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Compiled by Joyce E. Turner
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FOREWORD

In accordance with the NASA Space Act of 1958, the MSFC has provided for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.

Since July 1, 1960, when the George C. Marshall Space Flight Center was organized, the reporting of scientific and engineering information has been considered a prime responsibility of the Center. Our credo has been that "research and development work is valuable, but only if its results can be communicated and made understandable to others."

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GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama

FY 1992 SCIENTIFIC AND TECHNICAL REPORTS, ARTICLES, PAPERS, AND PRESENTATIONS

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NASA Marshall Space Flight Center Solar Observatory Report—January to June 1991. J.E. Smith. Space Science Laboratory.
N92-14958

This report provides a description of the NASA Marshall Space Flight Center's Solar Vector Magnetograph Facility and gives a summary of its observations and data reduction during January–June 1991. The systems that make up the facility are a magnetograph telescope, an H-alpha telescope, a Questar telescope, and a computer code.

TM-103556 November 1991
Atmospheric Environment for Space Shuttle (STS-37) Launch. G.L. Jasper and G.W. Batts. Space Science Laboratory. N92-12375

This report presents a summary of selected atmospheric conditions observed near space shuttle STS-37 launch time on April 5, 1991, at Kennedy Space Center, FL. Values of ambient pressure, temperature, moisture, ground winds, visual observations (cloud), and winds aloft are included. The sequence of prelaunch Jimsphere-measured vertical wind profiles is given in this report. The final atmospheric tape, which consists of wind and thermodynamic parameters versus altitude, for STS-37 vehicle ascent has been constructed. The STS-37 ascent atmospheric data tape has been constructed by Marshall Space Flight Center's Earth Science and Applications Division to provide an internally consistent data set for use in postflight performance assessments and represents the best estimate of the launch environment to the 400,000-ft altitude that was traversed by the STS-37 vehicle.

TM-103557 December 1991
High-Frequency Data Observations From Space Shuttle Main Engine Low-Pressure Fuel Turbopump Discharge Duct Flex Joint Tripod Failure Investigation. T.F. Zoladz and R.A. Farr. Structures and Dynamics Laboratory.
N92-13279

This report summarizes observations made by MSFC Structures and Dynamics Laboratory engineers during their participation in the space shuttle main engine (SSME) low-pressure fuel turbopump discharge duct flex joint tripod failure investigation. New signal processing techniques used by the Component Assessment Branch and the Induced Environments Branch during the failure investigation are described in detail. Moreover, nonlinear correlations between frequently encountered anomalous frequencies found in SSME dynamic data are discussed. Finally, the report concludes by recommending the continuation of low-pressure fuel (LPF) duct testing through laboratory flow simulations and MSFC-managed technology test bed (TTB) SSME testing.

TM-103558 December 1991
Characterization of the Effect of Boron Content on Weld Cracking of Inconel 718 Type Alloys—Center Director's Discretionary Fund Final Report. R.G. Thompson, W.R. Gamwell, and T.W. Malone. Materials and Processes Laboratory. X92-10214

Alloy 718 type compositions were studied to characterize the effect of boron content on their weld HAZ cracking. Alloy compositions studied were a combined subset of specimens from General Electric and University of Alabama at Birmingham studies. Microcrack data were available for all specimens used in this study. Differential thermal analyses, Gleeble thermal analysis, scanning auger microscopy, and microstructural evaluations were performed on all alloy compositions to investigate intergranular liquid formation and segregation behavior effects of boron.

Four alloy 718 type compositions were cast within the MSFC Materials and Processes Laboratory. Varestraint (weldability) testing was performed in an attempt to quantify the effect of boron on their hot cracking susceptibility.

Boron was found to increase microfissuring behavior in alloy 718 type compositions by its potency as a Laves former and by the resultant long solidification range that Laves-forming alloys have. It was found that carbon in large concentrations in these type alloys can significantly alter their solidification behavior and completely reverse the effect of a Laves former like boron.

