly demonstration slated --- for large space structures in low orbit

[AMS 78-101]
p0072 A78-38774

Tank tests validate structure assembly --- underwater zero-g tests for antrostal assembly of large space structures

[p0057 A78-42674]

The new generation of dynamic interaction problems --- for attitude control

[AAS PAPER 78-101]
p0009 A78-44376

Optimal digital control of large space structures

[AAS PAPER 78-305]
p0038 A78-44380

Continuum modeling of three-dimensional truss-like space structures

[p0009 A78-44061]

Dynamics of a flexible body in orbit

[AIAA PAPER 78-1818]
p0010 A78-45682

The control of spacecraft vibrations using multivariable output feedback

[AIAA PAPER 78-1819]
p0036 A78-45683

Dynamics and control of large spinning spacecraft

[AIAA PAPER 78-1820]
p0030 A78-45684

Computerized structural sizing at NASA Langley Research Center --- low mass design for aerospace vehicles

[AIAA PAPER 78-1850]
p0010 A78-46513

An institutional plan for multipurpose space platforms

[p0025 A78-47263]

A statistical evaluation of a space stable optical support structure

[p0025 A78-49546]

Geosynchronous information services platform in the year 2000

[AIAA PAPER 78-1636]
p0073 A78-51076

Design concept of geostationary platform

[AIAA PAPER 78-1642]
p0025 A78-51081

Large space structures at the Marshall Space Flight Center

[AIAA PAPER 78-1650]
p0073 A78-51082

Joints and implications on space construction

[AIAA PAPER 78-1653]
p0025 A78-51083

Space Spider - A concept for fabrication of large structures

[AIAA PAPER 78-1655]
p0025 A78-51094

Orbital servicing of space platforms

[AIAA PAPER 78-1659]
p0025 A78-51096

The installation of systems on large space structures

[AIAA PAPER 78-1661]
p0044 A78-51088

Large space structures assembly simulation

[AIAA PAPER 78-1662]
p0010 A78-51089

Maneuvering unit - A space platform support system

[AIAA PAPER 78-1663]
p0025 A78-51090

Advanced teleoperator spacecraft

[AIAA PAPER 78-1665]
p0057 A78-51091

A crate for construction in space

[AIAA PAPER 78-1666]
p0026 A78-51092

Maneuvering remote work stations --- for ultralarge space structure orbital assembly

[AIAA PAPER 78-1667]
p0073 A78-51093

Thermal control requirements for large space structures

[AIAA PAPER 78-1675]
p0010 A78-51099

Control of large space structures via singular perturbation optimal control

[AIAA PAPER 78-1690]
p0038 A78-52002

Automatic fabrication of large space structures - The next step

[AIAA PAPER 78-1651]
p0026 A78-52742

On-orbit fabrication and assembly of composite structures

[AIAA PAPER 78-1658]
p0026 A78-52743

Control system technology and tradeoffs for large space structures

[p0039 A78-52747]

Assembly of large space structures

[AAS PAPER 78-502]
p0057 A78-53605

Microwave performance characterization of large space antennas

[NASA-CR-153206]
p0005 N77-24333
LARGE SPACE TELESCOPE

SUBJECT INDEX

LOAD TESTS
Aluminium models of single cell simply supported folded plates to study instability phenomena possibly occurring in actual structure [NASA-CR-151849] p0032 W77-27156
Post buckling behaviour of thin-walled members --- of folded flat plates [NASA-CR-150285] p0008 W75-18864

LOADING FORCES
U LOADS (FORCES)
LOADING WAYS
U LOADS (FORCES)
LOADS (FORCES)
NT COMPRESSION LOADS
NT CRITICAL LOADS
NT STATIC LOADS
Structural efficiency of long lightly loaded truss and isogrid columns for space applications [NASA-TM-78687] p0033 W78-33860

LOGISTICS
U SPACE LOGISTICS
LONGERONS

LOW DENSITY MATERIALS
An appreciation of the design of carbon fibre rigid solar panels for spacecraft. [NASA-CR-157569] p0050 W78-30657

LOW THRUST PROPULSION
NT ION PROPULSION
NT SOLAR ELECTRIC PROPULSION
NT SOLAR PROPULSION

LST
U LARGE SPACE TELESCOPES

M
MACHINE LIFE
U SERVICE LIFE

MAGNETIC PROPERTIES
NT MAGNETIC SUSPENSION

MAGNETIC SUSPENSION
Comparative systems study of magnetically suspended flywheels --- for stationary satellites with flexible appendages [NASA-CR-121] p0027 W69-26238
Comparative systems study of magnetically suspended flywheels --- for stationary satellites with flexible appendages [ESA-TT-393] p0041 W77-33285

MANUEFACTURING
U SPACE MAINTENANCE

MAN SYSTEMS
Free-flying teleoperator for space missions [NASA-CR-151729] p0062 W78-23112
Shuttle remote manipulator system workstation - Man-machine engineering [NASA-SP-5047] p0057 W68-18870
Manipulator evaluation criteria [NASA-CR-151731] p0062 W78-25111
Engineering problems survey on teleoperator control systems [NASA-SP-5070] p0058 W69-21478
Development and operation of simulator to provide real-time visual scenes for man in the loop investigations of remote manipulator application for space shuttle [NASA-CR-115636] p0059 W72-24339
Design criteria and tradeoffs for man machine interface for teleoperator system performing on-orbit satellite retrieval and servicing [NASA-CR-123755] p0050 W72-29830
Manipulator system man-machine interface evaluation program --- technology assessment [NASA-CR-120216] p0050 W74-29859
Simulation of man-machine interaction on shuttle payload manipulator [NASA-CR-150285] p0061 W75-27586
Earth orbital teleoperator mobility system evaluation program [NASA-CR-150285] p0061 W75-27586

A-18
On-orbit payload handling for space shuttles, including manipulator arms for drawing docking vehicles together, closed circuit TV and airlocking.

Teleoperator manipulator for payload handling in space shuttle, noting design features and simulations of master-slave remote control system.

A teleoperator system for space application.

X-reference frame bilateral control for the Shuttle Attached Manipulator System.

Preliminary design and simulations of Shuttle-Attached Manipulator System.

Simulation concepts for a full-sized Shuttle manipulator system.

A manipulator system designed for Free-Flying Teleoperator Spacecraft.

Free-flying teleoperator for space manipulation.

Remote Manipulator System and satellite servicing experiment for Space Shuttle.

Shuttle manipulator design reviewed.

Vehicle/mannipulator/packaging interaction - A synergistic approach to large erectable space system design.

Shuttle remote manipulator system workstation - Man-machine engineering.

Manipulator evaluation criteria.

Development of a shuttle manipulator simulator.

Shuttle remote manipulator system safety and rescue support capabilities.

Application of optimal and adaptive algorithms to the system robot-manipulator in cosmic space.

The remote manipulator system for the Space Shuttle Orbiter.

Dynamics of a flexible manipulator arm for the Space Shuttle.

General purpose manipulator system for space station and shuttle - laboratory simulation studies.

Development and operation of simulator to provide real-time visual scenes for man-in-the-loop investigations of remote manipulator application for space shuttle.

Attached manipulator system for simulating and demonstrating shuttle manipulator cargo handling operations under weightless conditions.

Configuration and design study of manipulator systems applicable to the free flying teleoperator. Volume I: Executive summary.

Earth orbital teleoperator visual system evaluation program.

Variable ratio mixed-mode bilateral master-slave control system for shuttle remote manipulator system.

Concept design of the payload handling manipulator system -- space shuttle orbiters.

Robot manipulators -- in space exploration.

Simulation of man-machine interaction on shuttle payload manipulator.

A manipulator arm for zero-g simulations.

Proto-Flight Manipulator Arm (P-FMA).

Earth orbital teleoperator manipulator system evaluation program.

Remote manipulator system steering capability for SPS.

Robot manipulators -- dynamics capability in the SPS equations of motion.

The assembly of large structures in space -- a 25 ft. astronomy telescope and microwave antenna.

End effector device -- for manipulators.

MAWNED ORBITAL LABORATORIES

A 25 kw solar array/battery design for an earth orbiting space station.

MAWNED ORBITAL SPACE STATIONS 8 ORBITAL SPACE CRAFTS;

MAWNED SPACE FLIGHT

Space assembly of satellites and vehicles noting launch restraints, form factor, technology, logistics and maintainability.

MAWNED SPACECRAFT

MANNED ORBITAL LABORATORIES

MANNED ORBITAL SPACE STATIONS 8 ORBITAL SPACE STATIONS

MANNED SPACECRAFT

MANNED SPACE FLIGHT

Space assembling of satellites and vehicles noting launch restraints, technology, etc.

MANUAL CONTROL

Simulation of man-machine interaction on shuttle payload manipulator.

MANUALS

NT USER MANUALS (COMPUTER PROGRAMS)
MARINER VENUS-MERCURY 1973

INSTRUMENTATION

Space: A resource for earth — An AIAA review --- Book

PROBES

Materials Handling

Thermal vacuum environment tests of materials used in space technology to determine effect of ultraviolet radiation on contaminative properties [NASA-CR-122374] p0050 N73-19556

MATHEMATICAL MODELS

Matrices (Mathematics)

MATRICES (MATHEMATICS)

MATHEMATICAL METHODS

MEASURING INSTRUMENTS

MECHANICS

MECHANICAL DEVICES

Closed tubular extendible boom /Multiple Applications Storable Tube/ design, fabrication and applications, including stress factors and materials

End effector device --- for manipulators [NASA-CASE-MFS-20410] p0029 N71-12109

MECHANICAL PROPERTIES

METASTABLE METALS

NEWTONIAN COMPRESSION TESTS

MICROELECTRONICS

Microprocessor-based data acquisition system incorporating a floating-point arithmetic unit for complex mathematical computations

MICROWAVE ANTENNAS

Large deployable antennas and solar generators with ultralightweight design characteristics

Satellite power system LEO vs GEO assembly issues --- construction in Low Earth Orbits vs Geosynchronous Orbits

Antenna concepts for interstellar search systems

Large communication-satellite antenna

A future for large space antennas [NASA-CP-148720] p0074 N76-30262

Study of deployable antennas for satellites

Microwave performance characterization of large space antennas

A-20
Future space programs
[AAI PAPER 77-1097]

Application of optimal and adaptive algorithms to the system robot-manipulator in cosmic space
[IAA PAPER 77-57-02]

Stochastic optimal attitude control of spacecraft with movable appendages
[IAA PAPER 78-61690]

Optimal digital control of large space structures
[IAA PAPER 78-105]

Control of large space structures via singular perturbation optimal control
[IAA PAPER 78-1690]

Control system technology and tradeoffs for large space structures
[IAA PAPER 78-1686]

Optimal control of spin stabilized spacecraft with telescoping appendages
[IAA PAPER 76-28319]

Optimization

MT TIME OPTIMAL CONTROL
A new optimality criterion method for large scale structures
[IAA PAPER 78-470]

Size, performance and cost trades of large solar electric propulsion systems
[IAA PAPER 78-697]

Optimal control

OPTIMAL CONTROL

Nonlinear systems
Nonlinear attitude control system design for space vehicle
[POO39 N88-23821]

Nuclear auxiliary power units
Nuclear electric power generation
[POO43 A76-41890]

Nuclear power reactors
Nuclear power plants
[POO43 A76-43632]

Numerical control

Optimal digital control of large space structures
[AAI PAPER 78-105]

Observation

NT SATELLITE OBSERVATION
Onboard computers
[POO40 N76-28324]

Operations research

[NASA-CH-148703]

Operator performance
Engineering problems survey on teleoperator control systems
[NASA-SP-5070]

Optical absorption
U light transmission

Optical coupling
Losses in a statistically irregular focusing fiber
[POO43 A76-43632]

Optical equipment

Optical astronomical telescopes
Optical lasers
Optical waveguides
Multimode optical fibers - Steady state mode exciters
Fabrication and assembly of large composite structures in space [AIAA PAPER 77-546] p0023 A77-32065
Fabrication methods for large space structures [AIAA PAPER 77-546] p0023 A77-32059
Learning to build large structures in space [AIAA PAPER 77-546] p0023 A77-32059
Assembly in space of large communication structures [AIAA PAPER 77-546] p0003 A77-36723
Structure assembly demonstration slated for large space structures in low orbit [AIAA PAPER 77-546] p0072 A78-38774
Tank tests validate structure assembly -- underwater zero-g tests for astronaut assembly of large space structures [AIAA PAPER 77-546] p0057 A78-42474
Now laser for space robots and automation [AIAA PAPER 78-1653] p0025 A78-51983
Space Spider -- A concept for fabrication of large structures [AIAA PAPER 78-1655] p0025 A78-51984
The installation of systems on large space structures [AIAA PAPER 78-1661] p0044 A78-51980
Large space structure assembly simulation [AIAA PAPER 78-1662] p0010 A78-51989
Advanced teleoperator spacecraft [AIAA PAPER 78-1663] p0057 A78-51991
A crane for construction in space [AIAA PAPER 78-1666] p0026 A78-51992
Hanned remote work stations -- for ultralarge space structure orbital assembly [AIAA PAPER 78-1667] p0073 A78-51993
Automatic fabrication of large space structures -- the next step [AIAA PAPER 78-1651] p0026 A78-52742
Orbit fabrication and assembly of composite structures [AIAA PAPER 78-1659] p0026 A78-52743
Assembly of large space structures [AIAA PAPER 78-1652] p0057 A78-55695
Requirements and role of extravehicular activity /EVA/ in deployment, assembly, and maintenance of in-space erectable structures during earth orbital missions [AIAA PAPER 78-1654] p0058 A69-27934
Earth orbital teleoperator manipulator system evaluation program [NASA-CR-143874] p0061 W75-26657
Orbital assembly and maintenance study [NASA-CR-144022] p0060 W75-26657
Orbital construction demonstration study [NASA-CR-151352] p0032 W77-23136
Orbital construction demonstration study, executive summary [NASA-CR-151358] p0075 W77-23130
Large space erectable structures - building block structures study [NASA-CR-151648] p0032 W77-27156
The assembly of large structures in space -- radio astronomy telescope and microwave antenna [NASA-CR-143874] p0061 W77-29770
Structural members, method and apparatus [NASA-CASE-MFT-162171] p0033 W78-22146
Orbital Position Estimation An analytical Satellite Orbit Predictor (ASOP) [NASA-CASE-MFT-151583] p0075 W78-14066
Orbital Space Stations NT ORBITAL WORKSHOPS Space tools and support equipment for earth orbital system maintenance, replacement and repair, discussing Skylab requirements and teleoperator applications [AIAA PAPER 72-230] p0053 A72-25049
A 25 kw solar array/battery design for an earth orbiting space station. [AIAA PAPER 73-26010]
Use of Shuttle in establishing large space installations [AIAA PAPER 77-546] p0043 A73-26010
Orbital antenna farms -- geosynchronous platforms replacing satellites [AIAA PAPER 77-546] p0072 A77-47268
The OAP concept extended -- Orbital Antenna Farm [AIAA PAPER 78-1655] p0033 A78-32891
Design concept of geostationary platforms [AIAA PAPER 78-1642] p0025 A78-51990
Manned maneuvering unit -- A space platform support system [AIAA PAPER 78-1663] p0025 A78-51990
Orbital assembly and maintenance study. Executive summary -- space erectable structures/structural design criteria [NASA-CR-144408] p0060 W75-32971
Orbital Transfer U TRAVERSE ORBITS ORBITAL WORKERS The role of EVA on Space Shuttle -- experimental support and maintenance activities [AIAA PAPER 72-2301] p0053 A72-25049
Requirements and role of extravehicular activity /EVA/ in deployment, assembly, and maintenance of in-space erectable structures during earth orbital missions [AIAA PAPER 78-1654] p0058 A69-27934
Orbital Workshops Manned remote work stations -- for ultralarge space structure orbital assembly [AIAA PAPER 78-1657] p0073 A78-51993
Orbiting Satellites NT ARTIFICIAL SATELLITES ORBITS NT EARTH ORBITS NT GEOSTATIONARY ORBITS NT SYNTHETIC ORBITS NT SOLAR ORBITS NT SPACECRAFT ORBITS NT TRANSFER ORBITS OTY U ORBIT TRANSFER VEHICLES OUTGassing Thermal vacuum environment tests of materials used in space technology to determine effect of ultraviolet radiation on contaminative properties [NASA-CASE-MFT-162171] p0061 W75-26657
An outgassing data compilation of spacecraft materials [NASA-SF-1014] p0050 W78-17151
Packaging Characteristics of device for folding thin flexible sheets into compact configuration [NASA-CASE-MFT-162171] p0061 W78-33180
Parabolic Antennas Spaceborne paraboloidal antennas erecting techniques, considering applicability to near earth or interplanetary missions [AIAA PAPER 78-1655] p0072 A78-42453
Multidimensional node shape and frequencies of 100 ft space erectable parabolic antenna [NASA-CASE-MFT-162171] p0010 A69-25532
Zero g deployment dynamics of erectable truss parabolic antennas, obtaining latchup loads as function of reflector mechanical energy [NASA PAPER 69-3367] p0038 A69-2827
AIS P and G, discussing communications experimental program with deployable 30 ft parabolic antenna [NASA PAPER 700759] p0069 A71-21368
Lightweight parabolic antenna model with inflated Mylar tube torus and central mast interconnected by wires, discussing construction, performance tests and tradeoffs [AIAA PAPER 77-397] p0021 A71-25273
PARABOLIC REFLECTORS

Large space parabolic expandable truss antenna experiment
[NASA-CR-93837]  p0026 N68-20267
Parabolic expandable truss antenna experiment
Design, electrical, and mechanical characteristics of inflatable, rigid, and parabolic antenna systems
Erectable parabolic antenna with space applications
[NASA-CR-2894]  p0032 N77-33260
ARF large deployable antenna development program:
Executive summary
[NASA-CR-2894]  p0032 N77-33260
Telescoping columns --- parabolic antenna support
[NASA-CASE-LAR-12195-1]  p0033 N78-33446

PARABOLIC REFLECTORS

Testing program using electrical measurements for
determining adequacy of erectable parabolic reflector for space missions
p0007 A69-12812
Unfurlable spacecraft antenna design and
electrical characteristics, using Gregorian geometry with conical main and parabolic subreflector
p0020 A71-12324
Feasibility of deployment of self-deploying
electromagnetic energy focusing reflector for
space or transportable ground based operations
p0027 N68-27929
Self erecting parabolic reflector design for use
in space
[NASA-CASE-EMS-03949]  p0029 N77-20658
Deployable reflector design for Ku-band operation
[NASA-CASE-132553]  p0033 N77-33781
ARF large deployable antenna development program:
Executive summary
[NASA-CR-2894]  p0032 N77-33260

PARTICLE ACCELERATORS

MT ELECTRON ACCELERATORS

PARTICLE DENSITY (CONCENTRATION)

PARTICLE ACCELERATORS

MT ELECTRON ACCELERATORS

PARTICLE DENSITY (CONCENTRATION)

PARTICLES

MT SOLAR ELECTRONS

PAYLOAD RETRIEVAL (STR)

Dynamics of a flexible manipulator arm for the
Space Shuttle
p0057 A78-31877

PAYLOADS

MT SPACE SHUTTLE PAYLOADS

Orbital payload handling for space shuttles,
including manipulator arms for drawing docking
vehicles together, closed circuit TV and
airlocking
[AIAA PAPER 71-811]  p0071 A71-39713
Teleoperator manipulator for payload handling in
space shuttle, noting design features and
simulations of master-slave remote control system
[AIAA PAPER 72-238]  p0053 A72-29075
Teleoperators and EVA for Shuttle missions
p0055 A78-14177
Spoked wheels to deploy large surfaces in space
[AIAA PAPER 76-1267]  p0022 A75-11108
Integrating Shuttle payloads
p0071 A77-31834
Advanced technology laboratory experiments
in space, volume 2: Mission analysis and planning.
Part 1: Flight plan, payload 1
[NASA-CR-145572-1]  p0005 N77-31236
Analysis of selected activities of the remote manipulator system
PEGASUS SATELLITES

Performance characteristics analysis of large area
roll-up solar arrays based on support structure
size and weight
Earth orbital teleoperator visual system

PERFORMANCE

Microwave performance characterization of large
space antennas
[NASA-CR-15321]  p0005 N77-24333
Study of test methods for large flexible solar
arrays (VELS) --- dynamic characteristics

PERFORMANCE TESTS

Lightweight parabolic antenna model with inflated
tubular torus and central mast interconnected
by wires, discussing construction, performance
tests and tradeoffs
[AIAA PAPER 71-397]  p0021 A71-25273
Design and performance of roll-up solar array
engineering model
p0028 N71-22561
Highlights of the long-life assurance study ---
achievement of ten year service life in selected
aerospace vehicle components
p0044 A78-19129

PERSONNEL

MT ORBITAL WORKERS

PERTURBATION

MT ORBIT PERTURBATION

MT SATELLITE PERTURBATION

PERTURBATION THEORY

Control of large space structures via singular
perturbation optimal control
[AIAA PAPER 70-3690]  p0038 A70-52002

PHASE CONTROL

Large active retrodirective arrays for space
applications

PHASED ARRAYS

Large communication-satellite antenna
p0028 A70-27020

PHOTOELECTRIC CELLS

MT PHOTOVOLTAIC CELLS

PHOTOGRAPHY

MT HOLOGRAPHY

PHOTOTHERMOPHOTONICS

U TEMPERATURE EFFECTS

PHOTOVOLTAIC CELLS

Conceptual approach study of a 200 watt per
kilogram solar array
[NASA-CR-148505]  p0031 A76-28651

PIPER (TUBES)

Flexural instability of foldable tube with elastic
recovery for use as structural elements, pipes,
antennas and masts
p0017 A68-42162

Storable tubular extensible member /STEM/,
discussing advantages of BI-STEM for executing
unfurlable structures in space
p0020 A70-34111

Lightweight parabolic antenna model with inflated
tubular torus and central mast interconnected
by wires, discussing construction, performance
tests and tradeoffs
[AIAA PAPER 71-397]  p0021 A71-25273
Analytical studies on foldable tubes --- for
satellite hinges, noting prestressing
p0031 A76-24635

PLANETARY EXPLORATION

U SPACE EXPLORATION

PLANETARY MOTION

U SOLAR ORBITS

PLANETARY SPACECRAFT

U INTERPLANETARY SPACECRAFT

PLANNING

MT AIRPORT PLANNING

MT MANAGEMENT PLANNING

MT MISSION PLANNING

MT PROJECT PLANNING

PLASMA INTERACTIONS

Spacecraft-generated plasma interaction with high
voltage solar array
[AIAA PAPER 70-673]  p0044 A78-32751

PLASTIC FILMS

U POLYBENIC FILMS

PLASTIC PROPERTIES

U ELASTOPLASTICITY
PROPELION SYSTEM PERFORMANCE

CIS-LUNAR SPACE

System design of an ion drive spacecraft

AIAA PAPER 78-6675

PROPELION SYSTEM PERFORMANCE

Size, performance and cost trades of large solar electric propulsion systems

AIAA PAPER 78-697

PROTECTION

NT THERMAL PROTECTION

NT THERMAL PROTECTION COATINGS

Thermal coated extendable boom for space applications, describing construction and vacuum metallizing technique

p0047 A75-21265

Space erectable boom with interlocked seam, perforations and coatings to provide torsional rigidity and thermal stability

p0020 A70-34143

PYROGRAPHY

U COMPOSITE MATERIALS

PYROMETRY

U TEMPERATURE MEASUREMENT

QUALIFICATIONS

Thermal design verification, qualification and acceptance testing concept for future large space objects

[N-44/85/TFS/CBR]

p0014 A78-24273

RADIATION DISTRIBUTION

NT ANTENNA RADIATION PATTERNS

RADIATION EFFECTS

Mechanical of a boron-reinforced composite material radiation-induced of its epoxy matrix

p0047 A74-26649

Investigation of the physical-mechanical properties and supramolecular structure of epoxy resins exposed to UV radiation under atmospheric conditions

p0047 A75-21265

Behaviour of carbon fibre composites under simulated space environment -- radiation effects on solar array materials

p0047 A75-24190

Effects of space radiation on thin polymers and nonmetals

[AIAA PAPER 77-741]

p0048 A77-39510

Influence of ionizing radiation on the mechanical properties of fiberglass strengthened polyethylene

p0048 A77-40199

Effect of ionizing radiation on mechanical properties of glass-fiber-filled polyethylene

p0049 A78-33058

Radiation and temperature effects on composite structures in Pegasus satellite

[AIAA CR-88473]

p0049 N69-28424

Investigating mesh materials for deployable antennas, radiation tolerance of solar array components, and crack propagation threshold for isopropionate and titanium alloy

p0050 N71-16681

RADIATION MEASURING INSTRUMENTS

NT RADIOMETERS

RADIO ANTENNAS

NT MICROWAVE ANTENNAS

An antenna for large space antennas

p0002 A78-16699

Development planning for a lightweight deployable 12 GHz antenna

p0031 N76-12240

RADIO ASTRONOMY

Structure and systems design of large gravity gradient stabilized orbiting tethered satellites structure for radio astronomy

p0020 A70-44603

NASA contemplates radio Search for Extra-terrestrial Intelligence

p0020 A70-44603

Infinetly built-up space radio telescope

[JAP PAPER 77-67]

p0020 A77-51417

RADIO COMMUNICATION

NT RADIO RELAY SYSTEMS

Extraterrestrial intelligence - An observational approach

AIAA PAPER 78-6975

RADIO EQUIPMENT

NT RADIO ANTENNAS

NT RADIO TELESCOPES

NT SPACECRAFT ANTENNAS

NT SOLAR FREQUENCIES

NT SUPERHICH FREQUENCIES

NT SPACECRAFT ANTENNAS

NT SOLAR FREQUENCIES

NT SUPERHICH FREQUENCIES

RADIO RELAY SYSTEMS

Signal relay systems using large space arrays

p0001 A73-16102

RADIO TELESCOPES

Holographic structural control for large space reflectors and radio telescopes

p0035 A74-36663

NASA contemplates radio Search for Extra-terrestrial Intelligence

p0035 A74-36663

Infinitely built-up space radio telescope

p0024 A77-51417

Automatic control of the surface shape of large space radiotelescopes

p0037 A77-51417

Static and dynamic analysis of space radiotelescope thin wall structure elements

p0009 A77-51417

Searching for extraetererestrial life - The SMTI gamble

p0003 A78-16768

RADIO TRANSMISSION

NT MICROWAVE TRANSMISSION

RADIOASTROPHYSICS

Optimization of the design parameters for a wide-band radiometric system

[AIAA-TP-78662]

RANGE CONTROL

NT TRAJECTORY CONTROL

RATES (PER TIME)

NT ROTOR SPEED

REACTION WHEELS

Attitude control of synchronous satellites possessing flexible solar arrays using a double gimbaled momentum wheel

p0040 N76-28308

REASSEMBLY

NT ATTACHMENT

RECOVERABLE SPACECRAFT

NT SPACE SHIPMENTS

REFLECTORS

NT PARABOLIC REFLECTORS

NT SOLAR REFLECTORS

Metalized fiberglass antenna meshes for spacecraft deployable reflectors, discussing low mass/area, long term stability and performance characteristics and degradation tests

p0021 A73-13085

Holographic structural control for large space reflectors and radio telescopes

p0035 A74-36663

Antenna design with self erecting mesh reflector

[AIAA-CA5X-660-09190]

p0028 N71-16102

REGULATORS

NT VOLTAGE REGULATORS

REINFORCED MATERIALS

U COMPOSITE MATERIALS

REINFORCED PLASTICS

NT GLASS FIBER REINFORCED PLASTICS

Composite materials mechanical and thermal properties for ATS reflector supporting truss, noting graphite fiber reinforced epoxy plastic design, fabrication and tests

p0047 A72-28158

Mechanical of a boron-reinforced composite material radiation-induced of its epoxy matrix

p0047 A74-26644

Considerations on the use of graphite-reinforced plastics for space erectable antennas

[AIAA 79-591]

p0047 A74-26644

Space environment effect on adhesives and reinforced plastics

[REV-22]

p0050 N69-36663

Space environment effects on reinforced plastic materials for spacecraft structures

p0050 N70-21237

REINFORCING FIBERS

Composite materials mechanical and thermal properties for ATS reflector supporting truss, noting graphite fiber reinforced epoxy plastic design, fabrication and tests

p0047 A72-28158

Fibrous composite materials reviewed for potential applications in spacecraft structures [NASA-TM-I-60069].

RELIABILITY

RELIABILITY CONTROL

RELIABILITY ENGINEERING

Solid state remote power controllers for 120 VDC power systems --- for aerospace application.

REMOTE CONTROL

A teleoperator system for space application.

X-reference frame bilateral control for the Shuttle Attached Manipulator System.


Simulation concepts for a full-sized Shuttle manipulator system.

Solid state remote power controllers for 120 VDC power systems --- for aerospace application.

Remote Manipulator System and satellite servicing experiment for Space Shuttle.

Shuttle manipulator design review.

Vehicle/manipulator/packaging interaction - A synergistic approach to large acceptable space systems design.

Shuttle remote manipulator system workstation - Man-machine engineering.

Manipulator evaluation criteria.

Control and stability problems of remote orbital capture.

The remote manipulator system for the Space Shuttle Orbiter.

Design and application potentials of general purpose, dexterous, cybernetic machines for human augmentation.

Concept design of the payload handling manipulator system --- space shuttle orbiters.

Kinematic capability in the SVDS.

Earth orbital teleoperator mobility system evaluation program.

Remote manipulator system steering capability for SVDS.

The solid state remote power controller: Its status, use and perspective.

Analytical formulation of selected activities of the remote manipulator system.

End effector device --- for manipulators.

REMOTE HANDLING

Teleoperator manipulator for payload handling in space shuttle, noting design features and simulations of master-slave remote control system.

Experimental evaluation of remote manipulator systems.

Shuttle Payload Accommodation System teleoperator.

Development of a shuttle manipulator simulator.

Dynamics of a flexible manipulator arm for the Space Shuttle.

Engineering problems survey on teleoperator control systems.

Proceedings from colloquium on transfer of teleoperator device technology.

Study of roles of remote manipulator systems and EVA for shuttle mission support, volume 1.

Earth orbital teleoperator manipulator system evaluation program.

Concept design of the payload handling manipulator system --- space shuttle orbiters.

A manipulator arm for zero-g simulations.

Proto-Flight Manipulator Arm (P-FLA).

ERS massless arm dynamics capability in the SVDS --- equations of motion.

RESEARCH


REMOTE PILOTED VEHICLES

A manipulator system designed for Free-Flying Teleoperator Spacecraft.

Automatically controlled rendezvous and docking for orbital assembly of spacecraft, deriving motion equations for mass centers.

Automatically controlled rendezvous and docking for orbital assembly of spacecraft, deriving motion equations for mass centers.

RESEARCH REPORTS

Executive summary of the year 2000.

Geosynchronous information services platforms in the year 2000.


Research study on multi-KW-DC distribution system.


RESINS

NT EPOXY RESINS
Dynamics of a flexible body in orbit
(AIAA Paper 76-1419)
p0010 A78-45682

An Analytical Satellite Orbit Predictor (ASOP)
[NASA CR-151589]
p0075 N78-14066

SATELLITE PERTRURBATION

Weightlessness simulation for aerospace
mechanisms, using tower release and gynoetric
system for testing stage separation, satellite
perturbation, yo-yo, probes and ainst development
[ONERA-TP-940]
p0071 A71-36018

Selection and adaptation of a control law for a
double Gimbaled Momentus Wheel system on a
large solar array satellite

An atmospheric density model for application in
analytical satellite theories

SATELLITE POWER TRANSMISSION (TO EARTH)

Use of Shuttle in establishing large space
installations

Space power stations - Space construction,
transportation, and pre-development, space
project requirements

[SAT PAPER 77-64]
p0023 A77-51415

SATELLITE ROTATION

Equations of motion for a rotating flexible
structure — influence on spacecraft appendages

Stochastic optimal attitude control of spacecraft
with movable appendages

SATELLITE SOLAR ENERGY CONVERSION

Past experience - Basis for future advanced power
systems for communications satellites

[SAT PAPER 77-343]
p0044 A77-51390

SATELLITE SOLAR POWER STATIONS

Fabrication and assembly of large composite
structures in space

Space power stations - Space construction,
transportation, and pre-development, space
project requirements

[FAP PAPER 77-64]
p0023 A77-51415

Film reflector in space — Russian book on
orbiting solar power stations and solar sails

Propulsion options for orbital transfer in
cis-lunar space

Self-powered electric propulsion of satellite
power systems

[AIAA Paper 76-1944]
p0066 A76-32705

Automatic fabrication of large space structures -
The next step

[AIAA Paper 78-1651]
p0026 A78-52742

Application of NASPAN to large space structures

[ONERA-TR-20501]
p0013 A77-20501

Orbital construction support equipment

SATELLITE TRANSMISSION

Design considerations for multi-beam communication
satellite's antennas

[AIAA Paper 77-41]
p0023 A77-51402

On the active and passive CETI from earth
satellite orbit — communication with
extraterrestrial intelligence

[IAP PAPER A-77-41]
p0002 A77-51524

SATELLITES

MT ARTIFICIAL SATELLITES
MT ATS
MT COMMUNICATION SATELLITES
MT COMMUNICATIONS TECHNOLOGY SATELLITE
MT GEO SATELLITES (ESA)
MT GRAVITY GRADIENT SATELLITES
MT INDOOR SATELLITES
MT MARITIME SATELLITES
MT NAVIGATION SATELLITES
MT ORBITAL SPACE STATIONS
MT ORBITAL WORKSHOPS
MT PBGASS SATELLITES
MT SYNCHRONOUS SATELLITES
MT TDR SATELLITES

SCALE MODELS

Large space structures zero backlash deployment
mechanism, discussing dynamically scaled model
for mechanical and structural design and dynamic
analysis

[SAT PAPER 77-400]
p0021 A71-25276

SUBJECT INDEX

SCHEMULING

Airport alternate facilities, restrictive flight
schedules and fee schedules for relieving
airport congestion during peak traffic hours

SCIENTIFIC SATELLITES

MT ATS

SEARCH

Rigidized woven screen material study for gravity
gradient boom and antenna

SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE

U PROJECT SETI

SELF DEPLOYING SPACE STATIONS

U SELF DEPLOYING DEVICES

U SPACE STATIONS

SELF DEPLOYING DEVICES

Family of rigid shell Copparone structures self
deployable from foldable configurations of
coshell frusta

Large space structures zero backlash deployment
mechanism, discussing dynamically scaled model
for mechanical and structural design and dynamic
analysis

Self erecting parabolic reflector design for use
in space

Foldable boom systems study. Second phase:
Definition and development

SELF REGULATING

U AUTOMATIC CONTROL

SELF REGULATING DEVICES

MT PHOTOCYVOTIC CELLS

SENDERS

U TRANSmitTERS

SELF 2 SPACECRAFT

SERT 2 solar array power system in sun synchronous
orbit, considering power conditioning and
deployment techniques

SELF REGULATING MECHANISMS

Design and application potentials of general
purpose, dexterous, cybernetic machines for
human augmentation

SELF STABILITY CONTROL

U SELF CONTROL

SETI

U PROJECT SETI

SHARKS

U JOWTS (JUNCTIONS)

SHELLS (STRUCTURAL FORMS)

MT CONICAL SHELLS
MT CYLINDRICAL SHELLS
MT TORSION SHELLS
MT TORSIONAL SHELLS

SHUTTLE ORBITERS

U SPACE SHUTTLE ORBITERS

SIGNAL ACCEPTION

On the active and passive CETI from earth
satellite orbit — communication with
extraterrestrial intelligence

[IAP PAPER A-77-41]
p0002 A77-51524

Antenna concepts for interstellar search systems

SIGNAL TRANSMISSION

MT MICROWAVE TRANSMISSION
MT SATELLITE TRANSMISSION
Integrated dynamic analysis simulation of space stations with controllable solar arrays [NASA-CR-112145] p0012 NT2-32849
High voltage solar array for ion thruster electric propulsion system [NASA-TH-X-71163] p0067 NT3-33002
Computer program for calculating roll-up solar array performance characteristics [NASA-CR-135896] p0012 NT3-33003
The continuum mechanics dynamic study of a satellite with flexible solar panels [SPAR-R-554] p0012 NT4-17622
Spoked wheels to deploy large surfaces in space-weight estimates for solar arrays [NASA-CR-2347] p0030 NT5-14831
Communications technology satellite deployed solar array dynamics tests [CRC-1264] p0073 NT5-20468
Finite element dynamic analysis of large dimensional flexible solar arrays: Receptivity of nodal truncation for the simulation of spacecraft control manoeuvres [NASA-CR-29306]
Attitude control of synchronous satellites possessing flexible solar arrays using a double gimbaled momentum wheel [NASA-CR-28308]
The effect of flexibility on a control system design for a range of spacecraft and hybrid array configurations --- synchronous satellites [NASA-CR-27317]
Study of test methods for large flexible solar arrays (FLSA) --- dynamic characteristics [NASA-CR-NT1016] p0014 NT8-28688
SOLAR AUXILIARY POWER UNITS
Design, development, and evaluation of roll-up solar array rated at thirty watts per kilogram solar array [NASA-CR-138505] p0031 NT6-28651
SAS-C solar array development dynamics [AD-A0227113] p0031 NT6-31714
Power supply systems in the multi-kW power range --- solar arrays and power conditioning [NASA-CR-27317]
Study of test methods for large flexible solar arrays (FLSA) --- dynamic characteristics [NASA-CR-157403] p0014 NT8-28688
SOLAR FUEL CELLS
Deployment systems for extending large area lightweight flexible solar arrays in space, tabulating estimated design weights including power-weight ratios [NASA-CR-19392]
Performance characteristics analysis of large area roll-up solar arrays based on support structure size and weight [NASA-CR-21282]
SPAS 2 solar array power system in sun synchronous orbit, considering power conditioning and deployment technique [NASA-PAPER-70-1452] p0065 NT0-40202
Space power stations - Space construction, transportation, and pre-development, space project requirements [NASA-PAPER-77-64] p0023 NT7-51415
Design and fabrication of large area solar cell array capable of producing 50 kW of power for interplanetary spacecraft flights [NASA-CR-97688] p0027 NT9-13238
Conceptual approach study of a 200 watt per kilogram solar array [NASA-CR-148505] p0031 NT6-28651
SOLAR COLLECTORS
ST SOLAR REFLECTORS
Survey of future requirements for large space structures --- space platforms, large antennas, and power surfaces [NASA-CR-2621] p0074 NT6-15500
SOLAR CONVERTERS 3 SOLAR GENERATORS
SOLAR CORONA
SOLAR CYCLES
Electrons in the solar corona. II - Coronal streamers from k-coronameter measurements

SOLAR ELECTRIC PROPULSION
Thermal control of the solar electric propulsion stage
[AIAA PAPER 73-1118] p0065 A74-10693
Attitude stability of a flexible solar electric spacecraft - a parametric study
[TPP PAPER 76-171] p0035 A74-21394
The ubiquitous solar electric propulsion stage
[IAP PAPER 76-4613] p0065 A74-10693
SEP solar array technology development
[SOLAR PAPER 78-673] p0022 A77-12825
SEP full-scale wing technology development
[SOLAR PAPER 77-126] p0065 A77-48860
Spacecraft-generated plasma interaction with high temperature surfaces
[AIAA PAPER 78-673] p0044 A70-32751
Self-powered electric propulsion of satellite power systems
[AIAA PAPER 78-699] p0066 A70-32765
Size, performance and cost trades of large solar electric propulsion systems
[AIAA PAPER 78-699] p0066 A70-37440
Solar electric propulsion and interorbital transportation
[AAS-77-221] p0066 A78-43079
Solar sail-solar electric technology readiness and transfer assessment
[NASA-CR-157239] p0067 A78-26154
Study of SEP solar array modifications to technology assessment

SOLAR ELECTRONS
Electrons in the solar corona. II - Coronal streamers from k-coronameter measurements
p0048 A78-11519

SOLAR ENERGY
Three-axis attitude control for solar-powered electric propulsion spacecraft
[SAP PAPER 780874] p0036 A75-22946
Orbital construction demonstration study. Volume 1: Executive summary
[NASA-CR-151465] p0075 A77-28151
Solar energy absorbers
Design and performance of roll-up solar array engineering model
p0029 A71-22561

SOLAR GENERATORS
MT SOLAR AUXILIARY POWER UNITS
MT SOLAR CELLS
Solar/battery space station power plants combined with nuclear configurations, discussing rectified alternator current, direct energy transfer, and high voltage dc sources
p0043 A73-26008
Technological problems with large-area solar cell arrays
[DCRL PAPER 73-1207] p0021 A74-17204
Large deployable antennas and solar arrays with lightweight design characteristics
[DCRL PAPER 76-112] p0022 A76-4352
Effect of boost environment on design of large area solar array, its release and deployment on ground and in space, and electrical power source analysis
[NASA-CR-95999] p0027 A60-31404
Design, development, and evaluation of roll-up solar array rated at thirty watts per pound

SOLAR HEATING
Optimum overlap design of thin walled tubular extendible spacecraft structures under solar heating in zero-g environment
p0007 A70-30762
Flexible Storable Tubular Extendible Membrane /STEM/ in-place bending vibrations under solar heating
p0071 A71-10541
Librational dynamics of satellites with thermally flexed appendages
[AAS PAPER 73-232] p0008 A74-17602

SOLAR NEBULA
U SOLAR CORONA
SOLAR ORBITS
SPM 2 solar array power system in sun synchronous orbit, considering power conditioning and deployment technique

INDEX
A 32

[AIAA PAPER 70-1159] p0065 A70-40202
SOLAR POWER GENERATION
U SOLAR GENERATORS
SOLAR POWER SOURCES
U SOLAR GENERATORS
SOLAR PROPULSION
MT SOLAR ELECTRIC PROPULSION
Thermal control of a solar sail --- for Halley's Comet rendezvous
[AIAA PAPER 78-685] p0024 A78-37274
SOLAR RADIATION
MT SOLAR ELECTRONS
Attachment methods for thermal control composite system comprised of optical solar reflectors and multilayer insulation to minimize heating from incident solar energy
SOLAR REFLECTORS
Use of Shuttle in establishing large space installations