TM-103559 December 1991
The Effects of Multiple Repairs on Inconel 718 Weld Mechanical Properties. C.K. Russell, A.C. Nunes, Jr., and D. Moore. Materials and Processes Laboratory. N92-14380

Inconel 718 weldments were repaired 3, 6, 9, and 13 times using the gas tungsten arc welding process. The welded panels were machined into mechanical test specimens, postweld heat treated, and nondestructively inspected. Tensile properties

and high-cycle fatigue life were evaluated and the results compared to unrepaired weld properties. Mechanical property data were analyzed using the statistical methods of difference in means for tensile properties and difference in log means and Weibull analysis for high-cycle fatigue properties.

Statistical analysis performed on the data did not show a significant decrease in tensile or high-cycle fatigue properties due to the repeated repairs. Some degradation was observed in all properties; however, it was minimal.

TM-103560 June 1992

National Launch System Cycle 1 Loads and Models Data Book. F. Bugg, J. Brunty, G. Ernsberger, D. McGhee, L. Gagliano, F. Harrington, D. Meyer, and E. Blades. Structures and Dynamics Laboratory. N92-30215

This document contains preliminary cycle 1 loads for the National Launch System NLS 1 and NLS 2 vehicles. The loads provided and recommended as design loads represent the maximum loads expected during prelaunch and flight regimes, i.e., limit loads, except that propellant tank ullage pressure has not been included. Ullage pressure should be added to the loads book values for cases where the addition results in higher loads. The loads must be multiplied by the appropriate factors of safety to determine the ultimate loads for which the structure must be capable.

TM-103561 December 1991

No-Vent Fill Pressurization Tests Using a Cryogen Simulant. G.R. Schmidt, R.W. Carrigan, J.E. Hahs, D.A. Vaughan, and D.C. Foust. Propulsion Laboratory. N92-15354

This report describes the results of an experimental program which investigated the performance of various no-vent fill techniques for tank-to-tank liquid transfer. The tests were performed using a cryogen simulant (Freon-114) and a test-bed consisting of a multiple tank/plumbing network that enabled investigations of a variety of different inlet flow and active mixing regimes. Several results and conclusions were drawn from the 26 transfer experiments comprising the program. Most notable was the significant improvement in fill performance (i.e., minimized fill time and maximized fill fraction) with increased agitation of the liquid surface. Another was the close correlation between measured condensation rates and those predicted by recent theories which express condensation as a function of turbulent eddy effects on the liquid surface. In most cases, test data exhibited strong agreement with an analytical model which accounts for tank heat transfer and thermodynamics in a 1-g environment.

TM-103562 December 1991

Lunar Mission Aerobrake Performance Study. J. Mulqueen and D. Coughlin. Program Development Directorate and Systems Analysis and Integration Laboratory. N92-15079

Nine lunar mission scenarios were developed to show the transfer vehicle performance benefits of aerobraking into low-Earth orbit (LEO) upon Earth return as opposed to an all-propulsive maneuver. The initial mass in LEO (IMLEO) of the lunar transfer vehicle is considered the measure of vehicle performance. Four types of mission profiles in conjunction with two vehicle concepts were used to construct the scenarios. These nine scenarios were designed to represent a broad range of possible lunar missions so that a general knowledge base of aerobraking and lunar transfer vehicle performance levels could be obtained. Also discussed in this study are the mass sensitivities of each transfer vehicle to changes in the selected design parameters: ISP, crew module mass, payload to surface, and aerobrake mass fraction.

A parametric study was performed on two of the mission scenarios to help quantify the performance benefits by adding a set of drop tanks to the vehicle. The parametric study also provides partial derivatives which show the sensitivities of IMLEO to the four design parameters listed above. The last section of this report is a ranking of the mission scenarios based on vehicle performance.

The intent of this report is to present vehicle performance levels only. No consideration is given to the Earth-to-orbit vehicle, cost, or operational complexities such as rendezvous, aerobrake guidance, or contingencies.

TM-103563 December 1991

Differential Thermal Analysis of Lunar Soil Simulant. D. Tucker and A. Setzer. Materials and Processes Laboratory. N92-15951

Differential thermal analysis of lunar soil simulant known as "Minnesota Lunar Simulant-1" (MLS-1) was performed. The MLS-1 was tested in the as-received form, in glass form, and with additional silica. The silica addition was seen to depress nucleation events which leads to a better glass former.

TM-103564 January 1992

Space Station *Freedom* Environmental Control and Life Support System Phase III Water Recovery Test Stages 1A, 2A, and 3A Final Report. R.M. Bagdigian, D.L. Carter, D.W. Holder, C.F. McGriff, M.C. Roman, M.S. Traweek, and W.R. Williams. Structures and Dynamics Laboratory. X92-10218

A series of tests has been conducted at the NASA Marshall Space Flight Center (MSFC) to evaluate the performance of a predevelopment water recovery system. Potable, hygiene, and urine reclamation systems were integrated with end-use equipment items and successfully operated in open and partially closed-loop modes, with man-in-the-loop, for a total of 28 days. Several significant subsystem physical anomalies were encountered during testing. Reclaimed potable and hygiene water generally met the current Space Station *Freedom* (S.S. *Freedom*) water quality specifications for inorganic and microbiological constituents, but exceeded the maximum allowable concentrations for total organic carbon (TOC). This report summarizes the test objectives, system design, test activities/protocols, significant results/anomalies, and major lessons learned.

TM-103565 December 1991

Single Wall Penetration Equations. K.B. Hayashida and J.H. Robinson. Structures and Dynamics Laboratory. N92-16682

This report compares five single plate penetration equations for accuracy and effectiveness. These five equations are two well-known equations (Fish-Summers and Schmidt-Holsapple), two equations developed for the Apollo project (Rockwell and Johnson Space Center (JSC)), and one recently revised from JSC (Cour-Palais). They were derived from test results, with velocities ranging up to 8 km/s. Microsoft Excel software was used to construct a spreadsheet to calculate the diameters and masses of projectiles for various velocities, varying the material properties of both projectile and target for the five single plate penetration equations. The results were plotted on diameter versus velocity graphs for ballistic and spallation limits using Cricket Graph software, for velocities ranging from 2 to 15 km/s defined for the orbital debris. First, these equations were compared to each other, then each equation was compared with various aluminum projectile densities. Finally, these equations were compared with test results performed at JSC for the Marshall Space Flight Center. These equations predict a wide range of projectile diameters at a given velocity. Thus, it is very difficult to choose the "right" prediction equation. The thickness of the single plate could have a large variation by choosing a different penetration equation. Even though all five equations are empirically developed with various materials, and especially for aluminum alloys, one cannot be confident in the shield design with the predictions obtained by the penetration equations without verifying by tests.

TM-103566 April 1992

Space Science Laboratory Publications and Presentations January 1–December 31, 1991. Compiled by T.W. Moorehead. Space Science Laboratory. N92-25298

This document lists the significant publications and presentations of the Space Science Laboratory during the period January 1–December 31, 1991. Entries in the main part of the document are categorized according to NASA Reports (arranged by report number), Open Literature, and Presentations (arranged alphabetically by title). Also included for completeness is an appendix (arranged by report number) listing preprints issued by the Laboratory during this reporting period. Some of the preprints have not yet been published; those already published are so indicated. Most of the articles listed under Open Literature have appeared in refereed professional journals, books, or conference proceedings. Although many published abstracts are eventually expanded into full papers for publication in scientific and technical journals, they are often sufficiently comprehensive to include the significant results of the research reported. Therefore, published abstracts are listed separately in a subsection under Open Literature. Questions or requests for additional information about the entries in this report should be directed to Ms. T. Moorehead (ES01; 544-7581) or to one of the authors. The organizational code of the cognizant SSL branch or office is given at the end of each entry.

TM-103567 October 1991

FY 1991 Scientific and Technical Reports, Articles, Papers, and Presentations. Compiled by J.E. Turner. Management Operations Office. N92-17586

This document presents formal NASA technical reports, papers published in technical journals, and presentations by MSFC personnel in FY91. It also includes papers of MSFC contractors.

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The information in this report may be of value to the scientific and engineering community in determining what information has been published and what is available.

TM-103568 January 1992

Thermal Analysis Workbook. Edited by J.W. Owen. Structures and Dynamics Laboratory. N92-70379

This workbook is intended to allow the user to gain a better understanding of thermal analysis, problem-solving techniques, and interpretation of results. Many simple and complex engineering problems are presented and solved. These are solved using state-of-the-art thermal analysis codes, closed form solutions (which are used as "sanity checks" for the codes), and many different numerical techniques with explanations of the methods and assumptions used in solving the problems. Physical phenomena which are considered include conduction, convection, radiation, change of phase, compressible and incompressible flow, N-dimensional branching networks, conjugate thermal/hydraulic analysis, Joule-Thompson heating, analysis of gas mixture concentrations, venting, ablation, and related subjects. Some codes discussed include SINDA, TRASYS, ANSYS, PATRAN, and other job specific codes.