Film reflectors in space --- Russian book on orbiting solar power stations and solar sails
p0002 A78-15423
Feasibility development of self-deploying electromagnetic energy focusing reflector for space or transportable ground based operations
p0077 A68-27929
Attachment methods for thermal control composite system comprised of optical solar reflectors and multilayer insulation to minimize heating from incident solar energy
Design and behavior of ribless solar reflectors
p0041 A77-27537
SOLAR SAILS
Film reflectors in space --- Russian book on orbiting solar power stations and solar sails
p0002 A78-15423
Thermal control of a solar sail --- for Halley's Comet rendezvous
[AIAA PAPER 78-885] p0024 A78-37274
Large solar sail vehicle to operate in manor of helicopter rotor
Design and behavior of ribless solar reflectors
[NCHEL-52191] p0041 A77-27537
Conceptual analyses of extensible booms to support a solar sail
[NASA-CR-155615] p0032 A78-17124
The production of ultrathin polyimide films for the solar sail program and Large Space Structures Technology (LSST): A feasibility study
[NASA-CR-157569] p0050 A78-30657
SOLAR SYSTEM
CAST Space Trajectory Workshop 1976
[NASA-X-3486] p0075 A77-21107
SOLID ROTATION
U SPINNING BODIES
SOLID STATE DEVICES
MT PHOTOVOLTAIC CELLS
The solid state remote power controller: Its status, use and perspective
[NASA-TM-73695] p0046 A77-27306
SOTTIE CAN
U SPACELAB
SOTTIE LAB
U SPACELAB
SPACE BASES
MT SPACE COLONIES
Towards large space systems --- Space Construction Base development from shuttles
p0071 A77-31833
Structural members, method and apparatus
[NASA-CASE-56C-16217-1] p0033 A78-22146
Space Construction Automated Fabrication Experiment Definition Study (SCAFDS) , part 2
[NASA-CR-151705] p0062 A78-23112
SPACE COLONIES
Space: A resource for earth - An AIAA review

Book
p0001 A77-32440
Summary of problems of greatest urgency --- space colonies
p0072 A77-35825
SPACE COMMUNICATION
MT INTERPLANETARY COMMUNICATION
MT SPACECRAFT COMMUNICATION
Feasibility development of self-deploying electromagnetic energy focusing reflector for space or transportable ground based operations

SPACE DEBRIS
A comparison of spacecraft penetration hazards due to meteoroids and manmade earth-orbiting objects

SPACE ENVIRONMENT
Large space structures assembly simulation

SPACE DEPLOYMENT
Behaviour of carbon fibre composites under simulated space environment --- radiation effects on solar array materials

SPACE EFFECTS
Effects of space radiation on thin polyesters and nonmetallics

SPACE ERECTABLE STRUCTURES
Development of a shuttle manipulator simulator

SPACE EEVIROEBEIT
Large space structures assembly simulation

SPACE EEVIROEBEIT NT BEIGBTLESSBESS SIBULATION
Erectable parabolic antenna with space applications

SPACE EFFECTECECT STRUCTURES
Bending and stress distribution of foldable tubular connecting element, discussing application to space extendible reticular column

SPACE EFFECTECECT STRUCTURES
Spaceborne parabolic antennas erecting techniques, considering applicability to near earth or interplanetary missions

SPACE EFFECTECECT STRUCTURES
Space erectable trans communication antenna design capable of deploying rigid paraboloid from 5 to 300 ft in diam

SPACE EFFECTECECT STRUCTURES
Testing program using electrical measurements for determining adequacy of erectable parabolic reflector for space missions

SPACE EFFECTECECT STRUCTURES
Wire screen deployable boom concept for avoiding thermal bending of slender tubes problems in application to gravity gradient stabilization and antennas of spacecraft

SPACE EFFECTECECT STRUCTURES
Multidimensional mode shapes and frequencies of 100 ft space erectable parabolic antenna

SPACE EFFECTECECT STRUCTURES
Erectable metal booms and meshes structural analysis, design and mounting and deployment techniques for space applications

SPACE EFFECTECECT STRUCTURES
Zero g deployment dynamics of erectable trans parabolic antennas, obtaining latch-up loads as function of reflector mechanical energy

SPACE EFFECTECECT STRUCTURES
Large space erectable structures rigidity, stiffness, thermal stability, structural efficiency and integrity

SPACE EFFECTECECT STRUCTURES
Deployment systems for extending large lightweight flexible solar arrays in space, tabulating estimated design weights including power-weight ratios

SPACE EFFECTECECT STRUCTURES
Spacecraft boom design and performance, including Russian spacecraft photographs

SPACE EFFECTECECT STRUCTURES
Thermal and mechanical properties of materials for spacecraft boom design

SPACE EFFECTECECT STRUCTURES
Storable tubular extendible members/ STEM, discussing advantages of BI-STEM for erecting unfurlable structures in space

SPACE EFFECTECECT STRUCTURES
Closed tubular extendible boom/Multiple Applications Storable Tube design, fabrication and applications, including stress factors and materials

SPACE EFFECTECECT STRUCTURES
Space erectable boom with interlocked seam, perforations and coatings to provide torsional rigidity and thermal stability

SPACE EFFECTECECT STRUCTURES
Large space structures zero backlash deployment mechanisms, discussing dynamically scaled model for mechanical and structural design and dynamic analysis

SPACE EFFECTECECT STRUCTURES
Stowable extendible structures for spacecraft and space experiments, discussing inflatable, rigidized cloth and mechanically deployable apparatus

SPACE EFFECTECECT STRUCTURES
Metallized fiberglass antenna meshes for spacecraft deployable reflectors, discussing low mass/area, long term stability and performance characteristics and degradation tests

SPACE EFFECTECECT STRUCTURES
Space deployed expandable structures for spacecraft vehicular and environmental constraint effects on design, large structure requirements, and applications

SPACE EFFECTECECT STRUCTURES
Reliability estimate of a Space Deployable Antenna.

SPACE EFFECTECECT STRUCTURES
Some choices for design of deployable solar arrays

SPACE EFFECTECECT STRUCTURES
Discrete time attitude control of spacecraft containing low frequency lightly damped structural modes

SPACE EFFECTECECT STRUCTURES
Large deployable antennas and solar generators with ultralightweight design characteristics

SPACE EFFECTECECT STRUCTURES
Expandable structures for spacecraft

SPACE EFFECTECECT STRUCTURES
Vehicle/manipulator/packaging interaction -- a synergistic approach to large erectable space system design

SPACE EFFECTECECT STRUCTURES
Some design considerations for large space structures

SPACE EFFECTECECT STRUCTURES
Toward large space systems --- Space Construction

SPACE EFFECTECECT STRUCTURES
Fabrication and assembly of large composite structures in space

SPACE EFFECTECECT STRUCTURES
Fabrication methods for large space structures

SPACE EFFECTECECT STRUCTURES
Space power stations - Space construction, transportation, and pre-development, space project requirements

SPACE EFFECTECECT STRUCTURES
A flexible passive space array with springs

SPACE EFFECTECECT STRUCTURES
Learning to build large structures in space

SPACE EFFECTECECT STRUCTURES
An array for large space antennas

SPACE EFFECTECECT STRUCTURES
Multiflexible spacecraft integrated analysis - Structures, dynamics, and control

SPACE EFFECTECECT STRUCTURES
A future for large space antennas

SPACE EFFECTECECT STRUCTURES
Large space erectable antenna stiffness requirements

SPACE EFFECTECECT STRUCTURES
Considerations on the use of graphite-reinforced plastics for space erectable antennas

SPACE EFFECTECECT STRUCTURES
Assembly in space of large communication structures

SPACE EFFECTECECT STRUCTURES
Structure assembly demonstration clamps --- for large space structures in low orbit

SPACE EFFECTECECT STRUCTURES
Dynamical characteristics associated with deploying, orbiting, beam-type appendages

SPACE EFFECTECECT STRUCTURES
The booms and mechanisms of Geos

SPACE EFFECTECECT STRUCTURES
A statistical evaluation of a space stable optical support structure

SPACE EFFECTECECT STRUCTURES
A crane for construction in space

SPACE EFFECTECECT STRUCTURES
Automatic fabrication of large space structures - The next step

SPACE EFFECTECECT STRUCTURES
Control system technology and tradeoffs for large space structures
Large space parabolic expandable truss antenna experiment
[NASA-CS-93837] p0026 N60-20267
Parabolic expandable truss antenna experiment
Design for Apollo applications [NASA-CS-93838] p0026 N60-23040
Describing apparatus for manufacturing operations
in low and zero gravity environments of orbital space flight
[NASA-CASE-MPS-20810] p0029 N71-19214
Self erecting parabolic reflector design for use in space
[NASA-CASE-XMS-03854] p0029 N71-20658
Pneumatic cantilever beams and platform for space erectable structure
[NASA-CASE-XLA-01731] p0029 N71-21065
Development of expandable structures concepts for application to structures used in space missions
- Part 2
Expandable space frames with high expansion to collapse ratio
[NASA-CASE-ESC-10365-1] p0030 N73-32769
Orbital assembly and maintenance study
[NASA-CR-144822] p0060 N75-32144
Orbital assembly and maintenance study. Executive summary -- space erectable structures/structural design criteria
[NASA-CR-144484] p0060 N75-32971
A nestable tapered column concept for large space structures
Industry workshop on large space structures:
Executive summary
Orbital construction demonstration study.
Executive summary
[NASA-CR-151359] p0075 N77-23138
Large space erectable structures - building block structures study
[NASA-CR-151849] p0032 N77-27156
The assembly of large structures in space --- radio astronomy telescope and microwave antenna
[NASA-CR-28941] p0061 N77-29770
AAFE large deployable antenna development program:
Executive summary
[NASA-CS-92989] p0032 N77-33260
Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS). Volume 3: Requirements
Telescoping columns --- parabolic antenna support
SPACE EXPLORATION
Searching for extraterrestrial intelligence--The ultimate exploration
[NASA-CR-1487702] p0002 N77-66747
Robot manipulators -- in space exploration
[NASA-TT-F-16482] p0060 N75-29780
Advanced space program studies, overall executive summary
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
[NASA-CR-148708] p0005 N76-30247
SPACE FLIGHT
BY MAJ N. F. GRAY
SPACE INDUSTRIALIZATION
The industrialization of space; Proceedings of the Twenty-third Annual Meeting, San Francisco, Calif., October 18-20, 1971. Parts 1 & 2
p0072 X70-36701
Platform designed for numerous uses -- in geostationary orbit
p0072 X70-42509
Solar electric propulsion and interorbital transportation
[AAS 77-221] p0066 A78-43879
Space Construction Automated Fabrication Experiment Definition Study (SCAFEDS). Volume 3: Requirements
[NASA-CASE-XCR-151729] p0062 N78-25113
SPACE LABORATORIES
BY MAJ N. F. GRAY
SPACE INDUSTRIALIZATION
Space assembly of satellites and vehicles noting launch restraints, form factor, technology, logistics and maintainability
[ASME PAPER 68-DS-61] p0053 A68-27394
Design criteria and tradeoffs for man machine interface for teleoperator system performing on-orbit satellite retrieval and servicing
[NASA-CR-123755] p0059 N72-29830
SPACE MAINTENANCE
Space tools and support equipment for earth orbital systems maintenance, replacement and repair, discussing Skylab requirements and teleoperator applications
[AIAA PAPER 72-230] p0053 A72-25049
Experimental evaluation of remote manipulator systems.
[AN 75-37305 p0055 A75-19712
Fabrication methods for large space structures
Orbital servicing of space platforms
[AIAA PAPER 77-594] p0023 A77-32598
Advanced teleoperator spacecraft
[p0025 A76-5198
Requirements and role of extravehicular activity (EVA) in deployment, assembly, and maintenance of in-space erectable structures during earth orbital missions
p0056 N68-27938
Extended boom devices for orbital maintenance and safety of space shuttle
[p0028 N70-39609
Manned systems utilization analysis. Study 2:1 Space servicing pilot program study --- for automated payloads
[NASA-CR-142758] p0073 N75-23620
Earth orbital teleoperator manipulator system evaluation program
[NASA-CR-148422] p0060 N75-26651
Orbital assembly and maintenance study
[NASA-CR-148374] p0060 N75-26651
Orbital assembly and maintenance study. Executive summary -- space erectable structures/structural design criteria
[NASA-CR-148440] p0060 N75-32971
SPACE MANUFACTURING
Some results of studies in space technology in the USSR --- orbital fabrication, repair and maintenance
[p0055 A75-36475
Toward large space systems --- Space Construction Base development from shuttles
[p0071 A77-31833
Fabrication and assembly of large composite structures in space
[AIAA PAPER 77-543] p0023 A77-32065
Fabrication methods for large space structures
[AIAA PAPER 77-543] p0023 A77-32065
Summary of problems of greatest urgency --- space colonies
[p0077 A77-35825
Satellite power system LEO vs GEO assembly issue --- construction in Low Earth Orbits vs GEO synchronous Orbits
[AIAA 77-1029] p0055 A77-41568
New themes for space: Mankind's future needs and aspirations; Proceedings of the Bicentennial Space Symposium, Washington, D.C., October 6-8, 1976
[p0003 A78-29843
Automated space fabrication of structural elements
[AAS 77-201] p0024 A78-36703
A near term space demonstration program for large
structures
[AAS 77-202] p0072 A76-36700

New lattice for space robots and automation
[p0057 A76-49164

Large space structures at the Marshall Space Flight Center
[AIAA PAPER 78-1650] p0073 A76-51982

Space Spider - A concept for fabrication of large
structures
[AIAA PAPER 78-1655] p0025 A76-51984

The installation of systems on large space
structures
[AIAA PAPER 78-1661] p0044 A76-51988

A crane for construction in space
[AIAA PAPER 78-1666] p0026 A76-51992

NASA Office of Aeronautics and Space Technology
Summer Workshop. Volume 7: Materials panel
p0074 N77-13916

Space industrialization
[GO-09-159] p0005 W76-20149

SPACE NAVIGATION

Pointing and control technology needs for future
automated space systems
[AAS 76-1687] p0039 A78-52748

Outlook for space
[NASA SP-385] p0074 W76-18000

Advanced space program studies, overall executive
summary
[NASA-CS-148702] p0074 W76-30263

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)
[ NASA-CS-148708 ] p0005 W76-30267

Future space programs
[GO-26-215] p0076 W76-26157

SPACE POWER REACTORS

A highly reliable data handling and control system
of a spaceborne power unit
[ IAF PAPER 77-136 ] p0044 A77-51401

SPACE POWER Covid-19 1973

SPACE PROCESSING

Structural and assembly concepts for large
erectable space systems
[AAS 77-205] p0024 A76-36706

Orbital construction support equipment
[ NASA-CS-151460 ] p0061 W77-27157

Space industrialization
[ GO-99-159 ] p0005 W76-20184

SPACE PROGRAMS

A near term space demonstration program for large
structures
[AAS 77-202] p0072 A76-36700

Advanced space system concepts and their orbital
support needs (1980 - 2000). Volume 1:
Executive summary
[ NASA-CS-148704 ] p0004 W76-30244

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 --- for the U.S. space program
[ NASA-CS-148710 ] p0004 W76-30246

OAST Space Theme Workshop 1976
[ NASA-T-3486 ] p0075 W77-21107

Future space programs
[ GO-24-215 ] p0076 W78-26157

SPACE RADIATION

U-EXTRATERRESTRIAL RADIATION

SPACE SHUTTLE ORBITERS

Shuttle avionics system
[p0071 A76-28871

Remote Manipulator System and satellite servicing
experiment for Space Shuttle
[p0055 A76-42361

Shuttle remote manipulator system workstation -
Man-machine engineering
[p0056 A77-26628

Development of a shuttle manipulator simulator
[SME PAPER B76-606] p0056 A77-51017

Next steps in space transportation and operations
[p0072 A78-19543

The remote manipulator system for the Space
Shuttle Orbiter
[DGLE PAPER 77-060] p0057 A78-24447

Dynamics of a flexible manipulator arm for the
Space Shuttle
[p0057 A78-31877

Structural and assembly concepts for large
erectable space systems
[AAS 77-205] p0024 A76-36706

Concept design of the payload handling manipulator
system --- space shuttle orbiters
[ NASA-2M-X-72447 ] p0060 N75-29773

STS users study (study 2.2). Volume 1: Executive
summary
[ NASA-CS-148720 ] p0076 W76-30262

STS users study (study 2.2). Volume 2: STS users
plan (user data requirements) study
[ NASA-CS-148721 ] p0076 W76-30263

RMS manipulator arms: dynamics capability in the
SYDs --- equations of motion
[ NASA-CS-151458 ] p0046 W77-27162

Orbital construction demonstration study. Volume
1: Executive summary
[ NASA-CS-151465 ] p0075 W77-26151

Orbital construction demonstration study. Volume
2: Technical
[ NASA-CS-151467 ] p0075 W77-26152

Orbital construction demonstration study. Volume
3: Requirements document
[ NASA-CS-151468 ] p0075 W77-26153

Analytical formulation of selected activities of
the remote manipulator system
[ NASA-CS-151468 ] p0042 W78-15158

Space Construction Automated Fabrication
Experiment Definition Study (SCAFEDS), part 2
[ NASA-CS-151702 ] p0042 W78-23112

SPACE SHUTTLE PAYLOADS

ST SPACECAB

Structure assembly demonstration slated --- for
large space structures in low orbit
[ NASA PAPER 78-052 ] p0057 A78-53605

Assembly of large space structures
[AAS PAPER 78-052] p0057 A78-53605

SPACE SHUTTLES

On-orbit payload handling for space shuttles,
including manipulator arms for drawing docking
vehicles together, closed circuit TV and
airlocking
[ AIAA PAPER 71-811 ] p0071 A75-35427

Teleoperator manipulator for payload handling in
space shuttle, noting design features and
simulations of master-slave remote control system
[ AIAA PAPER 72-238 ] p0053 A72-29075

X-reference frame bilateral control for the
Shuttle Attached Manipulator System.
[ NASA-CS-148704 ] p0053 A73-35311

Shuttle Payload Accommodation System teleoperator.
[ NASA-CS-148704 ] p0054 A73-37307

Preliminary design and simulations of a
Shuttle-Attached Manipulator System.
[ NASA-CS-148704 ] p0054 A73-37308

Simulation concepts for a full-sized Shuttle
manipulator system.
[ NASA-CS-148704 ] p0054 A73-37309

Teleoperators and EVA for Shuttle missions
[p0055 A74-14117

Use of Shuttle in establishing large space
installations
[p0001 A74-14121

The role of EVA on Space Shuttle --- experimental
support and maintenance activities
[AIAA PAPER 74-21107 ] p0055 A74-39127

Free-flying teleoperator for space missions
[p0055 A75-27199

Large Deployable Antenna Shuttle Experiment
[AAS PAPER 75-253] p0059 A76-12889

Shuttle manipulator design reviewed
[p0056 A77-11899

Utilization of Space Shuttle and Spacecab;
Proceedings of the International Meeting, Bonn,
West Germany, June 2-4, 1976
[p0071 A77-20563

Toward large space systems --- Space Construction
Base development from shuttles
[p0071 A77-31833

A-35
SPACE STATIONS

Integrating Shuttle payloads p0071 A77-31834
Fabrication and assembly of large composite structures in space [AIAA PAPERS 77-543] p0023 A77-32065
Control and stability problems of remote orbital capture p0037 A77-43644
Impact of shock on technology and utility of national and regional communications satellites [TAP PAPERS 77-38] p0029 A77-51399
Shuttle remote manipulator system safety and rescue support capabilities [TAP PAPERS A-77-38] p0056 A77-51518
Large space structures at the Marshall Space Flight Center [AIAA PAPERS 78-1650] p0073 A79-51926
Extended boom devices for orbital maintenance and safety of space shuttle p0028 W70-39609
General purpose manipulator system, transferable between space station and shuttle, for assembly, docking, maintenance, cargo handling, and spacecraft retrieval - management summary [NASA-CR-115480] p0058 W72-22886
General purpose manipulator system for space station and shuttle - concept development and selection [NASA-CR-115481] p0058 W72-22887
Concept analysis of general purpose manipulator system for space station and shuttle - technical discussion [NASA-CR-115482-VOL-3-PT-1] p0058 W72-22888
Concept analysis of general purpose manipulator system for space station and shuttle - estimated development progress [NASA-CR-115484] p0059 W72-22889
General purpose manipulator system for space station and shuttle - laboratory simulation studies [NASA-CR-115483] p0059 W72-22890
Development and operation of simulator to provide real time visual scenes for man in the loop investigations of remote manipulator application for space shuttle [NASA-CR-115636] p0059 W72-24339
Design criteria and trade-offs for man machine interface for teleoperator system performing on-orbit satellite retrieval and servicing [NASA-CR-123755] p0059 W72-29830
Attached manipulator system for simulating and demonstrating shuttle manipulator cargo handling operations under weightless conditions [NASA-CR-130964] p0059 W73-27176
Configuration and design study of manipulator systems applicable to the free flying teleoperator. Volume 1: Executive summary [NASA-CR-120402] p0059 W74-31582
Study of roles of remote manipulator systems and EVA for shuttle mission support, volume 1 [NASA-CR-140364] p0059 W75-12036
Variable ratio mixed-mode bilateral master-slave control system for shuttle remote manipulator systems [NASA-CASE-MSC-14245-1] p0060 W75-27081
A manipulator arm for zero-g simulation p0060 W76-19178
Model verification of large structural systems - space shuttle model response [NASA-CR-151908] p0067 W76-14162

SUBJECT INDEX

[nasa-cr-150811] p0015 W78-31464

SPACE STATIONS

WT ORBITAL SPACE STATIONS

WT ORBITAL WORKSHOPS

Electron beam welding suitability for spacecraft and space stations assembly in space compared with various welding methods p0053 A68-27876
Solar/battery space station power plants combined with nuclear configurations, discussing rectified alternating current, direct energy transfer, and high voltage dc sources p0043 A73-26008
An institutional plan for multipurpose spacecraft platforms p0025 A78-47263
A crane for construction in space [AIAA PAPERS 78-1666] p0026 A78-51992
Material composition, weight, size, and unfolding factors entering into design of inflatable space station structures [NASA-CR-92596] p0026 W60-15239
General purpose manipulator system, transferable between space station and shuttle, for assembly, docking, maintenance, cargo handling, and spacecraft retrieval - management summary [NASA-CR-115480] p0058 W72-22886
General purpose manipulator system for space station and shuttle - concept development and selection [NASA-CR-115481] p0058 W72-22887
Concept analysis of general purpose manipulator system for space station and shuttle - technical discussion [NASA-CR-115482-VOL-3-PT-1] p0058 W72-22888
Concept analysis of general purpose manipulator system for space station and shuttle - estimated development program [NASA-CR-115484] p0059 W72-22889
General purpose manipulator system for space station and shuttle - laboratory simulation studies [NASA-CR-115483] p0059 W72-22890
Simulation, analysis, and evaluation of dynamic load interactions between solar arrays and space station resulting from orbital perturbations [NASA-TM-1-60469] p0011 W72-26050

SPACE STATION

Storable tubular extendible member /STEM/, discussing advantages of BI-STEM for erecting unfurlable structures in space p0020 A70-34114
Stowable extendible structures for spacecraft and space experiments, discussing inflatable, rigidized cloth and mechanically deployable apparatus p0021 A71-41981

SPACE SYSTEMS ENGINEERING

AEROSPACE ENGINEERING

SPACE TOOLS

Space tools and support equipment for earth orbital systems maintenance, replacement and repair, discussing Skylab requirements and teleoperator applications [NASA-PAPERS 77-200] p0053 W72-25049
New ladder for space robots and automation p0057 A78-49164

SPACE TRANSPORTATION

MT SPACE TRANSPORTATION SYSTEM

Building large structures in space p0071 W76-29321
Integrating Shuttle payloads p0071 A77-31834
Solar electric propulsion and interorbital transportation [AAS 77-221] p0066 A78-43879
SPACECRAFT CONSTRUCTION MATERIALS

Dynamics and control of non-rigid spacecraft --- conference held at Frascati, Italy, 24-26 May 1976 [ESA-SP-117] p0041 N77-10142

SPACECRAFT CONSTRUCTION MATERIALS

Thermal and mechanical properties of materials for spacecraft booms design
The potential application of carbon fibres to spacecraft.

Effects of space radiation on thin polymers and nearmetals
by analog simulation
[ASBE PAPER 68-DE-61] p0053 A68-27391

Thermally insert composite hardware applications for spacecraft
[ASBE PAPER 68-DE-61] p0050 N78-17151

Filamentary composite materials reviewed for potential applications in spacecraft structures
[NEAR-SP-8006] p0049 N80-27470

High vacuum effects on materials for use in space environments
[NASA-SP-1785] p0049 N69-35951

Aerosp ace environment and effects on materials, spacecraft material selection, and biological interaction with spacecraft materials - handbook
[NASA-SP-3051] p0050 N70-21226

An outgassing data compilation of spacecraft materials
[NASA-R-1018] p0050 N78-17151

SPACECRAFT CONTROL

#1 SATELLITE ATTITUDE CONTROL
#2 SATELLITE CONTROL

Spacecraft design for miniaturization of structure interaction with control system, noting susceptibility of extendible booms to solar environment
p0007 A69-25500

Flexible space vehicle multiple closed loop attitude control system design, discussing stability, structure interaction and performance by analog simulation
p0035 A72-32597

Attitude stability of a flexible solar electric spacecraft - A parametric study
p0035 A74-21394

Attitude control of a spinning flexible spacecraft
p0035 A74-33345

Flexible spacecraft control design using pole allocation technique
[IAA PAPER 77-1097] p0037 A77-24817

Active control of flexible systems
p0037 A78-12096

An active modal control system philosophy for a class of large space structures
p0037 A78-12099

Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control
p0009 A78-12098

Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control
p0009 A78-31888

Optimal digital control of large space structures
[ASAS PAPER 78-105] p0038 A78-44380

The control of spacecraft vibrations using multivariable output feedback
[IAA PAPER 78-1420] p0038 A78-45604

Dynamics and control of large spinning spacecraft
[IAA PAPER 78-1419] p0038 A78-45603

Control technology for large space structures
[IAA PAPER 78-1619] p0038 A78-52503

Nonlinear attitude control system design for space vehicle
p0039 N68-23421

Compensator improvement program with application to large space vehicles and tables noting relative stability versus frequency response
[NASA-CR-119959] p0041 N71-37603

The dynamics of spin stabilized spacecraft with movable appendages, part 2
p0009 N76-11216

Dynamics and control of non-rigid spacecraft vehicles
--- conference held at Frascati, Italy, 24-26 May 1976
p0039 N76-28297

SUBJECT INDEX

Finite element dynamic analysis of large dimensional flexible solar arrays: Necessity of modal truncation for the simulation of spacecraft control manoeuvres

Optimal control of spin stabilized spacecraft with telescoping appendages

Three axis control of spacecraft with large flexible appendages

Dynamics and control of non-rigid spacecraft --- conference held at Frascati, Italy, 24-26 May 1976 [ESA-SP-117] p0041 N77-10142


The dynamics and control of large flexible space structures. Part A: Discrete model and modal control

The dynamics and control of large flexible spacecraft structures. Part B: Development of continuum model and computer simulation

A digital computer program for the dynamic interaction simulation of controls and structure [DISCOS], volume 1
[NASA-SP-1219-VOL-1] p0014 N78-25123

SPACECRAFT DESIGN

#1 SATELLITE CONSTRUCTION DESIGN
Space assembling of satellites and vehicles noting launch restraints, force factor, technology, logistics and maintainability
[ASME PAPER 68-DE-61] p0053 A68-27391

Spacecraft design for miniaturization of structure interaction with control system, noting susceptibility of extendible booms to solar environment
p0007 A69-25500

Flexible space vehicle multiple closed loop attitude control system design, discussing stability, structure interaction and performance by analog simulation
p0035 A72-32597

Space deployed expandable structures, discussing vehicular and environmental constraint effects on design, large structure requirements, and applications
p0021 A73-18905

An appreciation of the design of carbon fibre rigid solar panels for spacecraft.

p0047 A73-36812

Preliminary design and simulations of a Shuttle-Attached Manipulator System.

p0054 A73-37309

Orbit assembly of unmanned spacecraft

p0054 A74-12818

Attitude stability of a flexible solar electric spacecraft - A parametric study
p0035 A74-21394

Spoked wheels to deploy large surfaces in space
[ASAS PAPER 74-1257] p0022 A75-11108

Some boom choices for design of deployable solar arrays
p0022 A75-23200

The ubiquitous solar electric propulsion stage
p0005 A76-46136

Shuttle manipulator design reviewed
p0056 A77-11899

SFP solar array technology development
p0022 A77-12825

Evaluation of rotor-induced gyroscopic coupling on the natural modes of large flexible spacecraft
[ASAS PAPER 77-1096] p0022 A77-12825

Specifying spacecraft flexible appendage rigidity
[ASAS PAPER 77-1098] p0027 A77-42823

Flexible spacecraft control design using pole allocation technique

p0023 A77-42823

Space power stations - Space construction, transportation, and pre-development, space project requirements
[IAA PAPER 77-64] p0023 A77-51415

System design of an ion drive spacecraft
[IAA PAPER 78-642] p0066 A78-32733

Computerized structural sizing at NASA Langley Research Center --- low mass design for
The dynamics and control of large flexible space structures.


Deployment systems for extending large area lightweight flexible solar arrays in space, tabulating estimated design weights including power-weight ratios.

Automatic controlled rendezvous and docking for orbital assembly of spacecraft, deriving motion equations for mass centers.

Solar/battery space station power plants combined with nuclear configurations, discussing rectified alternator current, direct energy transfer, and high voltage dc sources.

A 25 kW solar array/battery design for an earth orbiting space station.

Some choices for design of deployable solar arrays.

Advanced lightweight rigid solar arrays based on carbon fibre technology.

Past experience – Basis for future advanced power systems for communications satellites.

A highly reliable data handling and control system of a spacecraft power unit.

Next steps in space transportation and operations.

Multi-kW dc power distribution system study program.

Electromagnetic compatibility of ac power distribution.

Power supply systems in the multi-kW power range – solar arrays and power conditioning.

Multi-kW dc distribution system technology research study.

Three-axis attitude control for solar-powered electric propulsion spacecraft.

Electrical propulsion ready for space missions.

System design of an ion drive spacecraft.

Electrothermal propulsion system characteristics for large space systems.


Power supply systems in the multi-kW power range – solar arrays and power conditioning.

Multi-kW dc distribution system technology research study.

Shuttle-Attached Manipulator System requirements.

Shuttle-Attached Manipulator System requirements.

Multi-kW dc distribution system technology research study.


Power supply systems in the multi-kW power range – solar arrays and power conditioning.

Multi-kW dc distribution system technology research study.

Shuttle-Attached Manipulator System requirements.

Shuttle-Attached Manipulator System requirements.

Multi-kW dc distribution system technology research study.

Shuttle-Attached Manipulator System requirements.

Multi-kW dc distribution system technology research study.

Shuttle-Attached Manipulator System requirements.

Multi-kW dc distribution system technology research study.

Shuttle-Attached Manipulator System requirements.

Multi-kW dc distribution system technology research study.
SPACELAB INSTRUMENTS

Deployable STEM / storable tubular extendible sensor/booms for aerospace gravity gradient stabilization, noting interlocked BI-STEM

Dynamical characteristics of spacecraft with controlled flexible appendages using finite element approach

Influence of stored angular momentum on the modal characteristics of flexible appendages

Discrete time attitude control of spacecraft containing low frequency lightly damped structural modes

The new generation of dynamic interaction problems -- for attitude control

The control of spacecraft vibrations using multivariable output feedback

Compensator improvement program with application to large space vehicles and tables noting relative stability versus frequency response

Electron beam welding suitability for spacecraft structures

Mathematical models for stability analysis and time optimal control of flexible space structures, evaluating applicability

Expandable and modular structures for support on range, reconfigurable, chemically rigidizable, unfurtable and elastic recovery structures

Spacecraft design for minimization of structure interaction with control system, noting susceptibility of extendible booms to solar environment

Optimum overlap design of thin walled tubular extendible spacecraft structures under solar heating in zero-g environment

Spacecraft boom design and performance, including Russian spacecraft photographs

Spacecraft deployable booms, discussing structural design, self loading weight, storage volume and thermal stability requirements

Storable extendible structures for spacecraft and space experiments, discussing inflatable, rigidized cloth and mechanically deployable apparatus

Composite materials mechanical and thermal properties for ATS reflector supporting truss, noting graphite fiber reinforced epoxy plastic design, fabrication and tests

Damping augmentation for large space structures

Multibody flexible spacecraft integrated analysis

Dynamical characteristics associated with deploying, orbiting, beam-type appendages

Filamentary composite materials reviewed for potential applications in spacecraft structures

Expandable and Modular Structures Conference

Zero gravity simulation methods and applications in design and procedures determination for D-021 and D-023 space structure experiments

Requirements and role of directional activity /EVA/ in deployment, assembly, and maintenance of in-space erectable structures during earth orbital missions

Space environment effects on reinforced plastic materials for spacecraft structures

Digital computer programs for analysis of large complex structures applied to NASTAR project

Foldable boom systems study. First phase: Initial studies

Handbook for the thermal modelling of space mechanisms by the nodal network method

Structural dynamic testing considerations for large space vehicles

A semi-automatic modal-survey test technique for complex aircraft and spacecraft structures

Response of long, flexible cantilever beams applied root motions --- spacecraft structures

Preliminary design of a composite structure for an advanced technology laboratory experiment system

Orbital construction demonstration study

Mathematical methods in flexible spacecraft dynamics, volume 1

Mathematical methods in flexible spacecraft dynamics, volume 2

Spacecraft trajectories

Advanced Technology Laboratory experiment systems definition, Volume 2: Mission analysis and planning. Part 1: Flight plan, payload 1

Spacecraft Large deployable antennas and solar generators with ultralightweight design characteristics

Utilization of Space Shuttle and Spacelab; Proceedings of the International Meeting, Bonn, West Germany, June 2-4, 1976

Next steps in space transportation and operations

NASA Office of Aeronautics and Space Technology Summer Workshop, Volume 2: Sensing and data acquisitions panel

NASA Office of Aeronautics and Space Technology Summer Workshop, Volume 6: Structures and dynamics panel

NASA Office of Aeronautics and Space Technology Summer Workshop, Volume 7: Materials panel

NASA Office of Aeronautics and Space Technology Summer Workshop, Volume 8: Thermal control panel

Spacecraft Pointing Systems

Specifications

Equipment Specifications

Orbital construction demonstration study. Volume 3: Requirements document

Mathematical model for subdividing and transforming polyhedron into spherical shape

Fine pointing control for a large spinning spacecraft in earth orbit

Attitude control of a spinning flexible spacecraft

The dynamics of spin stabilized spacecraft with movable appendages, part 2

NASA-CR-1456051 p0039 N76-11216

NASA-CR-1514661 p0075 N77-28153

NASA-CR-145772-1 p0005 N77-31236

NASA-CR-145772-1 p0006 N77-19254

NASA-CR-145772-1 p0005 N77-13911

NASA-CR-145772-1 p0031 N77-13915

NASA-CR-145772-1 p0007 N77-13916

NASA-CR-145772-1 p0007 N77-13917

NASA-CR-145772-1 p0075 N77-13921

NASA-CR-1514661 p0075 N77-28153

NASA-CR-145772-1 p0005 N77-29847

NASA-CR-145772-1 p0028 N76-29447

NASA-CR-145772-1 p0042 N78-26162

NASA-CR-145772-1 p0035 N76-33365

NASA-CR-145772-1 p0039 N76-11216

NASA-CR-1514661 p0075 N77-28153

NASA-CR-145772-1 p0005 N77-29847

NASA-CR-145772-1 p0028 N76-29447

NASA-CR-145772-1 p0042 N78-26162

NASA-CR-145772-1 p0035 N76-33365

NASA-CR-145772-1 p0039 N76-11216

NASA-CR-145772-1 p0005 N77-13911

NASA-CR-145772-1 p0031 N77-13915

NASA-CR-145772-1 p0007 N77-13916

NASA-CR-145772-1 p0007 N77-13917

NASA-CR-145772-1 p0075 N77-13921
Optimum overlap design of thin walled tubular extendible spacecraft structures under solar heating in zero-g environment

Spacecraft boom design and performance, including Russian spacecraft photographs

Spacecraft deployable booms, discussing structural design, self loading, weight, storage volume and thermal stability requirements

Large space structures zero backlash deployment mechanisms, discussing dynamically scaled model for structural and design and dynamic analysis

Space deployed expandable structures, discussing vehicular and environmental constraint effects on design, large structure requirements, and applications

Curved, tapered, circular cross section graphite/epoxy antenna ribs

Some choices for design of deployable solar arrays

Ion thruster design and analysis

Fabrication methods for large space structures


Continuum modeling of three-dimensional truss-like space structures

Computerized structural sizing at NASA Langley Research Center — low mass design for aerospace vehicles

Design concept of geostationary platforms

Large space structures at the Marshall Space Flight Center

Joints and implications on space construction

Control system technology and tradeoffs for large space structures

Design and performance of roll-up solar array engineering model

Study on the use of carbon fibre reinforced plastics in satellite structures, phase 1

Configuration and design study of manipulator systems applicable to the free flying teleoperator. Volume 1: Executive summary

NASA Office of Aeronautical and Space Technology Summer Workshop. Volume 6: Structures and dynamics panel

Preliminary design of a composite structure for an Air Force space application

AAPE large deployable antenna development program: Executive summary

Some design considerations for large space structures

A new optimality criterion method for large scale structures

Design, fabrication and test of graphite/epoxy metering truss structure components, phase 3

Orbital assembly and maintenance study. Executive summary — space storable structures/structural design criteria

STRUCTURAL DYNAMICS

U DYNAMIC STRUCTURAL ANALYSIS

STRUCTURAL ENGINEERING

A nestable tapered column concept for large space structures

Optimum overlap design of thin walled tubular extendible spacecraft structures under solar heating in zero-g environment

Spacecraft boom design and performance, including Russian spacecraft photographs

Spacecraft deployable booms, discussing structural design, self loading, weight, storage volume and thermal stability requirements

Large space structures zero backlash deployment mechanisms, discussing dynamically scaled model for structural and design and dynamic analysis

Space deployed expandable structures, discussing vehicular and environmental constraint effects on design, large structure requirements, and applications

Curved, tapered, circular cross section graphite/epoxy antenna ribs

Some choices for design of deployable solar arrays

Ion thruster design and analysis

Fabrication methods for large space structures


Continuum modeling of three-dimensional truss-like space structures

Computerized structural sizing at NASA Langley Research Center — low mass design for aerospace vehicles

Design concept of geostationary platforms

Large space structures at the Marshall Space Flight Center

Joints and implications on space construction

Control system technology and tradeoffs for large space structures

Design and performance of roll-up solar array engineering model

Study on the use of carbon fibre reinforced plastics in satellite structures, phase 1

Configuration and design study of manipulator systems applicable to the free flying teleoperator. Volume 1: Executive summary

NASA Office of Aeronautical and Space Technology Summer Workshop. Volume 6: Structures and dynamics panel

Preliminary design of a composite structure for an Air Force space application

AAPE large deployable antenna development program: Executive summary

Some design considerations for large space structures

A new optimality criterion method for large scale structures

Design, fabrication and test of graphite/epoxy metering truss structure components, phase 3

Orbital assembly and maintenance study. Executive summary — space storable structures/structural design criteria

STRUCTURAL DYNAMICS

U DYNAMIC STRUCTURAL ANALYSIS

STRUCTURAL ENGINEERING

A nestable tapered column concept for large space structures
TECHNOLOGICAL FORECASTING

Anticipated developments in communications satellite technology
[AD-A000841]
P0001 A76-23085

Building large structures in space
[IAF PAPER 77-34]
P0002 A77-51395

Impact of shuttle on technology and utility of national and regional communications satellites
[IAF PAPER 77-38]
P0002 A77-51399

Next steps in space transportation and operations
[PA0072 A76-19543]

Future space systems A survey of the next 25 years
[PA0003 A78-24853]

Solar electric propulsion and interorbital transportation
[AAS 77-221]
P0006 A78-43879

Automatic fabrication of large space structures - The next step
[AIAP PAPER 78-1651]
P0026 A78-52762

Pointing and control technology needs for future automated space systems
[AIAP PAPER 78-1667]
P0039 A78-52748

TECHNOLOGIES

NT ENERGY TECHNOLOGY

TECHNOLOGY ASSESSMENT

Three-axis attitude control for solar-powered electric propulsion spacecraft
[SAP PAPER 768071]
P0036 A75-22946

SEP solar array technology development
[PA0022 A77-12825]

Electric propulsion ready for space missions
[P0005 A75-30247]

NASA Office of Aeronautics and Space Technology
Sumer Workshop, Volume 2: Sensing and data acquisitions panel
[NASA-TM-X-73962]
P0085 A77-13911

NASA Office of Aeronautics and Space Technology
Sumer Workshop, Volume 3: Navigation, guidance and control panel
[NASA-TM-X-73963]
P0081 A77-13912

NASA Office of Aeronautics and Space Technology
Sumer Workshop, Volume 4: Power technology panel
[NASA-TM-X-73964]
P0045 A77-13913

NASA Office of Aeronautics and Space Technology
Sumer Workshop, Volume 5: Propulsion technology panel, part I
[NASA-TM-X-73965]
P0067 A77-13914

NASA Office of Aeronautics and Space Technology
Sumer Workshop, Volume 8: Thermal control panel
[P0078 A77-13917]

Solar sail-solar electric technology readiness and transfer assessment
[NASA-C8-157239]
P0067 A78-26154

TECHNOLOGY UTILIZATION

Technological problems with large-area solar cell arrays
[DGLF PAPER 73-107]
P0021 A74-17204

Utilization of Space Shuttle and Spacelab: Proceedings of the International Meeting, Bonn, West Germany, June 2-4, 1976

Advanced lightweight solar array technology --- for communication satellites
[AIAP 78-531]
P0024 A78-32883

Large space structures at the Marshall Space Flight Center
[AIAP PAPER 78-1650]
P0073 A78-51982

Proceedings from colloquia on transfer of teleoperator device technology
[SAF AP 50801]
P0058 A70-28670

Study of the commonality of space vehicle applications to future national needs (unclassified portion)
[AIAA PAPER 75-7365-2]
P0047 A76-14978

Orbital construction demonstration study.