TM-103569 November 1991

BUGS System Clock Distributor. T.M. Dietrich. Space Science Laboratory. N92-20371

A printed circuit board which will provide external clocks and precisely measure the time at which events take place has been designed for the Bristol University Gas Spectrometer (BUGS). The board, which has been designed to interface both mechanically and electrically to the CAMAC system, has been named the BUGS system clock board. This document describes the board's design and how to use it.

TM-103570 January 1992

SUNSPOT—A Program to Model the Behavior of Hypervelocity Impact Damaged Multilayer Insulation in the Sunspot Thermal Vacuum Chamber of Marshall Space Flight Center. W.K. Rule and K.B. Hayashida. Structures and Dynamics Laboratory. N92-18383

This report describes the development of a computer program to predict the degradation of the insulating capabilities of the multilayer insulation (MLI) blanket of Space Station *Freedom* due to a hypervelocity impact with a space debris particle. A finite difference scheme is used for the calculations. The computer program was written in Microsoft BASIC. This report also describes a test program that was undertaken to validate the numerical model. Twelve MLI specimens were impacted at hypervelocities with simulated debris particles using a light gas gun at Marshall Space Flight Center. The impact-damaged MLI specimens were then tested for insulating capability in the space environment of the Sunspot thermal vacuum chamber at MSFC. Two undamaged MLI specimens were also tested for comparison with the test results of the damaged specimens. The numerical model was found to adequately predict the behavior of the MLI specimens in the Sunspot chamber. A parameter, called diameter ratio, was developed to relate the nominal MLI impact damage to the apparent (for thermal analysis purposes) impact damage based on the hypervelocity impact conditions of a specimen.

TM-103571 January 1992

Optical Synthesizer for a Large Quadrant-Array CCD Camera—Center Director's Discretionary Fund Final Report (Project Number 90-11). M.J. Hagyard. Space Science Laboratory. N92-19001

This document constitutes the final report for MSFC Center Director's Discretionary Fund Project Number 90-11. The objective of this program was to design and develop an optical device, an optical synthesizer, that focuses four contiguous quadrants of a solar image on four spatially separated CCD arrays that are part of a unique CCD camera system. This camera and the optical synthesizer will be part of the new MSFC Experimental Vector Magnetograph, an instrument developed to measure the Sun's magnetic field as accurately as present technology allows. This report outlines the tasks undertaken in the program and presents the final detailed optical design.

TM-103572 January 1992

Space Transportation Architecture: Reliability Sensitivities. A.M. Williams. Preliminary Design Office. N92-19542

This report is a sensitivity analysis of the benefits and drawbacks associated with a proposed Earth-to-orbit vehicle architecture. The architecture represents a fleet of six vehicles (two existing, four proposed) that would be responsible for performing various missions as mandated by NASA and USAF. Each vehicle has a prescribed flight rate per year for a period of 31 years.

By exposing this fleet of vehicles to a probabilistic environment where the fleet experiences failures, downtimes, setbacks, etc., the analysis involves determining the resiliency and costs associated with the fleet of specific vehicle/subsystem reliabilities.

The resources required were actual observed data on the failures and downtimes associated with existing vehicles, data based on engineering judgment for proposed vehicles, and the development of a sensitivity analysis program.

TM-103573 February 1992

A Real-Time Recursive Filter for the Attitude Determination of the Spacelab Instrument Pointing Subsystem. M.E. West. Structures and Dynamics Laboratory. N92-19920

A real-time estimation filter which reduces sensitivity to system variations and reduces the amount of preflight computation is developed for the instrument pointing subsystem (IPS). The IPS is a three-axis stabilized platform developed to point various astronomical observation instruments aboard the shuttle. Currently, the IPS utilizes a linearized Kalman filter (LKF), with premission defined gains, to compensate for system drifts and accumulated attitude errors. Since the a priori gains are generated for an expected system, variations result in a suboptimal estimation process.

This report compares the performance of three real-time estimation filters with current LKF implementation. An extended Kalman filter and a second-order Kalman filter are developed to account for the system nonlinearities, while a linear Kalman filter implementation assumes that the nonlinearities are negligible. The performance of each of the four estimation filters are compared with respect to accuracy, stability, settling time, robustness, and computational requirements. It is shown that, for the current IPS pointing requirements, the linear Kalman filter provides improved robustness over the LKF with less computational requirements than the two real-time nonlinear estimation filters.

TM-103574 January 1992

Atmospheric Environment for Space Shuttle *Atlantis* (STS-39) Launch. G.L. Jasper and G.W. Batts. Space Science Laboratory. N92-20411

This report presents a summary of selected atmospheric conditions observed near space shuttle *Atlantis* STS-39 launch time on April 28, 1991, at Kennedy Space Center, FL. Values of ambient pressure, temperature, moisture, ground winds, visual observations (cloud), and winds aloft are included. The sequence of prelaunch Jimsphere-measured vertical wind profiles is given in this report. The final atmospheric tape, which consists of wind and thermodynamic parameters versus altitude, for STS-39 vehicle ascent has been constructed. The STS-39 ascent atmospheric data tape has been constructed by Marshall Space Flight Center's Earth Science and Applications Division to provide an internally consistent data set for use in postflight performance assessments and represents the best estimate of the launch environment to the 400,000-ft altitude that was traversed by the STS-39 vehicle.

TM-103575 January 1992

Space Transportation System and Associated Payloads: Glossary, Acronyms, and Abbreviations. Compiled by Management Operations Office and Space Shuttle Projects Office. N92-22108

This is a collection of some of the acronyms and abbreviations now in everyday use in the shuttle world. It is a combination of lists that have been prepared at Marshall Space Flight Center and Kennedy and Johnson Space Centers, places where intensive shuttle activities are being carried out. This list is intended as a guide or reference and should not be considered to have the status and sanction of a dictionary.

TM-103576 February 1992

Space Station *Freedom* Delta Pressure Leakage Rate Comparison Test Data Analysis Report. E.B. Sorensen. Propulsion Laboratory. N92-22032

This report provides results of a series of tests performed to identify the relationship between gas leakage rates across a seal at various internal to external pressure ratios. This report is intended to complement the results and provide insight into the analysis technique used to obtain the results

presented in MSFC SSF/DEV/EL91-008, "Space Station *Freedom* (S.S. *Freedom*) Seal Flaw Study With Delta Pressure Leak Rate Comparison Test Report."

TM-103577 March 1992

NASA Marshall Space Flight Center Solar Observatory Report—July–December 1991. J.E. Smith. Space Science Laboratory. N92-22387

This report provides a description of the NASA Marshall Space Flight Center's Solar Vector Magnetograph Facility and gives a summary of its observations and data reduction during July–December 1991. The systems that make up the facility are a magnetograph telescope, an H-alpha telescope, a Questar telescope, and a computer code.

TM-103578 April 1992

High-Altitude Solar-Powered Platform. M.D. Bailey and M.V. Bower. Structures and Dynamics Laboratory. N92-21546

Solar power is a preeminent alternative to conventional aircraft propulsion. Previously, relatively small solar-powered aircraft with limited usefulness have flown for short durations. With continued advances in solar cells, fuel cells, and composite materials technology, the solar-powered airplane is no longer a simple curiosity constrained to flights of several feet in altitude or minutes of duration.

A high-altitude solar-powered platform (HASPP) has several potential missions, including communications and agriculture. In remote areas, a HASPP could be used as a communications link. In large farming areas, a HASPP could perform remote sensing of crops.

The impact of a HASPP in continuous flight for 1 year on an agriculture monitoring mission is presented. This mission provides farmers with near real-time data twice daily from an altitude which allows excellent resolution on water conditions, crop diseases, and insect infestation. Accurate, timely data will enable farmers to increase their yield and efficiency.

A design for a HASPP for the foregoing mission is presented. In the design, power derived from solar cells covering the wings is used for propulsion, avionics, and sensors. Excess power produced mid-day will be stored in fuel cells for use at night to maintain altitude and course.