Teleoperator-robot development program,

Executive summary
[SAF CR-151505]
P0075 A77-23130

Space industrialization
[GPO-99-159]
P0005 A78-20149

TELECOMMUNICATIONS

G REMOTE HANDLING

TELECOMMUNICATION

NT CLOSED CIRCUIT TELEVISION

NT HYDROTELEMETRY

NT RADIO COMMUNICATION

NT SPACECRAFT ANTENNAS

NT SPACE COMMUNICATION

NT SPACECRAFT COMMUNICATION

ATS P and G, discussing communications experimental program with deployable 30 ft parabolic antenna
[SAP PAPER 700750]
P0069 A71-21368

Geosynchronous information services platforms in the year 2000
[AIAP PAPER 78-1636]
P0073 A78-51976

Space industrialization
[GPO-99-159]
P0005 A78-20149

TELEOPERATORS

Space tools and support equipment for earth orbital systems maintenance, replacement and repair, discussing Skylab requirements and teleoperator applications
[AIAP PAPER 72-230]
P0053 A72-25049

Teleoperator manipulator for payload handling in space shuttle, noting design features and simulations of master-slave remote control system
[AIAP PAPER 72-218]
P0053 A72-29075

NASA teleoperator-robot development program, discussing technology and design studies related to space shuttle and stations, satellites and planetary vehicles
[P0053 A72-32315]

A teleoperator system for space application
[P0053 A72-45174]

X-reference frame bilateral control for the Shuttle Attached Manipulator System
[P0053 A73-35317]

Teleoperator and XVA for Shuttle missions
[P0057 A74-14117]

A manipulator system designed for Free-Flying Teleoperator Spacecraft
[P0055 A75-19712]

Free-flying teleoperator for space missions
[P0055 A75-27199]

Shuttle remote manipulator system workstation - Human-machine engineering
[P0056 A77-26628]
Manipulator evaluation criteria

Control and stability problems of remote orbital capture

The remote manipulator system for the Space Shuttle Orbiter

[SS Ex PAPER 77-1040] p0057 A78-28447

Space Spider - A concept for fabrication of large structures

[AIAA PAPER 78-1665] p0025 A78-51984

Advanced teleoperator spacecraft

[AIAA PAPER 78-1665] p0057 A78-51991

 unmanned remote control teleoperator spacecraft module for space maintenance

p0058 W72-20438

Design criteria and tradeoffs for manned machine interface for teleoperator system performing on-orbit satellite retrieval and servicing

[NASA CR-123755] p0059 W72-29830

Configuration and design study of manipulator system applicable to the free flying teleoperator. Volume 1: Executive summary

[NASA CR-152-7674] p0055 W78-31502

Earth orbital teleoperator manipulator system evaluation program

[NASA CR-143075] p0060 W75-26561

Earth orbital teleoperator visual system evaluation program

[NASA CR-143075] p0060 W75-26562

Proto-Flight Manipulator Arm (P-FMA)

[NASA CR-150277] p0061 W77-24768

Earth orbital teleoperator mobility system evaluation program

[NASA CR-150285] p0061 W77-25786

Earth orbital teleoperator manipulator system evaluation program

[NASA CR-150286] p0061 W77-25787

TELESCOPES

NT ASTRONOMICAL TELESCOPES

NT LARGE SPACE TELESCOPE

NT RADIOT ELESCOPES

NT SPACEBORNE TELESCOPES

TELEVISION SYSTEMS

NT CLOSED CIRCUIT TELEVISION

TELEMECH THEORY

U NETWORK ANALYSIS

TEMPERATURE CONTROL

Thermal control of the solar electric propulsion stage

[AIAA PAPER 73-1118] p0065 A78-10693

Thermal stabilisation of gravity gradient boom rods

p0035 A74-42816

Thermal control requirements for large space structures

[AIAA PAPER 78-1675] p0010 A78-51999

Mathematical model for orbiting satellite structure with passive temperature control

p0026 N68-12276

Attachment methods for thermal control composite system comprised of optical solar reflectors and multilayer insulation to minimize heating from incident solar energy

[NASA CR-21519] p0049 N68-28689

NASA Office of Aeronautics and Space Technology Summer Workshop. Volume 8: Thermal control panel


Thermal technology. Part 1: Thermal problems of satellite antennas --- conference proceedings

[NASA CR-152-7674] p0016 W76-16214

TEMPERATURE DISTRIBUTION

Handbook for the thermal modelling of space mechanisms of the nodal network method

[SS Ex PAPER-CR-219] p0012 W74-26394

TEMPERATURE EFFECTS

Radiation and temperature effects on composite structures in Pegasus satellite

[NASA CR-21519] p0049 N68-28624

Thermal distortion and static bending plus twist measurements on deployable boom structures for spacecraft

p0011 W72-25789

TEMPERATURE FIELDS

U TEMPERATURE DISTRIBUTION

Temperature measurement

Handbook for the thermal modelling of space mechanisms by the nodal network method

[SS Ex PAPER-CR-219] p0012 W74-26394

TERIAL FACILITIES

Airport alternate facilities, restrictive flight schedules and fee schedules for relieving airport congestion during peak traffic hours

[AIAA PAPER 69-520] p0018 A69-35595

THERMAL STABILITY

Large space erectable structures rigidity,
THERMAL STRESSES

Efficiency and integrity of graphite epoxy test program for space telescope [AAS PAPER 77-78-087] p0020 A70-34143

Thermal stabilization of gravity gradient boom tests [AIA A 77-152-152] p0020 A70-152-3140

Thermally inert composite hardware applications for spacecraft [AAS PAPER 77-78-087] p0049 A70-3630

A statistical evaluation of a space stable optical support structure [AIA A 77-152-152] p0025 A70-34143

THERMAL STRESSES


THERMAL VACUUM TESTS

Graphite epoxy test program for space telescope [AIA A 77-152-152] p0048 A77-44414

Thermal design verification, qualification and acceptance testing concept for future large space objects [AIA A 77-152-152] p0014 N78-24273

THERMOMETRIC REACTORS

ION ENGINES

THERMODYNAMIC PROPERTIES

NT THERMAL EXPANSION

NT THERMAL STABILITY

Thermal and mechanical properties of materials for spacecraft booms design [AIA A 77-152-152] p0020 A70-34138

Composite materials mechanical and thermal properties for ACT reflector supporting trusses, noting graphite fiber reinforced epoxy plastic design, fabrication and tests [AIA A 77-152-152] p0047 A72-28158

Thermal control requirements for large space structures [AIA A 77-152-152] p0010 A78-51999

THERMOELECTRIC GENERATORS

Effect of boost environment on design of large area solar array, its release and deployment on ground and in space, and electrical power source analysis [AIA A 77-152-152] p0027 N68-31404

THERMOELECTRICITY

U TEMPERATURE MEASUREMENT

THERMOPHYSICAL PROPERTIES

NT THERMAL STABILITY

THERMOSETTING RESINS

NT EPOXY RESINS

THERMOPLASTIC

U THERMAL STABILITY

THERMOPHYSICS

U TEMPERATURE EFFECTS

THICKNESS

Analysis of thickness tapered booms for space applications [AIA A 77-152-152] p0008 A74-21398

THIN FILMS

The production of ultrathin polyimide films for the solar sail program and large Space Structures Technology (LSSST): A feasibility study [NASA-CR-157568] p0050 N78-36467


THIN PLATES

Post buckling behaviour of thin-walled members --- of folded flat plates [AIA A 77-152-152] p0008 A75-18464

THIN WALLED SHELLS

Optimum overlap design of thin walled tabular extendible spacecraft structures under solar heating in zero-g environment [AAS PAPER 69-336] p0007 A70-30762

Transforming welded shells for space systems [AIA A 77-152-152] p0023 A77-51414

Static and dynamic analysis of space radiotelescope thin wall structure elements [AIA A 77-152-152] p0009 A77-51414

THREE AXIS STABILIZATION

Attitude control of three-axes stabilized spacecraft with flexible appendages, volume 1 [NSS/SS-78-03-VOL-1] p0041 A77-29198
WAVE EQUATIONS
W

WAVE EQUATIONS
Modal control of certain flexible dynamic systems p0038 A78-35756

WAVE PROPAGATION
German monograph - Wave propagation in glass-fiber light waveguides p0043 A72-36249

WAVEGUIDE ANTENNAS
Design, electrical, and mechanical characteristics of inflatable cigar and parabolic antennas p0027 668-27933

WAVEGUIDES
NT OPTICAL WAVEGUIDES
German monograph - Wave propagation in glass-fiber light waveguides p0043 A72-36249

WEAPON SYSTEMS
NT GROUND OPERATIONAL SUPPORT SYSTEM
Film reflectors in space --- Russian book on orbiting solar power stations and solar sails p0002 A76-15423

WEIGHT (MASS)
NT STRUCTURAL WEIGHT
Material composition, weight, size, and unfolding factors entering into design of inflatable space station structures [NASA-CR-92596] p0026 860-15239

WEIGHT ANALYSIS
Spoked wheels to deploy large surfaces in space-weight estimates for solar arrays [NASA-CR-2347] p0030 75-14831

WEIGHT FACTORS
NT WEIGHT (MASS)
WEIGHT REDUCTION
Advanced lightweight rigid solar arrays based on carbon fibre technology [TAP PAPER 74-005] p0022 A75-13717
Thermally inert composite hardware applications for spacecraft p0009 A70-36430
Computerized structural sizing at NASA Langley Research Center --- low mass design for aerospace vehicles [AIAA PAPER 78-601] p0010 A70-46513

WEIGHTLESSNESS
Zero g deployment dynamics of erectable truss parabolic antennas, obtaining latchup loads as a function of reflector mechanical energy [AERS PAPER 69-136] p0018 A69-12827
Optimum overlap design of thin walled tubular extendible spacecraft structures under solar heating in zero-g environment p0007 A70-30762
Attached manipulator system for simulating and demonstrating shuttle manipulator cargo handling operations under weightless conditions [NASA-CR-13364] p0059 73-27776

WEIGHTLESSNESS SIMULATION
Weightlessness simulation for aerospace mechanisms, using tower release and gyrometric system for testing stage separation, satellite perturbation, yo-yo, probe and mast development [OKERA-70-940] p0071 A71-36018
Tank tests validate structure assembly --- underwater zero-g tests for astronaut assembly of large space structures p0057 A78-82474
Zero gravity simulation methods and applications in design and procedures determination for D-021 and D-023 space structure experiments p0069 668-27931
A manipulator arm for zero-g simulations p0060 76-19114

WELDED STRUCTURES
Transforming welded shells for space systems [JAP PAPER 71-60] p0023 A77-51414

WELDING
NT ELECTRON BEAM WELDING
WHEELS
NT FLWHEELS
NT REACTION WHEELS
NT TURBINE WHEELS
WHEEL NT ROTATION

WIRE CLOTH
NT SUPERHIGH FREQUENCIES

WIREMESH
NT WIRE CLOTH
WRAPAROUND CONTACT SOLAR CELLS

X

Y

Z

ZERO GRAVITY
NT WEIGHTLESSNESS

A-48
# PERSONAL AUTHOR INDEX

## TECHNOLOGY FOR LARGE SPACE SYSTEMS / A Special Bibliography

**APRIL 1979**

## Typical Personal Author Index Listing

<table>
<thead>
<tr>
<th>PERSONAL AUTHOR</th>
<th>TITLE</th>
<th>REPORT NUMBER</th>
<th>PAGE NUMBER</th>
<th>NASA ACCESSION NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARMSTRONG, W. E.</td>
<td>Large space erectable structures - building block structures study</td>
<td>p0032</td>
<td>n77-27156</td>
<td></td>
</tr>
<tr>
<td>ARNOLD, J. N.</td>
<td>Feasibility development of a self-deploying electromagnetic energy focusing reflector for space or transportable ground based applications</td>
<td>p0027</td>
<td>n69-27929</td>
<td></td>
</tr>
<tr>
<td>ARNOLD, E. S.</td>
<td>Continuum models for static and dynamic analysis of repetitive lattices</td>
<td>p0008</td>
<td>n77-25760</td>
<td></td>
</tr>
<tr>
<td>ATTARD, G. J.</td>
<td>Attitude control of three-axes stabilised spacecraft with flexible appendages, volume 2</td>
<td>p0041</td>
<td>n77-29198</td>
<td></td>
</tr>
<tr>
<td>AUTONIDES, G. J.</td>
<td>Study of SEP solar array modifications</td>
<td>p0067</td>
<td>n70-30659</td>
<td></td>
</tr>
<tr>
<td>BAKER, B. E.</td>
<td>Solid state remote power controllers for 120 VDC power systems</td>
<td>p0043</td>
<td>n76-31510</td>
<td></td>
</tr>
<tr>
<td>BALAS, N. J.</td>
<td>Active control of flexible systems</td>
<td>p0037</td>
<td>n70-12096</td>
<td></td>
</tr>
<tr>
<td>BALAS, N. J.</td>
<td>Inactive control system philosophy for a class of large space structures</td>
<td>p0037</td>
<td>n70-12096</td>
<td></td>
</tr>
<tr>
<td>BALAS, N. J.</td>
<td>Modal control of certain flexible dynamic systems</td>
<td>p0038</td>
<td>n78-35756</td>
<td></td>
</tr>
<tr>
<td>BALAS, N. J.</td>
<td>Dynamics and control of large spinning spacecraft</td>
<td>p0036</td>
<td>n78-45604</td>
<td></td>
</tr>
<tr>
<td>BALKHANAY, V. P.</td>
<td>Investigation of the physical-mechanical properties and supramolecular structure of epoxy resins exposed to UV radiation under atmospheric conditions</td>
<td>p0047</td>
<td>n75-21365</td>
<td></td>
</tr>
</tbody>
</table>

## B

<table>
<thead>
<tr>
<th>PERSONAL AUTHOR</th>
<th>TITLE</th>
<th>REPORT NUMBER</th>
<th>PAGE NUMBER</th>
<th>NASA ACCESSION NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAKER, B. E.</td>
<td>Solid state remote power controllers for 120 VDC power systems</td>
<td>p0043</td>
<td>n76-31510</td>
<td></td>
</tr>
<tr>
<td>BALKHANAY, V. P.</td>
<td>Investigation of the physical-mechanical properties and supramolecular structure of epoxy resins exposed to UV radiation under atmospheric conditions</td>
<td>p0047</td>
<td>n75-21365</td>
<td></td>
</tr>
<tr>
<td>BALKHANAY, V. P.</td>
<td>Feedback control of flexible systems</td>
<td>p0038</td>
<td>n79-49256</td>
<td></td>
</tr>
<tr>
<td>BALKHANAY, V. P.</td>
<td>Application of NASTRAN to large space structures</td>
<td>p0008</td>
<td>n73-39545</td>
<td></td>
</tr>
<tr>
<td>BALKHANAY, V. P.</td>
<td>Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control</td>
<td>p0009</td>
<td>n78-12108</td>
<td></td>
</tr>
<tr>
<td>BALKHANAY, V. P.</td>
<td>Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control</td>
<td>p0009</td>
<td>n78-31888</td>
<td></td>
</tr>
<tr>
<td>BALKHANAY, V. P.</td>
<td>The ubiquitous solar electric propulsion stage</td>
<td>p0066</td>
<td>n78-43799</td>
<td></td>
</tr>
<tr>
<td>BARBER, S.</td>
<td>Graphite epoxy test program for space telescope</td>
<td>p0045</td>
<td>n77-44414</td>
<td></td>
</tr>
<tr>
<td>BARRETT, J.</td>
<td>Continuum models for static and dynamic analysis of repetitive lattices</td>
<td>p0008</td>
<td>n77-25760</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Attitude control of three-axes stabilised spacecraft with flexible appendages, volume 1</td>
<td>p0041</td>
<td>n77-29198</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Attitude control of three-axes stabilised spacecraft with flexible appendages, volume 2</td>
<td>p0041</td>
<td>n77-29198</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Optimal control of spin stabilized spacecraft with movable appendages, part 2</td>
<td>p0039</td>
<td>n76-11216</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Optimal control of spin stabilized spacecraft with telescoping appendages</td>
<td>p0040</td>
<td>n76-28319</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>The dynamics of spin stabilized spacecraft with movable appendages, part 2</td>
<td>p0040</td>
<td>n76-31272</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>The dynamics and control of large flexible space structures. Part A: Discrete model and modal control</td>
<td>p0042</td>
<td>n79-23139</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>The dynamics and control of large flexible space structures. Part B: Development of continuos model and computer simulation</td>
<td>p0044</td>
<td>n78-23140</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>The ubiquitous solar electric propulsion stage</td>
<td>p0066</td>
<td>n78-43799</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control</td>
<td>p0009</td>
<td>n78-12108</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control</td>
<td>p0009</td>
<td>n78-31888</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>The ubiquitous solar electric propulsion stage</td>
<td>p0066</td>
<td>n78-43799</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control</td>
<td>p0009</td>
<td>n78-12108</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control</td>
<td>p0009</td>
<td>n78-31888</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>The ubiquitous solar electric propulsion stage</td>
<td>p0066</td>
<td>n78-43799</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control</td>
<td>p0009</td>
<td>n78-12108</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control</td>
<td>p0009</td>
<td>n78-31888</td>
<td></td>
</tr>
<tr>
<td>BABBETT, E. J.</td>
<td>The ubiquitous solar electric propulsion stage</td>
<td>p0066</td>
<td>n78-43799</td>
<td></td>
</tr>
</tbody>
</table>
BALTISKII, V. N.  p0013 N77-20501

BALTISKII, V. N.  Transforming welded shells for space systems [JAF PAPER 77-60] p0023 N77-51814


BARCLAY, R. G.  Non-linear consideration of gravity in a stiffness test of a weak structure at small strains p0011 W71-36256

Weaving tail vibration absorber [NASA-2M-67505] p0011 N72-16871

BARKER, G.  Deployable structures p0021 A73-18905

BASLIE, D. R.  Antenna concepts for interstellar search systems p0002 A78-13323

BATHNER, D. R.  Microwave performance characterization of large space antennas [NASA-CE-153206] p0005 N77-24333


BERMAN, L. D.  Reliability of composite zero-expansion structures for use in orbital environment p0048 A76-16569


BLACK, D.  Searching for extraterrestrial intelligence: The ultimate exploration p0002 A77-66747

BLAIR, J. C.  Control systems technology and tradeoffs for large space structures [AIAA PAPER 78-1606] p0039 A78-52747

BODDY, C. E.  Shuttle-Attached Manipulator System requirements. p0054 A73-37307

BODDY, C. S.  A digital computer program for the dynamic interaction simulation of controls and structure (DISCOS), volume 1

BOOKER, B. A.  Attached manipulator system design and concept verification for zero-g simulation [NASA-CR-133964] p0059 N73-27176

BOOKER, B. J.  X-reference frame bilateral control for the Shuttle Attached Manipulator System. p0053 A73-35317

BOUFFEI, R. E.  Three-axis attitude control for solar-powered electric propulsion spacecraft [CAS PAPER 74087A] p0036 A75-22946

BRADFORD, W. C.  Shuttle avionics system p0071 A76-28871

BRADSHA, J.  Synthesis of active on-board controllers for vibratory systems with rigid body-modes p0040 A76-28324

BRADA, H. S.  A test of shuttle on technology and utility of national and regional communications satellites [JAF PAPER 77-38] p0002 A77-51399


BRADSHAW, K. G.  Present and future applications of expandable structures for spacecraft and space experiments p0021 A71-41981

EXPANDABLE structures for spacecraft [NASA-CE-76-201] p0022 A76-46081

BEELA, M. V.  A flexible passive space array with springs p0037 A78-12095

BREIDBACH, E.  A semi-automatic nodal-survey test technique for complex aircraft and spacecraft structures p0012 N75-22539


BRODIE, J. A.  Preliminary design and simulations of a Shuttle-Attached Manipulator System. p0054 A73-37309

Variable ratio mixed-mode bilateral master-slave control system for shuttle remote manipulator system [NASA-CASE-MSC-14265-1] p0060 A75-27081 A manipulator arm for zero-g simulations p0060 N76-19174 The assembly of large structures in space p0067 A76-29770

BROGEN, E. W.  Simplified thermal estimation techniques for large space structures [NASA-CE-145253] p0013 N78-13105


BROOKES, J. W.  Selection and adaptation of a control law for a Double Gyroscrolled Momentum Wheel system on a large solar array satellite p0036 A76-28880

BROWN, J. W.  Shuttle remote manipulator system workstation - Man-machine engineering p0056 A77-26628 Shuttle remote manipulator system safety and rescue support capabilities [AIAA PAPER A-77-38] p0057 A77-51518

BROWN, W. E.  Space tools and support equipment - Current technology and future requirements [AIAA PAPER 72-230] p0053 A72-25049

BROWN, W. C.  Microwave power transmission system studies. Volume 3, section 8: Mechanical systems and
On-orbit fabrication and assembly of composite Earth orbital teleoperator manipulator system

Fabrication and assembly of large composite structures in space [AIAA PAPER 77-543]

[B2023 A77-32065]

On-orbit fabrication and assembly of composite structures

[AIAA PAPER 78-1654]

[B026 A78-52743]

Earth orbital teleoperator manipulator system evaluation program [NASA-CR-143678]

[B0060 N75-26651]

Earth orbital teleoperator manipulator system evaluation program [NASA-CR-150289]

[B0061 N77-25786]

Earth orbital teleoperator manipulator system evaluation program [NASA-CR-150286]

[B0061 N77-25787]

Bogrovskii, V. V.

A highly reliable data handling and control system of a spacecraft power unit [IAF PAPER 77-138]

[B004 A77-51401]

Buzas, V. E.

Infinitely built-up space radio telescope [IAF PAPER 77-67]

[B0024 A77-51417]

Automatic control of the surface shape of large space radio-telescopes [IAF PAPER 77-194]

[B0037 A77-51470]

Bullock, R. E.

Improved mechanical properties of composites reinforced with neutron-irradiated carbon fibers.

[B0047 A73-65143]

Mechanical of a boron-reinforced composite material radiation-induced of its epoxy matrix

[B0047 A74-26644]

BurgoA, G. R.

Axisymmetric filamentary structures [NASA-CR-1518]

[B0028 N70-27128]

Burns, W. W.