TM-103579 April 1992

Microbial Biofilm Studies of the Environmental Control and Life Support System Water Recovery Test for Space Station *Freedom*. D.C. Obenhuber, T.L. Huff, and E.B. Rodgers. Materials and Processes Laboratory. N92-22283

NASA is developing a water recovery system (WRS) for Space Station *Freedom* to reclaim human waste water for reuse by astronauts as hygiene or potable water. A water recovery test (WRT) currently in progress investigates the performance of a prototype of the WRS. Analysis of biofilm accumulation, the potential for microbially influenced corrosion (MIC) in the WRT, and studies of iodine disinfection of biofilm are reported.

Analysis of WRT components indicated the presence of organic deposits and biofilms in selected tubing. Water samples for the WRT contained acid-producing and sulfate-reducing organisms implicated in corrosion processes. Corrosion of an aluminum alloy was accelerated in the presence of these water samples; however, stainless steel corrosion rates were not accelerated.

Biofilm iodine sensitivity tests using an experimental laboratory-scale recycled water system containing a microbial check valve (MCV) demonstrated that an iodine concentration of 1 to 2 mg/L was ineffective in eliminating microbial biofilm. For complete disinfection, an initial concentration of 16 mg/L was required which was gradually reduced by the MCV over 4 to 8 hours to 1 to 2 mg/L. This treatment may be useful in controlling biofilm formation.

TM-103580 March 1992

Testing and Analyses of Electrochemical Cells Using Frequency Response—Center Director's Discretionary Fund Final Report, Project No. 90-18. O.A. Norton, Jr. and D.L. Thomas. Information and Electronic Systems Laboratory. N92-23437

The feasibility of electrochemical impedance spectroscopy as a method for analyzing battery state of health and state of charge was investigated. Porous silver, zinc, nickel, and cadmium electrodes as well as silver/zinc cells were studied. State of charge could be correlated with impedance data for all but the nickel electrodes. State of health was correlated with impedance data for two silver/zinc cells, one apparently good and the other dead. The experimental data were fit to equivalent circuit models.

TM-103581 May 1992
Coupled Loads Analysis for Space Shuttle Payloads. J. Eldridge. Structures and Dynamics Laboratory. N92-24708

This report describes a method for determining the transient response of, and the resultant loads in, a system exposed to predicted external forces. In this case, the system consists of four racks mounted on the inside of a space station resource node module (SSRNMO) which is mounted in the payload bay of the space shuttle. The predicted external forces are forcing functions which envelop worst case forces applied to the shuttle during lift-off and landing. This analysis, called a coupled loads analysis, is used to; (a) couple the payload and shuttle models together, (b) determine the transient response of the system; and then (c) recover payload loads, payload accelerations, and payload to shuttle interface forces.

TM-103582 April 1992
Performance of Thermal Control Tape in the Protection of Composite Materials to Space Environmental Exposure. R.R. Kamenetzky and A.F. Whitaker. Materials and Processes Laboratory. N92-24982

Thermal control tape flown on the long duration exposure facility (LDEF) experiment AO171 has shown to be effective in protecting epoxy fiberglass composites from atomic oxygen and ultraviolet (UV) degradation. The tape adhesive performed well. The aluminum, however, appeared to have become embrittled by the 5.8 years of space exposure.

TM-103583 June 1992
Report for Neutral Buoyancy Simulations of Transfer Orbit Stage Contingency Extravehicular Activities. J.D. Sexton. Mission Operations Laboratory. N92-26268

The transfer orbit stage (TOS) will propel the advanced communications technology satellite (ACTS) from the space shuttle to an Earth geosynchronous transfer orbit. Two neutral buoyancy test series were conducted at MSFC to validate the extravehicular activities (EVA) contingency operations for the ACTS/TOS mission. This report delineates the results of the neutral buoyancy tests and gives a brief history of the TOS EVA program. Test numbers are: NBS–TOS–90.1 and NBS–TOS–91.1.

TM-103584 June 1992
Microbiology Report for Phase III Stage A Water Recovery Test. M.C. Roman and S.A. Minton. Structures and Dynamics Laboratory. X92-10382

The Environmental Control and Life Support System (ECLSS) test program at NASA/Marshall Space Flight Center (MSFC) developed a physical/chemical treatment system to reclaim wastewater for reuse aboard Space Station *Freedom* (S.S. *Freedom*). This report provides microbiological data gathered during phase III testing of the water recovery test (WRT) which was conducted from May through July, 1990. Phase III testing was conducted in the Core Module Integration Facility (CMIF) located in building 4755 at MSFC. The CMIF included a core module simulator (CMS) containing separate potable and hygiene water reclamation hardware integrated with the End-Use Equipment Facility (EEF) which included exercise equipment, shower, handwasher, clotheswasher, and dishwasher. With the participation of human test subjects, wastewater and metabolic condensate were produced.

TM-103585 June 1992
Atmospheric Environment for Space Shuttle *Columbia* (STS-40) Launch. G.L. Jasper and G.W. Batts. Space Science Laboratory. N92-26288

This report presents a summary of selected atmospheric conditions observed near Space Shuttle *Columbia* (STS-40) launch time on June 5, 1991, at Kennedy Space Center, Florida. Values of ambient pressure, temperature, moisture, ground winds, visual observations (cloud), and winds aloft are included. The sequence of prelaunch Jimsphere-measured vertical wind profiles is given in this report. The final atmospheric tape, which consists of wind and thermodynamic parameters versus altitude, for STS-40 vehicle ascent has been constructed. The STS-40 ascent atmospheric data tape has been constructed by Marshall Space Flight Center's Earth Science and Applications Division to provide an internally consistent data set for use in postflight performance assessments and represents the best estimate of the launch environment to the 400,000-ft altitude that was traversed by the STS-40 vehicle.

TM-103586 May 1992

Taguchi Methods in Electronics—A Case Study. R. Kissel. Information and Electronic Systems Laboratory. N92-28456

A pilot project in Taguchi methods was completed using actual electronic hardware. The primary purpose was to familiarize engineers and managers with the theory and mechanics of doing a Taguchi experiment. The hardware selected was the National Launch System (NLS) electromechanical actuator (EMA) control electronics. This is a 25-kW motor controller. Actual preparation and test time was 3 to 4 weeks. Results were quite good since the predicted optimum set of component values also had the highest measured signal-to-noise ratio (S/N).

TM-103587 June 1992

Assessment of a Head-Mounted Miniature Monitor—Center Director's Discretionary Fund Final Report (Project Number 89-07). J.P. Hale II. Mission Operations Laboratory. N92-30381

Two experiments were conducted to assess the capabilities and limitations of the Private Eye, a miniature, head-mounted monitor. The first experiment compared the Private Eye with a CRT and hard copy in both a constrained and unconstrained work envelope. The task was a simulated maintenance and assembly task that required frequent reference to the displayed information. A main effect of presentation media indicated faster placement times using the CRT as compared with hard copy. There were no significant differences between the Private Eye and either the CRT or hard copy for identification, placement, or total task times. The goal of the second experiment was to determine the effects of various local visual parameters on the ability of the user to accurately perceive the information of the Private Eye. The task was an interactive video game. No significant performance differences were found under either bright or dark ambient illumination environments nor with either visually simple or complex task backgrounds. Glare reflected off of the bezel surrounding the monitor did degrade performance. It was concluded that this head-mounted, miniature monitor could serve a useful role for in situ operations, especially in microgravity environments.

TM-103588 June 1992

Anthropomorphic Teleoperation: Controlling Remote Manipulators With the DataGlove—Center Director's Discretionary Fund Final Report (Project Number 89-06). J.P. Hale II. Mission Operations Laboratory. N92-28521

A two-phase effort was conducted to assess the capabilities and limitations of the DataGlove, a lightweight glove input device that can output signals in real-time based on hand shape, orientation, and movement. The first phase was a period for system integration, checkout, and familiarization in a virtual environment. The second phase was a formal experiment using the DataGlove as an input device to control the protoflight manipulator arm (PFMA)—a large telerobotic arm with an 8-ft reach. The first phase was used to explore and understand how the DataGlove functions in a virtual environment, build a virtual PFMA, and consider and select a reasonable teleoperation control methodology. Twelve volunteers (six males and six females) participated in a 2×3 (× 2) full-factorial formal experiment using the DataGlove to control the PFMA in a simple retraction, slewing, and insertion task. Two within-subjects variables, time delay (0, 1, and 2 seconds) and PFMA wrist flexibility (rigid/flexible), were manipulated. Gender served as a blocking variable. A main effect of time delay was found for slewing and total task times. Correlations among questionnaire responses, and between questionnaire responses and session mean scores and gender, were computed. The experimental data were also compared with data collected in another study that used a six degree-of-freedom hand controller to control the PFMA in the same task. It was concluded that the DataGlove is a legitimate teleoperations input device that provides a natural, intuitive user interface. From an operational point of view, it compares favorably with other "standard" telerobotic input devices and should be considered in future trades in teleoperation systems' designs.