Attached manipulator system design and concept verification for zero-g simulation [NASA-CR-133964]

[B0059 N73-27176]

Burrows, W. W.

Highlights of the long-life assurance study

[B0044 N74-19129]

Burton, R.

The effect of flexibility on a control system design for a range of spacecraft and hybrid array configurations

[B0040 N76-28325]

Bush, R. G.

Some design considerations for large spacecraft structures [AIAA 77-395]

[B0023 A77-25747]

Computerized structural sizing at NASA Langley Research Center [AIAA PAPER 78-1500]

[B0010 A76-46513]

A nestable tapered column concept for large space structures [NASA-TN-K-73927]

[B0031 N76-29358]

Structural stiffness, strength and dynamic characteristics of large tetrahedral space truss structures

[B0013 N77-19487]

Lightweight structural columns [NASA-CASE-LAR-12095-1]

[B0032 N77-27432]

Bushnell, D.

Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control

[B0009 A78-12108]

Multibody flexible spacecraft integrated analysis - Structures, dynamics, and control

[B0009 A78-31888]

Byers, D. C.

Electron bombardment propulsion system characteristics for large space systems [NASA-M-1-11555]

[B0067 N77-11106]

C

Campbell, F. J.

Thermal stabilization of gravity gradient boom rods

[NASA-RP-1014]

[0035 A74-42016]

Campbell, W. A., Jr.

An outstanding data compilation of spacecraft materials

[NASA-RP-1014]

[0050 N78-17151]
COPPA, A. P.
A family of rigid shell structures, self-deployable from folded configurations of small initial volume.
[AIAA PAPER 68-359] p0017 A66-24311

CORLIS, W. R.
Teleoperators and human augmentation. An AEC-NASA technology survey
[NASA-SP-5047] p0057 W68-18670
Teleoperator control An AEC-NASA technology survey
[NASA-SP-5070] p0059 M69-25478

COOLEY, P.
Attached manipulator system design and concept verification for zero-g simulation

COXALD, C.
Structure assembly demonstration slated
Task tests validate structure assembly
Platform designed for numerous uses
p0072 A78-68774

COTNER, J. V., Jr.
Analysis of performance characteristics and weight variations of large-area roll-up solar arrays
FASME PAPER 69-NA/DEP-11) p0019 A70-14898
Radial rib antenna surface deviation analysis program
RUSAP: A computer program for the calculation of Roll-Up Solar Array Performance characteristics
[NASA-CR-135898] p0012 W73-33003

CRAWFORD, R. F.
Comparative systems study of magnetically suspended flywheels
[BMPT-PE-W-76-20] p0041 N77-23166
Comparative systems study of magnetically suspended flywheels
[ESA-TT-393] p0041 N77-33245

CRAWFORD, P.
Attached manipulator system design and concept verification for zero-g simulation

CRAH E, R. F.
Strength and efficiency of deployable booms for space applications
[AIAA PAPER 77-396] p0020 A71-25272
Spoked wheels to deploy large surfaces in space
[AIAA PAPER 74-1267] p0022 A75-11108
Investigation of a collapsible lattice column
Spoked wheels to deploy large surfaces in space-weight estimates for solar arrays
[NASA-CR-2347] p0030 N75-14831
Conceptual analyses of extendible booms to support a solar sail
[NASA-CR-155615] p0032 N78-17124

CRELIN, E. B.
Mathematical methods in flexible spacecraft dynamics, volume 1
[ESRO/SS-765-VOL-1] p0013 N77-23188
Mathematical methods in flexible spacecraft dynamics, volume 2
[ESRO/SS-765-VOL-2] p0013 N77-23189

CURCIA, C. L.
Communication satellite technologies in the early twenty-first century - A projection into the post Intelsat-V era
[TAP PAPER 77-34] p0002 A77-51395

CUEZ, J. M.
Searching for extraterrestrial intelligence - The ultimate exploration
p0002 A77-46787

D

DAHLGREN, J. B.
Pointing and control technology needs for future automated space systems
[AIAA PAPER 78-1687] p0039 A78-52748

DAMES, C. J.
Toward large space systems
p0071 A78-31833

DAWSON, C. R.
Large space structures at the Marshall Space Flight Center
[AIAA PAPER 78-1650] p0073 A70-51982

DAVIES, R.
Space: A resource for earth - An AIAA review
p0001 A77-32440

DELMONTE, J.
Multi-KW DC distribution system technology research study

DELABRE, J.
Foldable boom systems study. First phase: Initial studies
[ESRO-CR-164] p0030 W74-16154
Foldable boom systems study. Second phase: Definition and development
[ESRO-CR-211] p0030 N75-20461

DELL, A. L.
Handbook for the thermal modelling of space mechanisms by the nodal network method
[ESRO-CR-219] p0012 W74-26394

DENTON, C. J.
Torsionally rigid and thermally stable boom
p0020 A70-34143

DIERKICH, W. L., Jr.
Shuttle Payload Accommodation System teleoperator. - Orbit control system platform
[AIAA PAPER 78-1659] p0025 A78-51986
DURBRUCK, R.
Manipulator systems extend man's capabilities in space
Teleoperators and EVA for Shuttle missions
p0053 A72-32315
p0055 A74-14117

DYER, A. B.
A digital computer program for the dynamic interaction simulation of controls and structure
(DISCO3), volume 1
p0014 W74-25123

DICKINSON, J.
Large spacecraft antenna study, analytical pattern subtask

DISHNER, J.
Next steps in space transportation and operations
p0072 A78-19543

DOD, R. E.
The ubiquitous solar electric propulsion stage
p0065 A76-46136

DOBERN, K. W.
The remote manipulator system for the Space Shuttle Orbiter
p0057 A78-24947

DOOLFSD, A.
Electrons in the solar corona. II - Coronal streamers from K-coronameter measurements
p0048 A78-11519

DONAVAN, R.
Assembly in space of large communication structures
p0003 A78-36723

DONGES, P. K.
Remote manipulator dynamic simulation
[NASA-CR-115636] p0059 W72-24339

DOUGLAS, F. J.
The NASTRAN programmer's manual
[NASA-SP-223] p0011 W70-43143

DOUGLAS, W. J.
Bending stiffness of an inflated cylindrical cantilever beam
p0007 A69-41981

DOWSETT, P.
Space: A resource for earth - An AIAA review
p0001 A77-32440

DOWNING, R.
Deployment latchup dynamics of an erectable truss antenna
[AAS PAPER 69-336] p0010 A69-42827

DUNAW, C.
Attached manipulator system design and concept verification for zero-g simulation

DYKSTRA, V.
Application of NASTRAN to large space structures
p0013 W73-20501

E

EASTMAN, F.
Advanced aerospace power distribution and control
techniques. p0043 A73-15389

EDY, B. J. Solar deflection of thin-walled cylindrical, extendable structures p0007 A70-30762

MCLENNAM, D. Analysis of transmission-line accelerator concepts [AD-A056364] p0076 N78-32849

EDELSON, R. J. Orbital antenna farms p0072 A77-47268

The OAF concept extended [AIAA 78-546] p0003 A78-32891

EDELSON, R. E. Extraterrestrial intelligence - An observational approach p0003 A78-22524

EDER, H. Passive temperature control for large space ships p0026 N68-12276

EDWARDS, A. Microwave power transmission system studies. Volume 3, section 8: Mechanical systems and flight operations [NASA-CR-138066-VOL-3] p0004 W76-15596

EHICKE, K. A. Use of Shuttle in establishing large space installations p0001 A74-18121

ELISE, J. A. Thermal stabilization of gravity gradient boom rods p0035 A74-42816


Foldable boom systems study. Second phase: Definition and development [ESRO-CR-211] p0030 W75-20461

ELTS, R. V. Jr. SEP solar array technology development p0022 A77-12825

SEP full-scale wing technology development p0965 A77-48860

EIGLER, E. Z. Automated space fabrication of structural elements p0024 A78-36703


Foldable boom system study. Second phase: Definition and development [ESRO-CR-211] p0030 W75-20461

FAGER, J. A. Large space erectable communication antennas. [IPAP PAPER SD-9] p0017 A66-44253

Large space erectable antenna stiffness requirements [AIAA 78-500] p0026 A78-32929

Large erectable antennas for space application Final report [NASA-CR-102522] p0028 W70-25762

FALCONE, J. C. Space electric rocket test solar array power system [AIAA PAPER 76-1159] p0065 A70-40202

FEE, J. E. Integrated dynamic analysis simulation of space stations with controllable solar arrays (supplemental data and analyses) [NASA-CR-112165] p0012 W72-32849

FERNANDEZ-SUNYES, J. Flexural instability of elastic recovery foldable tubes. p0017 A68-42162

A foldable tubular connection and its application to an expandable lattice column. p0018 A69-17608

Analytical studies on foldable tubes [NASA-CR(6)-793] p0031 W76-24635


FERRANTE, J. G. Finite element dynamic analysis of large dimensional flexible solar arrays: Necessity of modal truncation for the simulation of spacecraft control maneuvers p0013 W76-28306


EMs manipulator arm dynamics capability in the SVDS [NASA-CR-151458] p0061 W77-27162

FLATOW, C. R. Attended manipulator system design and concept verification for zero-g simulation [NASA-CR-133964] p0059 W73-27746

Variable radius mixed-mode bilateral master-slave control system for space shuttle remote manipulator system [NASA-CASE-NESC-4245-1] p0060 W75-27041

FLOOD, R. Structural design concepts for future space missions [NASA-CR-101577] p0026 N69-29417

FLOOD, R. The effect of flexibility on a control system design for a range of spacecraft and hybrid array configurations p0040 W76-28325

FOGDAH, L. N. Effects of space radiation on thin polymers and nonmetallics [AIAA PAPER 77-741] p0048 A77-39510

FOLGATE, K. Discrete time attitude control of spacecraft containing low frequency lightly damped structural modes [AIAA PAPER 76-262] p0008 W76-26807

FORBES, F. W. Expandable and modular structures technology for support of manned missions. p0017 A68-42769

FORREICHER, S. M. Future communications concepts. I - The switchboard-in-the-sky Switchboard in the sky p0003 A78-26827

p0024 A78-37243

FORESTER, R. H. The production of ultrathin polyimide films for the solar sail program and Large Space Structures Technology (LSST): A feasibility study p0050 W78-30657

FORNOFF, R. Experimental evaluation of remote manipulator systems. p0054 A73-37305

FOX, D. Conceptual approach study of a 200 watt per kilogram solar array [NASA-CR-148505] p0031 W76-26851

FRALEJS DE VERDURERS, R. The dynamics of flexible bodies p0036 A76-46286

FRALICH, R. W. Response of long, flexible cantilever beams applied root motions p0031 W77-10276


FRASER, A. V. Response of long, flexible cantilever beams applied root motions p0031 W77-10276

FRASER, A. V. Response of long, flexible cantilever beams applied root motions p0031 W77-10276

FRASER, A. V. Response of long, flexible cantilever beams applied root motions p0031 W77-10276


FEEDERICK, W. N. Earth orbital teleoperator manipulator system evaluation program [NASA-CR-143876] p0060 W75-26651

Earth orbital teleoperator visual system evaluation program [NASA-CR-143875] p0060 W75-26652

Earth orbital teleoperator manipulator system evaluation program [NASA-CR-150286] p0061 W77-25787

FREELAND, R. E. Large Deployable Antenna Shuttle Experiment [AIAA PAPER 75-253] p0069 A76-12889

P. E. PREITAG. R. F. Toward large space systems p0071 A77-31833

Summary of problems of greatest urgency p0072 A77-35825
FRISCH, R. P.

A digital computer program for the dynamic interaction simulation of controls and structure (DISCOS), volume 1

FONSEKES, E.

Foldable boom systems study. Second phase:
Definition and development
[ZERO-CR-211] p0030 N75-20461

FOLTZ, E. B.

Structural design concepts for future space missions

GALLOV, G. K.

Design considerations for multi-beam communication satellite's antennas
[IAP PAPER 77-41] p0023 A77-51402

GARAND, W. A.

Remote manipulator dynamic simulation
[NASA-CR-115636] p0059 W72-28339

GARR, P.

Attached manipulator system design and concept verification for zero-g simulation
[NASA-CR-133967] p0059 W73-27176

GARDNER, E. A.

Shuttle avionics system
p0071 A76-28871

GATES, J. D.

Feasibility development of a self-deploying electromagnetic energy focusing reflector for space or transportable ground based applications
p0027 N68-27299

Self-erecting reflector Patent
[NASA-CASE-BOS-09190] p0026 N71-16102

GERWIN, R. L.

Applications technology satellites Y and G
[SIA PAPER 700759] p0069 A71-21368

GIESKE, R. K.

Frequencies and mode shapes of a 100-foot space erectable parabolic antenna.
p0018 A69-25532

GLOHOSZ, A.

Inflatable structures in space

GOBERNIK, R.

Past experience - Basis for future advanced power systems for communications satellites
[IAP PAPER 77-22] p0046 A77-51390

Power supply systems in the multi-kW power range
p0045 A77-23317

GOLDENBERG, G. L.

A zero backlash deployment mechanism for large space structures
[IAA PAPER 71-400] p0021 A71-25276

GOMEZ-FERNANDEZ, F.

Foldable boom systems study. Second phase:
Definition and development
[ZERO-CR-211] p0030 W75-20461

GOSEKSHKO, V. P.

Influence of ionizing radiation on the mechanical properties of fiberglass strengthened polyethylene
p0048 A77-40199

Effect of ionizing radiation on mechanical properties of glass-fiber-filled polyethylene
p0049 A78-33058

GORBA, D.

Orbital assembly and maintenance study
[NASA-CR-144422] p0060 W75-32144

Orbital assembly and maintenance study. Executive summary
[NASA-CR-144448] p0060 W75-32971

GORSHKOV, L. M.

Infinitely built-up space radio telescope
[IAP PAPER 77-67] p0024 A77-51417

GOTT, C.

Attached manipulator system design and concept verification for zero-g simulation

Orbital assembly and maintenance study
[NASA-CR-144422] p0060 W75-32144

Orbital assembly and maintenance study. Executive summary
[NASA-CR-144448] p0060 W75-32971

A manipulator arm for zero-g simulations
p0060 W76-19147

GRASSE, A.

The design of compressor and turbine disks operating in the elastoplastic regime
p0057 A79-19036

GREEN, P. J.

Attached manipulator system design and concept verification for zero-g simulation

Variable ratio mixed-mode bilateral master-slave control system for shuttle remote manipulator system
[NASA-CASE-MSC-14245-1] p0060 W75-27041

GREENE, W. H.

Continuum models for static and dynamic analysis of repetitive lattices
[IAA PAPER 77-414] p0008 A77-25760

GREENFIELD, E. L.

Thermal control of a solar sail
[IAA PAPER 78-885] p0024 A78-37274

GER, J.

Space: A resource for earth - An IAA review
p0001 A77-32440

GRESBYSKY, F. T.

Influence of ionizing radiation on the mechanical properties of fiberglass strengthened polyethylene
p0048 A77-40199

Effect of ionizing radiation on mechanical properties of glass-fiber-filled polyethylene
p0049 A78-33058

GERSHMAN, E. R.

Deployable booms for gravity gradient stabilization - A progress report
p0019 A70-14725

GROSKOPPS, E.

The HI-STER - A new technique in unfurlable structures
p0020 A70-34161

GULIK, G.

Extraterrestrial Intelligence - An observational approach
p0003 A78-22524

GURKDE, E. J.

A crane for construction in space
[IAA PAPER 78-1666] p0026 A78-51992

GUNTER, S. M.

Pointing and control technology needs for future automated space systems
[IAA PAPER 78-1667] p0039 A78-52768

GURALNICK, S. A.

Buckling of folded-plate structures.
p0007 A69-30679

GULICH, A. N.

Infinitely built-up space radio telescope
[IAP PAPER 77-67] p0024 A77-51417

Automatic control of the surface shape of large space radiotelescopes
[IAA PAPER 77-194] p0037 A77-51470

HAGLER, T.

Building large structures in space
p0071 A76-29321

Learning to build large structures in space
p0072 A78-16698

HALB, A. L.

A Bayleigh-Biltz approach to the synthesis of large structures with rotating flexible components
p0013 A77-10280

HALLY, J. T.

Microwave power transmission system studies. Volume 3, section 6: Mechanical systems and flight operations
HOLDEN, C. J.
Orbit assembly of unmanned spacecraft
[870] A74-12816
Orbit assembly of unmanned spacecraft
[870] A75-13586

HOLLEN, R. E.
A crane for construction in space
[869] A78-16661
BOLT, D.
Electrical measurements of an erectable parabola
[882] A79-70812

HOOKWAY, B. O.
Simulation of man-machine interaction on shuttle
payload manipulator
[870] A75-33698

HOPEWOOD, J.
Microprocessor-based data acquisition system
incorporating a floating-point arithmetic unit
for complex mathematical computations
[897] A78-25786

HOPEWELL, J. M.
Microwave power transmission system studies,
Volume 3, section 8: Mechanical systems and
flight operations
[889] A76-15596

HURBY, W. C.
Foldable construction block
[889] A72-25458

HUFFMAN, H. M.
Electromagnetic compatibility of ac power
distribution
[836-93 Y.-792]
Hughes, P. C.
Influence of stored angular momentum on the model
characteristics of spacecraft with flexible
appendages
[896-75-40667]

Hughes, P. C.
Influence of stored angular momentum on the model
characteristics of spacecraft with flexible
appendages
[896-75-40667]

HYDE, R. A.
Dynamics of a flexible manipulator arm for the
Space Shuttle
[870] A76-31877

HYDE, R. A.
Free-flying teleoperator for space missions
[870] A75-27199

I

IKEDA, K.
Multimode optical fibers - Steady state noise exciter
[870] A76-41890

IKEMOTO, T.
Multimode optical fibers - Steady state noise exciter
[870] A76-41890

ILSE, K. E.
Influence of ionizing radiation on the mechanical
properties of fiberglass strengthened polyethylene
[877-140199]

Influence of ionizing radiation on the mechanical
properties of fiberglass strengthened polyethylene
[887-140199]

IRWIN, J. D.
Free-flying teleoperator for space missions
[870] A75-27199

J

JACKSON, R. S.
Simulation of man-machine interaction on shuttle
payload manipulator
[870] A75-33698

JAPANESE, C.
Future communications concepts. I - The
switchboard-in-the-sky
[870] A78-26827

JAMES, P. K.
The dynamics and control of large flexible space
structures. Part B: Development of continuum
model and computer simulation
[870] A78-156976

JAWORSKI, W.
Thermal control of a solar sail
[870] A78-23140

K

KARI, S.
Ion thruster design and analysis
[870] A75-15106

KAPLAN, D. H.
Design of satellite flexibility experiments
[870] A75-13627

KARAN, R. D.
Solar deflection of thin-walled cylindrical,
extendible structures
[870] A70-30762

KATZ, E.
Structural and assembly concepts for large
erectable space systems
[870] A78-37606

KATZ, E.
Industry workshop on large space structures:
Executive summary
[870] A76-31258

KATZ, E.
Spacecraft-generated plasma interaction with high
voltage solar array
[870] A78-6733

KHAL, A. Q.
Post buckling behaviour of thin-walled members
[870] A75-18480

KHAL, N. R.
A new optimality criterion method for large scale
structures
[870] A78-29178

KING, P. M.
Non-linear consideration of gravity in a stiffness
test of a weak structure at small strains
[870] A71-36256

PERSONAL AUTHOR INDEX
Comparative systems study of magnetically
Earth orbital teleoperator manipulator system
Manipulator evaluation criteria
Comparative systems study of magnetically
Earth orbital teleoperator mobility system
Self-erecting reflector Patent
A high reliability data handling and control system of a spaceborne power unit
Fabrication methods for large space structures
Advanced lightweight rigid solar arrays based on carbon fibre technology
Study of attachment methods for advanced spacecraft thermal-control materials Final report
Investigation of the physical- mechanical properties and supramolecular structure of epoxy resins exposed to UV radiation under atmospheric conditions
Feasibility development of a self-deploying electromagnetic energy focusing reflector for space or transportable ground based applications
A highly reliable data handling and control system of a spaceborne power unit
Inflatable structures in space
Multi-kw dc power distribution system study program
Research study on multi-kw-DC distribution system
Fabrication and assembly of large composite structures in space
Wave propagation in glass-fiber light waveguides
Structural and assembly concepts for large erectorable space systems
Development of a shuttle manipulator simulator
Vibrational dynamics of satellites with thermally flexed appendages
LEUERTZ, G. E.

Feasibility of a 30-meter space based laser transmitter
[NASA-CR-134903] p0030 W76-11921

LESTER, B. J.

Integrating Shuttle payloads
[p0071 A77-31838]

LEVY, P.

The new generation of dynamic interaction problems
[AIAA PAPER 78-101] p0009 A78-44376

LIKIAS, P.

Study of roles of remote manipulators in satellites
[NASA-CR-120218] p0059 W74-29459

LIPS, K.

Remote Manipulator System and satellite servicing
experiment for Space Shuttle
[p0055 A76-42361]

LORD, C.

Orbital assembly and maintenance study
[PO060 W75-32104]

LUDWIG, A. C.

A new geometry for unfurlable antennas
[p0020 A71-12324]

LOBB, F. L.

Study of test methods for large flexible solar arrays
(TFIVA)
[p0060 W76-29468]

LOUIANO, A. V.

Foil reflectors in space
[p0002 A76-15423]

LOPICHYOY, L. M.

Automatic control of the surface shape of large space radiotelescopes
[JAP PAPER 77-194] p0637 A77-51870

MALLOSALAGRE, J. L.

Foldable boom systems study. Second phase: Definition and development
[ESRO-CR-211] p0030 W75-20461

MALONE, T. B.

Teleoperators and EVA for Shuttle missions
[p0055 A74-14117]

Manipulator evaluation criteria
[p0055 A77-26629]

Teleoperator system man-machine interface
requirements for satellite retrieval and satellite servicing. Volume 2: Design criteria
[NASA-CR-123755] p0059 A78-29830

Manipulator system man-machine interface
evaluation program
[NASA-CR-120218] p0059 W74-29459

Study of roles of remote manipulators in satellites
[NASA-CR-140364] p0059 W75-12036

Earth orbital teleoperator manipulator system
evaluation program
[NASA-CR-143874] p0060 W75-26651

Earth orbital teleoperator visual system
evaluation program
[NASA-CR-143875] p0060 W75-26652

MANOFF, H.

Thermal control requirements for large space structures
[p0010 A70-51999]

MARCUS, D.

Steady-state losses of optical fibers and fiber resonators
[p0044 A77-16826]

MARGERY, R.

Study of aerospace mechanisms in weightlessness
[PO071 A74-36108]

MARGOLIS, G.

Multibody flexible spacecraft integrated analysis
- Structures, dynamics, and control
[p0009 A70-12108]

Multibody flexible spacecraft integrated analysis
- Structures, dynamics, and control
[p0009 A70-31888]

MARRIOTT, R.

An outgassing data compilation of spacecraft materials
[NASA-RP-1014] p0050 W70-17151

MARRIOTT, R. L.

Attitude stability of a flexible solar electric spacecraft - A parametric study
[p0035 A74-21394]

MARTIN, A.

Foldable boom systems study. First phase: Initial studies
[ESRO-CR-164] p0030 W74-16154

Foldable boom systems study. Second phase: Definition and development
[ESRO-CR-211] p0030 W75-20461

MARTIN, C. H.

The potential application of carbon fibres to spacecraft
[p0047 A73-38811]

MARTIN, D. T.

Remote manipulator system steering capability for SVDS
[NASA-CR-151430] p0061 W77-26804

MARTINEZ DE LLANOS, E.

Foldable boom systems study. First phase: Initial studies
[ESRO-CR-164] p0030 W74-16154

Foldable boom systems study. Second phase: Definition and development
[ESRO-CR-211] p0030 W75-20461

MARTINS, N. J.

Electrons in the solar corona. II - Coronal streamers from Y-coronograph measurements
[p0068 A70-11519]

MASE, T.

Economics of ion propulsion for large space systems
[AIAA PAPER 78-698] p0066 A78-37541

MASON, R. J.

Collapsible reflector Patent

MATTIE, R. A.

Extendible space structures
[AD-707512] p0030 W75-15728

MATTIES, R. F.

Losses in a statistically irregular focusing fiber
[p0043 A76-43632]
BATHAN, N.  
Microwave power transmission system studies.  
Volume 3, section B: Mechanical systems and flight operations  

BATHAN, A.  
Learning to build large structures in space  
A near term space demonstration program for large structures  
[AAS 77-202]  p0072 A78-16698

BAUMABB, E. C.  
Manned remote work stations  
[AIAA PAPER 76-1667]  p0073 A78-51993

BAYBER, E.  
Structural and assembly concepts for large erectable space systems  
[AAS 77-205]  p0024 A78-36706

BAYBER, A.  
Continuum modeling of three-dimensional truss-like space structures  
p0009 A78-48901

WILSON, P. T.  
A strut with infinitely adjustable thermal expansivity and length  
p0031 W76-19177

NEUBURG, H. D.  
Thermally inert composite hardware applications for spacecraft  
p0049 A78-36430

THURNER, D.  
Application of optimal and adaptive algorithms to control the system robot-manipulator in cosmic space  
[AIAA 1977-ST-02]  p0056 A77-51567

HENDRIN, E. M.  
The books and mechanisms of Geos  
p0025 A78-45869

NG, S. P. F.  
A refined finite element analysis of folded plate structures.  
p0008 A73-39585

HOLL, R. E.  
Minimizing spacecraft structure-contol-system interaction.  
p0007 A69-25500

NODE, A. K.  
Continuum models for static and dynamic analysis of repetitive lattices  
[AIAA 77-411]  p0008 A77-25760

RHEE, D. A.  
Large area solar array Quarterly report - Phase 2, 1 Mar. - 31 May 1968  

Large area solar array, phase 2 Final report  

OKHOTIN, A. S.  
Some results of studies in space technology in the USSR  
p0055 A76-36475

OERKNER, G.  
Preliminary design of a composite structure for an Air Force space application  
[AD-A029014]  p0032 W77-17126

ORTega PEDES, R. A.  
Foldable boom systems study. Second phase: Definition and development  
[EESCO-CR-211]  p0030 W75-20461

ORTega PEDES, R. A.  
Foldable boom systems study. First phase: Initial studies  
[EESCO-CR-164]  p0030 W74-16154

PAPATONI, Z.  
On the active and passive CETI from earth satellite orbits  
[AIAA 1977-ST-02]  p0002 A77-51524

PARK, A. C.  
A digital computer program for the dynamic interaction simulation of controls and structure (DISCOS), volume 1  
[NASA-TP-1219-VOL-1]  p0014 W78-25123

PARK, J. J.  
An outgassing data compilation of spacecraft materials  
[AIAA 1977-ST-02]  p0072 A78-16698

PAYE, J. S.  
Attitude control of a spinning flexible spacecraft  
p0035 A74-33345

PATO, E. R.  
Transforming welded shells for space systems  
[AIAA PAPER 77-66]  p0023 A77-51518

PATTON, R. G.  
Learning to build large structures in space  
p0072 A78-16698

PENASARELLA, A.  
Foldable boom systems study. First phase: Initial studies  
[EESCO-CR-164]  p0030 W74-16154

PETROV, B. N.  
A highly reliable data handling and control system of a spacecraft power unit  
[AIAA PAPER 77-138]  p0044 A77-51541

PETROVA, L. V.  
Investigation of the physical-mechanical properties and supramolecular structure of epoxy resins exposed to UV radiation under atmospheric conditions  
p0047 A75-21365

PIELAND, R.  
Space power station - Space construction, transportation, and pre-development, space project requirements  
[AIAA 1977-ST-02]  p0023 A77-51415

PISZTWER, J.  
Multi-loop analysis of a precision pointing spacecraft with controlled flexible appendages  
[AIAA PAPER 76-1262]  p0036 A75-12572

PLASA, J.  
Inflatable support structure Patent  

POPOV, V.  
Construction and evaluation of a lightweight paraboloid antenna model  
[AIAA PAPER 71-397]  p0021 A72-25273

POPOV, V. F.  
Robot manipulators  
[NASA-TP-16462]  p0060 W75-29780

PORCELLI, G.  
Attitude control of flexible space vehicles.  
p0035 A72-32587

PORTER, B.  
Synthesis of active on-board controllers for vibratory systems with rigid body-modes  
p0040 W76-28324

POWELL, B. V.  
An entree for large space antennas  
[AIAA 78-500]  p0003 W78-32528

PREDMORE, R.  
Experimental thermal mechanics of deployable boom structures  
p0011 W72-25789

PREDMORE, R.  
Spoked wheels to deploy large surfaces in space  
[AIAA PAPER 74-1267]  p0025 A75-11108

AXI symmetric and cylindrical isostabiloids  

AXI symmetric filamentary structures  

Spoked wheels to deploy large surfaces in space-weight estimates for solar arrays  
[NASA-CR-2347]  p0030 W75-14631

PRITCHARD, K. L.  
STS users study (study 2.2). Volume 1: Executive summary  
[NASA-CR-188720]  p0078 W76-30262

STS users study (study 2.2). Volume 2: STS users plan (user data requirements) study  
[NASA-CR-188721]  p0074 W76-30263

PURI, R. W.  
Analysis and control of flexible structures  
p0035 A68-35236

RADAVY, E. W.  
Relative rating of 9' - 16' deployed diameter spaceborne antenna erecting techniques.
RAI, J.
Past experience - Basis for future advanced power systems for communications satellites
[IAP PAPR 77-22]
[5600 A4-1448]
[1210-0348]

RATH, B. N.,
Curved, tapered, circular cross section graphite/epoxy antenna ribs
[AIAA PAPER 68-436]
p0017 A68-25464

RATHORE, B. V.
Power supply systems in the multi-kW power range
[AIAA PAPER 77-224]
[5600 A77-51390]

REISENBACH, B. V.
Automatic assembly in space
[AIAA PAPER 78-32726]
p0035 A78-32726

REYNOLDS, B. M.
New closed tubular extendible boom
[AIAA PAPER 78-34142]
p0020 A78-34142

RICHARDS, R. D.
Integrated dynamic analysis of a space station with controllable solar arrays
[NASA-TM-1-78-68659]
p0011 W78-26850

RITTENHOUSE, E. Y.
Space Materials Handbook
[AIAA PAPER 1986-3051]
p0050 W70-21226

ROBINSON, J. Y.
Developments of a unique graphite/epoxy antenna subreflector
[AIAA PAPER 77-107]
p0021 A78-17204

RUFFINO, M.
Thermal design verification, qualification and acceptance testing concept for future large space objects
[K-84/85/PB/CHH]
p0014 W78-26273

RUBENSTEIN, J. P.
Orbital assembly and maintenance study
[NASA-CR-144422]
p0060 W75-32144

[Orbital assembly and maintenance study. Executive summary]

[NASA-CR-144488]
p0060 W75-32971

ROSS, A. G., Jr.
Analysis of performance characteristics and weight variations of large-area roll-up solar arrays
[AIAA-PAPER 68-68/16]
p0019 A70-18498

The development, design and test of a 66 W/ft
(30-40k) roll-up solar array
[NASA-CR-125998]
p0029 W72-32070

[RSUP: A computer program for the calculation of Roll-up Solar Array Performance characteristics]

[NASA-CR-135998]
p0012 W72-33003

ROSSI, M.
Optical digital control of large space structures
[AAS PAPER 78-105]
p0038 A78-64380

RUSSELL, F. C.
Assembly of large space structures
[AAS PAPER 78-052]
p0057 A78-53305

SABATIE, R.
An appreciation of the design of carbon fibre rigid solar panels for spacecraft.
[AIAA PAPER 77-108]
p0047 A78-34812

SAGE, E.
Orbital assembly and maintenance study
[NASA-CR-144422]
p0060 W75-32144

[Orbital assembly and maintenance study. Executive summary]

[NASA-CR-144488]
p0060 W75-32971

SCHNEIDER, W. C.
New themes for space: Mankind's future needs and aspirations; Proceedings of the Bicentennial Space Symposium, Washington, D.C., October 6-8, 1976
[581047 A78-34812

SCHNEIDER, E.
Thermal design verification, qualification and acceptance testing concept for future large space objects
[K-84/85/PB/CHH]
p0014 W78-26273

SCHNEIDER, J. P.
Orbital assembly and maintenance study
[NASA-CR-144422]
p0060 W75-32144

[Orbital assembly and maintenance study. Executive summary]

[NASA-CR-144488]
p0060 W75-32971

SCHUETT, J.
Large communication-satellite antennas
[AIAA PAPER 77-27020]
p0024 A78-27020

SCHUEIB, R.
An appreciation of the design of carbon fibre rigid solar panels for spacecraft.
[AIAA PAPER 77-108]
p0047 A78-34812
Control of large space structures via singular manipulator system man-machine interface

The dynamics and control of large flexible space structures. Part A: Discrete model and modal control

A high-reliable data handling and control system for the Earth orbital teleoperator manipulator system

Zero-G simulation and its relationship to space experiments

A manipulator system man-machine interface evaluation program

Earth orbital teleoperator manipulator system evaluation program

Earth orbital teleoperator visual system evaluation program

Earth orbital teleoperator mobility system evaluation program

Space electric rocket test solar array power system

Influence of stored angular momentum on the modal characteristics of spacecraft with flexible appendages

Searching for extraterrestrial life - The SETI gable

Selective structures and meshes for space applications

NASA contemplates radio Search for extra-terrestrial intelligence

Some results of studies in space technology in the USSR

A high-reliable data handling and control system of a spaceborne power unit

A statistical evaluation of a space stable optical support structure

An institutional plan for multipurpose space platforms

Teleoperator Spacecraft

Orbital assembly and maintenance study

Orbital assembly and maintenance study. Executive summary

Earth orbital teleoperator mobility system

Earth orbital teleoperator manipulator system

Space electric rocket test solar array power system

The dynamics and control of large flexible space structures. Part A: Discrete model and modal control

Attitude control of a spinning flexible spacecraft

Specifying spacecraft flexible appendage rigidity

Control of large space structures via singular perturbation optimal control

Influence of stored angular momentum on the modal characteristics of spacecraft with flexible appendages

Losses in a statistically irregular focusing fiber

Teleoperator spacecraft

NASA investigates radio Search for extra-terrestrial intelligence

X-reference frame bilateral control for the Shuttle Attached Manipulator System.
WAGNER, H.
Electromagnetic compatibility of ac power distribution
[NASA-CP(79)-792] p0045 N76-22304

WALKER, J. E.
Computerized structural sizing at NASA Langley Research Center
[AIAA PAPER 78-1550] p0010 A78-46513

WARD, J. W.
Economics of ion propulsion for large space systems
[AIAA PAPER 78-698] p0066 A78-37941

WARRECK, W. L.
Thermal stabilization of gravity gradient boom rods
[p0035 A76-42416

WARREN, R. E.
Use of extendable boom devices for space shuttle and MVA operations
[p0028 N70-39609

WEDDELL, J. B.
Self-powered electric propulsion of satellite power systems
[AIAA PAPER 78-694] p0066 A78-32765

WIEDEL, H. C.
Large area solar array, Quarterly report - Phase 2, 1 Ear.- 31 May 1968
[AIAA PAPER 78-9599] p0027 N68-31404

WIEGMANN, L. H.
Integrated dynamic analysis of a space station with controllable solar arrays
[AIAA PAPER 76-1246] p0011 N72-26850

WEINGARTEN, H.
Comparative systems study of magnetically suspended flywheels
[RMT-PB-W-76-20] p0041 N77-23166

WEISS, N. C.
Comparative systems study of magnetically suspended flywheels
[ESA-TT-393] p0047 N77-33245

WEINTHERH, K. D.
Unfurlable antennas
[p0027 N68-27933

WETRAN, H. W.
The BI-STER - A new technique in unfurlable structures
[p0020 A70-34141

WETRNER, R. E.
Collapsible reflector Patent
[NASA-CASE-KSS-03454] p0029 N71-20658

WHITAKER, C. D.
A space station Support system - Stability and rescue support capabilities
[(IAP PAPER A-77-28) p0056 A77-51518

WHITEHEAD, C. E., JR.
Maneuvering unit - A space platform support system
[AIAA PAPER 78-663] p0025 A78-51990

WIKAM, H.
Wire screen booms for gravity gradient and antenna application
[p0018 N68-18350

WILLES, W.
Gravity gradient boom and antenna material study
Final report
[NASA-CF-92680] p0049 N68-17090

WINTER, R. E.
A teleoperator system for space application
[p0053 A72-45174

WILD, E. C.
Remote manipulator dynamic simulation
[AIAA PAPER 76-11563] p0059 N72-24339

WILLIAMS, C. E.
SAS-C solar array development dynamics
[AD-A022713] p0031 N76-33714

WILLIAMS, C. J. B.
Mathematical methods in flexible spacecraft dynamics, volume 1
[ESS/S-576-VOI-1] p0013 N77-23188

WILLIAMS, C. J. B.
Mathematical methods in flexible spacecraft dynamics, volume 2
[ESS/S-576-VOI-2] p0013 N77-23189

WILLIAMS, R. B.
A new optimality criterion method for large scale structures
[AIAA PAPER 78-470] p0009 A78-29781

WILSON, W.
Conceptual approach study of a 200 watt per...
Typical Corporate Source Index Listing

CORPORATE SOURCE

BOEING AEROSPACE CO., HUNTSVILLE, ALA.
Simplified thermal estimation techniques for large space structures [NASA-CR-145253] p0013 N78-13105

A

ARC-AER LAB ENGINEERING CO., INC., GOLETA, CALIF.
Conceptual analyses of extensible booms to support a solar sail [NASA-CH-155615] p0032 N78-17124

ARC-TELEPOLIS, MUNCHEN, WEST GERMANY.
Power supply systems in the multi-kW power range [NASA-CH-145507] p0067 N76-14161

AEROSPACE CORP., EL SEGUNDO, CALIF.
Named systems utilization analysis. Study 2.1: Space servicing pilot program study [NASA-CR-142275] p0073 N75-23620


Study of the commonality of space vehicle applications to future national needs (unclassified portion) [JPL-TR-75(3765)-2] p0004 N76-23317

Advanced space program studies, overall executive summary [NASA-CR-148702] p0074 N76-30243


STS users study (study 2.2). Volume 2: STS users plan (user data requirements) study [NASA-CR-148721] p0074 N76-30263

AEROSPACE ENGINEERING OFFICE, ZURICH (SWITZERLAND).
Study of test methods for large flexible solar arrays [VELSA] [NASA-CR-151469] p0032 N77-27156

AIR FORCE SYSTEMS COMMAND, WRIGHT-PATTERSON AFB, OHIO.
Expandable and modular structures conference [AFAPL-TN-60-17] p0073 N66-27917


The requirements and role of EVA associated with orbital structures [NASA-CR-151468] p0062 N78-15158

ANALYTICAL AND COMPUTATIONAL MATHEMATICS, INC., HOUSTON, TEX.
An atmospheric density model for application in analytical satellite theories [NASA-CR-151605] p0075 N78-15136

A singularity free analytical solution of artificial satellite motion with drag [NASA-CR-151601] p0076 N78-15147


Analytical formulations of selected activities of the remote manipulator system [NASA-CR-151608] p0062 N78-15158

ANALYTICAL AND COMPUTATIONAL MATHEMATICS, ZURICH (SWITZERLAND).
An Analytical Satellite Orbit Predictor (ASOP) [NASA-CR-151603] p0075 N78-14066

APPLIED PHYSICS LAB., JOHNS HOPKINS UNIV., LAUREL, MD.
SAS-C solar array development dynamics [IAF PAPER 76-1711] p0065 N76-33714

APPLIED PHYSICS LAB., JOHNS HOPKINS UNIV., SILVER SPRING, MD.
Extendible space structures [NASA-AD-765142] p0030 N75-15728

ASTRO RESEARCH CORP., SANTA BARBARA, CALIF.
Investigation of a deployable lattice column [NASA-CH-13011] p0027 N69-26234

Heliohydro solar sailer Summary report [NASA-CH-13239] p0066 N70-28861


Axisymmetric filamentary structures [NASA-CR-15148] p0028 N70-27124

Spoked wheels to deploy large surfaces in space-weight estimates for solar arrays [NASA-CR-23474] p0030 N75-14831


BALLISTIC RESEARCH LABS., ABERDEEN PROVING GROUND, MD.
Analysis of transmission-line accelerator concepts [ARPA-TMP-855] p0076 N78-132849

BOEING AEROSPACE CO., HUNTSVILLE, ALA.
Simplified thermal estimation techniques for large space structures [NASA-CR-151463] p0013 N78-13105

BOEING AEROSPACE CO., KNIGHTS PIZZA, WASH.
The ubiquitous solar electric propulsion stage [IAP PAPER 76-171] p0065 N76-46136

BOEING AEROSPACE CO., SEATTLE, WASH.
Large space erectable structures - building block structures study [NASA-CR-151465] p0032 N77-27156

BOEING CO., SEATTLE, WASH.
Effects of space radiation on this polyurethane and
MARTIN MARIETTA AEROSPACE, DENVER, COLO.

Space Spider - A concept for fabrication of large structures
[AIAS PAPEB 78-1655] p0025 A78-51988
Orbital servicing of space platforms
[AIAS PAPEB 78-1659] p0025 A78-51986
Maneuvering unit - A space platform support system
[AIAS PAPEB 78-1663] p0025 A79-51990
Configuration and design of manipulator systems applicable to the free flying teleoperator. Volume 1: Executive summary
MARTIN MARIETTA CORP., BALTIMORE, MD.

Highlights of the long-life assurance study

MARTIN MARIETTA CORP., DENVER, COLO.

Attached manipulator system design and concept verification for zero-g simulation
[NASA-CR-1316] p0059 N73-27176
Variable ratio geared master-slave control system for shuttle remote manipulator system
[NASA-CASE-MSC-14245-1] p0060 N75-20741
Orbital assembly and maintenance study
[NASA-CR-14462] p0060 N75-31214
Orbital assembly and maintenance study
[NASA CR-14462] p0060 N75-32971
Simulation of man-machine interaction on shuttle payload manipulator
p0015 N75-33698
A manipulator arm for zero-g simulations
p0060 N76-19176
Proto-flight Manipulator Arm (P-FMA)
[NASA-CR-150277] p0061 N77-24768
Orbital construction support equipment
[NASA-CR-151660] p0061 N77-27157
The assembly of large structures in space
p0061 N77-29770
Structural attachments for large space structures. Task 1 report: Development of attachment concepts

MASSACHUSETTS INST. OF TECH., CAMBRIDGE.

Preliminary design of a composite structure for an Air Force space application [AD-A029014] p0032 N77-17126

MD ASSOCIATES, SAN RAMON, CALIF.

A shuttle and space station manipulator system for assembly, docking, maintenance, cargo handling and spacecraft retrieval (preliminary design).
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
[NASA-CR-115762-VOL-3-PT-1] p0058 N72-22887
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
A shuttle and space station manipulator system for assembly, docking, maintenance, cargo handling and spacecraft retrieval (preliminary design). Volume 4: Simulation studies

MC DONNELL-DOUGLAS ASTRONAUTICS CO., HUNTINGTON BEACH, CALIF.

Industry workshop on large space structures
Volume 1: Executive summary
[NASA-CR-2709] p0074 N76-31525
Information services platforms at geosynchronous earth orbit: A requirements analysis
MC DONNELL-DOUGLAS TECHNICAL SERVICES CO., INC., HOUSTON, TX.

Application of shuttle EVA systems to payloads
Volume 1: EVA systems and operational modes description
[NASA-CR-105721] p0061 N76-31265

Comparative systems study of magnetically suspended flywheels
[BMFT-FB-8-76-20] p0081 N77-23166

Study of deployable antennas for satellites
[NASA-CR-147732] p0050 N76-12233
Development planning for a lightweight deployable 12 GHz antenna
p0031 N76-12240
Electromagnetic compatibility of ac power distribution
p0045 W76-23204
K I N D E R S K Y RESE ARC INST., HAMPTON, VA.

The production of ultrathin polyester films for the solar sail program and Large Space Structures Technology (LST): A feasibility study

Compensator improvement with an application to a large space vehicle

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D. C.

Building large structures in space
p0071 N76-29321
Summary of problems of greatest urgency
p0072 N77-35625
Next steps in space transportation and operations
p0072 N78-16698
Switchboard in the sky
p0004 N78-37243
Teleoperators and human augmentation. An AEC-NASA technology survey
[NASA-SP-5057] p0057 N69-18670
Teleoperator control. An AEC-NASA technology survey
[NASA-SP-5070] p0057 N69-21478
Advancements in teleoperator systems. An AEC-NASA technology utilization publication
[NASA-SP-5081] p0058 N70-28670
The NASAcomputer manual
[NASA-SP-223] p0011 N70-34314
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.

Computerized structural sizing at NASA Langley

Wauuinu tail vibration absorber

Applications of composite materials in space MARSHALL SPACE PLIGET CEBTBR, EUBTSVILLE, ALA.

Variable ratio mixed-mode bilateral master-slave control system for shuttle remote manipulator system

Non-linear consideration of gravity in a structure interaction simulation of controls and technology panel, part 1

NASA Office of Aeronautics and Space Technology

Concept design of the payload handling apparatus Patent SEP solar array technology development

Folding apparatus Patent

An outgassing data compilation of spacecraft materials

An ongoing data compilation of spacecraft materials (NASAD-SP-101)- volume 1

A digital computer program for the dynamic stiffness test of a weak structure at small strains

Learning to build large structures in space

Manned maneuvering unit - A space platform support system

Shuttle remote manipulator system worksetation - Man-machine engineering

Space power stations - Space construction, transportation, and pre-development, space project requirements

Shuttle remote manipulator system safety and rescue support capabilities

Testing of deployable boom structures

NASA-TM-X-75247

Concept design of the payload handling

Manoeuvering unit - A space platform support system

Manoeuvering unit - A space platform support system

SHUTTLE AVIONICS SYSTEM

NASA-CASE-MSC-15247-1 p0033 N78-22146

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION.

NASA Office of Aeronautics and Space Technology

NASA Office of Aeronautics and Space Technology

NASA Office of Aeronautics and Space Technology

Structural efficiency of long lightly loaded truss and isogrid columns for space applications

Integrated dynamic analysis of a space station with controllable solar arrays

Integrated dynamic analysis of a space station with controllable solar arrays

A comparison of spacecraft penetration hazards due to meteoroids and manmade earth-orbiting objects

The advantages of the high voltage solar array for electric propulsion

Electron bombardment propulsion system characteristics for large space systems

The solid state remote power controller: Its status, use and perspective

Solid state remote power controllers for 120 VDC power systems

Economics of ion propulsion for large space systems

The ubiquitous solar electric propulsion stage

The ultimate explosion

The ubiquitous solar electric propulsion stage

Solid state remote power controllers for 120 VDC power systems

Economics of ion propulsion for large space systems

The advantages of the high voltage solar array for electric propulsion

Electron bombardment propulsion system characteristics for large space systems

The solid state remote power controller: Its status, use and perspective

Solid state remote power controllers for 120 VDC power systems

Economics of ion propulsion for large space systems

The advantages of the high voltage solar array for electric propulsion

Electron bombardment propulsion system characteristics for large space systems

The solid state remote power controller: Its status, use and perspective

Solid state remote power controllers for 120 VDC power systems

Economics of ion propulsion for large space systems

The advantages of the high voltage solar array for electric propulsion

Electron bombardment propulsion system characteristics for large space systems

The solid state remote power controller: Its status, use and perspective

Solid state remote power controllers for 120 VDC power systems
Integrating Shuttle payloads

Specifying spacecraft flexible appendage rigidity

[ AIAA 77-1960 ]

Sizing full-scale wing technology development

[ AIAA 77-2101 ]

Automated space fabrication of structural elements

[ AIAA 77-205 ]

Switchboard in the sky

[ AIAA 76-8660 ]

Solar electric propulsion and interorbital transportation

[ AIAA 76-36706 ]

Design concept of geostationary platform

[ AIAA 76-8198 ]

Large space structures at the Marshall Space Flight Center

[ AIAA 76-8198 ]

Space Spider - A concept for fabrication of large structures

[ AIAA 76-8198 ]

Orbital servicing of space platforms

[ AIAA 76-8198 ]

Large space structures assembly simulation

[ AIAA 76-8198 ]

Control system technology and tradeoffs for large space structures

[ AIAA 76-8198 ]

Space manufacturing machine Patent

[ AIAA 74-19773 ]

End effector device

[ AIAA -19660 ]

NATIONAL AEROSPACE LAB., ARBREDAM (NETHERSLANDS).

Handbook for the thermal modeling of space mechanisms by the nodal network method

[ NASA-CASE-CH-219 ]

OLD DOMINION UNIV., NORFOLK, VA.

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume 1: Data processing and transfer panel

[ NASA-TX-73926 ]

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume 2: Sensing and data acquisitions panel

[ NASA-TX-73926 ]

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume 3: Navigation, guidance, and control panel

[ NASA-TX-73926 ]

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume 4: Power technology panel

[ NASA-TX-73926 ]

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume 5: Propulsion technology panel, part 1

[ NASA-TX-73926 ]

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume 6: Structures and dynamics panel

[ NASA-TX-73926 ]

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume 7: Materials panel

[ NASA-TX-73926 ]

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume 8: Thermal control panel

[ NASA-TX-73926 ]

NASA Office of Aeronautics and Space Technology

Summer Workshop. Volume Executive summary

[ NASA-TX-73926 ]

PENNSYLVANIA STATE UNIV., UNIVERSITY PARK.

Control and stability problems of remote orbital capture

[ AIAA 77-8366 ]

Attitude control of synchronous satellites possessing flexible solar arrays using a double gimbaled momentum wheel

[ AIAA 76-28308 ]
CORPORATE SOURCE INDEX

STANFORD UNIV., CALIF.
A fine pointing control for a large spinning spacecraft in earth orbit
 p0042 A78-26162

SYSTEMS SCIENCE AND SOFTWARE, LA JOLLA, CALIF.
Spacecraft-generated plasma interaction with high voltage solar array
 (AIAA PAPER 78-673) p0084 A78-32751

TRW DEFENSE AND SPACE SYSTEMS GROUP, REDONDO BEACH, CALIF.
Multi-kW dc distribution system technology research study
 [NASA-CR-150789] p0046 A78-31353
Feasibility demonstration for electroplating ultra-thin polyimide films
 [NASA-CR-157775] p0051 A78-33266

TRW SYSTEMS GROUP, REDONDO BEACH, CALIF.
Multi-kW dc power distribution system study program
 [NASA-CR-120241] p0044 A78-29535
Research study on multi-kW DC distribution system
 [NASA-CR-143696] p0045 A75-27263
Research study on multi-kW DC distribution system
 [NASA-CR-144051] p0045 A76-13204
A strut with infinitely adjustable thermal expansivity and length
 p0031 A76-19177

UNITED KINGDOM ATOMIC ENERGY AUTHORITY, HABWELL (ENGLAND).
Study on the use of carbon fibre reinforced plastics in satellite structures, phase 1
 [RSD-TP-7427] p0050 A78-17297

VIRGINIA POLYTECHNIC INST. AND STATE UNIV., BLACKSBURG.
A Rayleigh-Ritz approach to the synthesis of large structures with rotating flexible components
 p0013 A77-10280

WESTINGHOUSE ELECTRIC CORP., LIMA, OHIO.
Solid state remote power controllers for 120 VDC power systems
 p0043 A76-31510

WIGGINS (J. H.) CO., REDONDO BEACH, CALIF.
Model verification of large structural systems
 [NASA-CR-150811] p0015 A78-31464
<table>
<thead>
<tr>
<th>Contract Number</th>
<th>Page Number</th>
<th>Accession Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1933-1917</td>
<td></td>
<td>177-15106</td>
</tr>
<tr>
<td>1933-1900</td>
<td></td>
<td>176-11421</td>
</tr>
<tr>
<td>1933-2010</td>
<td></td>
<td>176-37441</td>
</tr>
<tr>
<td>1933-2019</td>
<td></td>
<td>176-32751</td>
</tr>
<tr>
<td>1935-1597</td>
<td></td>
<td>169-18350</td>
</tr>
<tr>
<td>1935-10130</td>
<td></td>
<td>168-17090</td>
</tr>
<tr>
<td>1935-10130</td>
<td></td>
<td>175-34143</td>
</tr>
<tr>
<td>1935-10197</td>
<td></td>
<td>169-18350</td>
</tr>
<tr>
<td>1935-10135</td>
<td></td>
<td>168-17090</td>
</tr>
<tr>
<td>1935-10135</td>
<td></td>
<td>175-34143</td>
</tr>
<tr>
<td>1935-10197</td>
<td></td>
<td>169-18350</td>
</tr>
<tr>
<td>1935-10135</td>
<td></td>
<td>175-34143</td>
</tr>
</tbody>
</table>

Listings in this index are arranged alphabetically by contract number. Under each contract number, the accession numbers denoting documents that have been produced as a result of research done under that contract are arranged in ascending order with the LAA accession numbers appearing first. Preceding the accession number is the page number where the citation may be found.

AF 33/657/-9926
p0053 160-27476

ESA 32/34/44
p0083 174-32974

ESTEC-1234/74
p0021 176-22308

ESTEC-1234/74
p0039 176-27352

F04701-71-C-0021
p0017 173-14990

F04701-76-C-0087
p0062 170-25786

F04701-76-C-0087
p0036 175-12572

F36315-75-C-0265
p0032 177-17126

F36315-75-C-0265
p0032 177-17126

JPL-951834
p0027 166-31004

JPL-951834
p0027 166-31004

JPL-951834
p0031 176-26561

TECHNOLOGY FOR LARGE SPACE SYSTEMS/ A Special Bibliography

APRIL 1979
<table>
<thead>
<tr>
<th>Contract Number</th>
<th>Index Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSG-1185</td>
<td>p0040 N76-31272</td>
</tr>
<tr>
<td>NSG-1186</td>
<td>p0009 A78-44901</td>
</tr>
<tr>
<td>p0045 N77-13910</td>
<td></td>
</tr>
<tr>
<td>p0045 N77-13911</td>
<td></td>
</tr>
<tr>
<td>p0041 N77-13912</td>
<td></td>
</tr>
<tr>
<td>p0045 N77-13913</td>
<td></td>
</tr>
<tr>
<td>p0067 N77-13914</td>
<td></td>
</tr>
<tr>
<td>p0031 N77-13915</td>
<td></td>
</tr>
<tr>
<td>p0074 N77-13916</td>
<td></td>
</tr>
<tr>
<td>p0074 N77-13917</td>
<td></td>
</tr>
<tr>
<td>p0075 N77-13921</td>
<td></td>
</tr>
<tr>
<td>NSG-1414</td>
<td>p0010 A78-45682</td>
</tr>
<tr>
<td>p0012 N78-23139</td>
<td></td>
</tr>
<tr>
<td>p0014 N78-23140</td>
<td></td>
</tr>
<tr>
<td>NSG-7078</td>
<td>p0037 A77-43644</td>
</tr>
<tr>
<td>N00016-76-C-0064</td>
<td></td>
</tr>
<tr>
<td>p0009 A78-29781</td>
<td></td>
</tr>
<tr>
<td>N00017-72-C-4401</td>
<td></td>
</tr>
<tr>
<td>p0030 N75-15728</td>
<td></td>
</tr>
<tr>
<td>p0031 N76-33714</td>
<td></td>
</tr>
<tr>
<td>N00025-76-C-0011</td>
<td></td>
</tr>
<tr>
<td>p0046 N77-33422</td>
<td></td>
</tr>
<tr>
<td>SHI PROJ. PSU-7907</td>
<td></td>
</tr>
<tr>
<td>p0050 N73-19556</td>
<td></td>
</tr>
<tr>
<td>W-7405-PNO-40</td>
<td></td>
</tr>
<tr>
<td>p0041 N77-27537</td>
<td></td>
</tr>
<tr>
<td>506-16-36-07</td>
<td></td>
</tr>
<tr>
<td>p0013 N77-12119</td>
<td></td>
</tr>
<tr>
<td>506-17-26-01</td>
<td></td>
</tr>
<tr>
<td>p0031 N76-29358</td>
<td></td>
</tr>
<tr>
<td>506-17-31</td>
<td></td>
</tr>
<tr>
<td>p0014 N78-25123</td>
<td></td>
</tr>
<tr>
<td>750-01-23-04</td>
<td></td>
</tr>
<tr>
<td>p0014 N78-18117</td>
<td></td>
</tr>
<tr>
<td>Report/Accession Number Index</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>9ARD-77-8046</strong>..............</td>
<td>P0062 N78-25786 #</td>
</tr>
<tr>
<td><strong>SD-76-SA-0093-2-1</strong>.........</td>
<td>P0005 N77-31236##</td>
</tr>
<tr>
<td><strong>SME PAPER NR76-606</strong>........</td>
<td>P0056 N77-51017</td>
</tr>
<tr>
<td><strong>SPAR-R-554</strong>................</td>
<td>P0012 N74-17622 #</td>
</tr>
<tr>
<td><strong>TR-78-1300</strong>................</td>
<td>P0015 N78-31464##</td>
</tr>
<tr>
<td><strong>TRW-32053-6009-90-00</strong>.....</td>
<td>P0051 N78-33266##</td>
</tr>
<tr>
<td><strong>UCEL-52191</strong>................</td>
<td>P0041 N77-27537</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-9203........</td>
<td>P0028 N70-33180*</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-73422........</td>
<td>P0029 N72-25458*</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-99198........</td>
<td>P0030 N73-32749*</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-250331.......</td>
<td>P0034 N73-31988*</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-389916.......</td>
<td>P0060 N75-27041*</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-425363.......</td>
<td>P0029 N71-20658*</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-429365.......</td>
<td>P0029 N71-21085*</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-647298.......</td>
<td>P0028 N71-16102*</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-811401.......</td>
<td>P0032 N77-27432##</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-885061.......</td>
<td>P0062 N78-19773##</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-893383.......</td>
<td>P0033 N78-22146##</td>
</tr>
<tr>
<td>US-PATENT-APPL-SN-946991.......</td>
<td>P0033 N78-33466##</td>
</tr>
<tr>
<td>US-PATENT-CLASS-52-2...........</td>
<td>P0029 N71-21045*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-52-64...........</td>
<td>P0030 N73-32749*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-52-80...........</td>
<td>P0030 N73-32749*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-52-109..........</td>
<td>P0030 N73-32749*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-52-169..........</td>
<td>P0029 N72-25458*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-52-173..........</td>
<td>P0029 N72-25458*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-52-594..........</td>
<td>P0029 N72-25458*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-52-686..........</td>
<td>P0030 N73-32749*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-93-1............</td>
<td>P0028 N70-33180*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-214-1CM.........</td>
<td>P0060 N75-27041*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-284-1...........</td>
<td>P0029 N71-19214*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-287-92..........</td>
<td>P0030 N73-32749*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-307-29..........</td>
<td>P0044 N73-31988*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-307-38..........</td>
<td>P0044 N73-31988*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-334-915.........</td>
<td>P0028 N71-16102*</td>
</tr>
<tr>
<td>US-PATENT-CLASS-334-915.........</td>
<td>P0029 N71-20658*</td>
</tr>
<tr>
<td>US-PATENT-3,010,372.............</td>
<td>P0028 N70-33180*</td>
</tr>
<tr>
<td>US-PATENT-3,360,798.............</td>
<td>P0029 N71-20658*</td>
</tr>
<tr>
<td>US-PATENT-3,364,631.............</td>
<td>P0029 N71-21045*</td>
</tr>
<tr>
<td>US-PATENT-3,521,290.............</td>
<td>P0029 N71-16102*</td>
</tr>
<tr>
<td>US-PATENT-3,534,926.............</td>
<td>P0029 N71-19214*</td>
</tr>
<tr>
<td>US-PATENT-3,665,669.............</td>
<td>P0029 N72-25458*</td>
</tr>
<tr>
<td>US-PATENT-3,755,686.............</td>
<td>P0044 N73-31988*</td>
</tr>
<tr>
<td>US-PATENT-3,757,476.............</td>
<td>P0030 N73-32749*</td>
</tr>
<tr>
<td>US-PATENT-3,893,573.............</td>
<td>P0060 N75-27041*</td>
</tr>
<tr>
<td>WGRG-77-4764..................</td>
<td>P0067 N78-26158##</td>
</tr>
</tbody>
</table>
NASA SP-7046

4. Title and Subtitle  
TECHNOLOGY FOR LARGE SPACE SYSTEMS  
A Special Bibliography

5. Report Date  
April 1979

7. Author(s)  


9. Performing Organization Name and Address  
National Aeronautics and Space Administration  
Washington, D. C. 20546

10. Work Unit No.

12. Sponsoring Agency Name and Address

13. Type of Report and Period Covered

15. Supplementary Notes  

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))  
Folding Structures  
Orbital Space Stations  
Space Erectable Structures  
Spacecraft Structures

18. Distribution Statement  
Unclassified - Unlimited

19. Security Classif. (of this report)  
Unclassified

20. Security Classif. (of this page)  
Unclassified

21. No. of Pages  
168

22. Price  
$8.00 HC

*For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1979
PUBLIC COLLECTIONS OF NASA DOCUMENTS

DOMESTIC

NASA distributes its technical documents and bibliographic tools to eleven special libraries located in the organizations listed below. Each library is prepared to furnish the public such services as reference assistance, interlibrary loans, photocopy service, and assistance in obtaining copies of NASA documents for retention.

**CALIFORNIA**
University of California, Berkeley
**COLORADO**
University of Colorado, Boulder
**DISTRICT OF COLUMBIA**
Library of Congress
**GEORGIA**
Georgia Institute of Technology, Atlanta
**ILLINOIS**
The John Crerar Library, Chicago

**MASSACHUSETTS**
Massachusetts Institute of Technology, Cambridge
**MISSOURI**
Linda Hall Library, Kansas City
**NEW YORK**
Columbia University, New York
**OKLAHOMA**
University of Oklahoma, Bizzell Library
**PENNSYLVANIA**
Carnegie Library of Pittsburgh
**WASHINGTON**
University of Washington, Seattle

NASA publications (those indicated by an “*” following the accession number) are also received by the following public and free libraries:

**CALIFORNIA**
Los Angeles Public Library
San Diego Public Library
**COLORADO**
Denver Public Library
**CONNECTICUT**
Hartford Public Library
**MARYLAND**
Enoch Pratt Free Library, Baltimore
**MASSACHUSETTS**
Boston Public Library
**MICHIGAN**
Detroit Public Library
**MINNESOTA**
Minneapolis Public Library
**MISSOURI**
Kansas City Public Library
St. Louis Public Library
**NEW JERSEY**
Trenton Public Library
**NEW YORK**
Brooklyn Public Library
Buffalo and Erie County Public Library
Rochester Public Library
New York Public Library
**OHIO**
Akron Public Library
Cincinnati Public Library
Cleveland Public Library
Dayton Public Library
Toledo Public Library
**TENNESSEE**
Memphis Public Library
**TEXAS**
Dallas Public Library
Fort Worth Public Library
**WASHINGTON**
Seattle Public Library
**WISCONSIN**
Milwaukee Public Library

An extensive collection of NASA and NASA-sponsored documents and aerospace publications available to the public for reference purposes is maintained by the American Institute of Aeronautics and Astronautics, Technical Information Service, 750 Third Avenue, New York, New York 10017.

EUROPEAN

An extensive collection of NASA and NASA-sponsored publications is maintained by the British Library Lending Division, Boston Spa, Wetherby, Yorkshire, England. By virtue of arrangements other than with NASA, the British Library Lending Division also has available many of the non-NASA publications cited in STAR. European requesters may purchase facsimile copy of microfiche of NASA and NASA-sponsored documents, those identified by both the symbols “#” and “*”, from: ESA - Information Retrieval Service, European Space Agency, 8-10 rue Mario-Nikis, 75738 Paris CEDEX 15, France.