TM-103589 May 1992

The Effect of Induced Charges on Low-Energy Particle Trajectories Near Conducting and Semiconducting Plates. V.N. Coffey. Space Science Laboratory. N92-28986

The effect of the induced charge was found on particles less than 1 eV as they passed through simulated parallel, grounded channels that are comparable in dimension to those that are presently in space plasma instruments which measure the flux of low-energy ions. Applications were made to both conducting and semiconducting channels that ranged in length from 0.1 to 50 mm and in aspect ratio from 1 to 100. The effect of the induced charge on particle

trajectories is illustrated, and results are given for the reduction of the channel geometric factor as a function of particle energy due to the deviation of trajectories from simple straight lines. Several configurations of channel aspect ratio and detector locations are considered. The effect is important only at very low energies with small dimensions.

TM-103590 July 1992

A Generalized Reusable Guidance Algorithm for Optimal Aerobraking. G.A. Dukeman. Systems Analysis and Integration Laboratory. N92-28981

A practical real-time guidance algorithm has been developed for guiding aerobraking vehicles in such a way that the maximum heating rate, the maximum structural loads, and the post-aeropass delta-V requirement (for post-aeropass orbit insertion) are all minimized. The algorithm is general and reusable in the sense that a minimum of assumptions are made, thus minimizing the number of gains and mission-dependent parameters that must be laboriously determined prior to a particular mission. A particularly interesting feature is that inplane guidance performance is tuned by simply adjusting one mission-dependent parameter, the bank margin; similarly, the out-of-plane guidance performance is tuned by simply adjusting a plane controller time constant. Other objectives in the algorithm development are simplicity, efficiency, and ease of use. The algorithm is developed for, but not necessarily restricted to, a single pass mission and a trimmed vehicle with bank angle modulation as the method of trajectory control. Guidance performance is demonstrated via results obtained using this algorithm integrated into an aerobraking test-bed program. Comparisons are made with numerical results from a version of the aerobraking guidance algorithm that was to be flown onboard NASA's aeroassist flight experiment (AFE) vehicle. Promising results are obtained with a minimum of development effort.

TM-103591 July 1992

Linear Elastic Fracture Mechanics Primer. C.D. Wilson. Structures and Dynamics Laboratory. N92-30416

This primer is intended to remove the "blackbox" perception of fracture mechanics computer software by structural engineers. The fundamental concepts of linear elastic fracture mechanics are presented with emphasis on the practical application of fracture mechanics to real problems. Numerous "rules of thumb" are provided. Recommended texts for additional reading, and a discussion of the significance of fracture mechanics in structural design, are given. Griffith's criterion for crack extension, Irwin's elastic stress field near the crack tip, and the influence of small-scale plasticity are discussed. Common stress intensity factor solutions and methods for determining them are included. Fracture toughness and subcritical crack growth are discussed. The application of fracture mechanics to damage tolerance and fracture control is discussed. Several example problems and a practice set of problems are given.

TM-103592 July 1992

Comparison of Epifluorescent Viable Bacterial Count Methods. E.B. Rodgers and T.L. Huff. Materials and Processes Laboratory. N92-30305

Two methods, the 2-(4-Iodophenyl)-3-(4-nitrophenyl)-5-phenyltetrazolium chloride (INT) method and the direct viable count method (DVC), were tested and compared for their efficacy for the determination of the viability of bacterial populations. Use of the INT method results in the formation of a dark spot within each respiring cell. The DVC method results in elongation or swelling of growing cells that are rendered incapable of cell division. Although both methods are subjective and can result in false positive results, the DVC method is best suited to analysis of waters in which the number of different types of organisms present in the sample is assumed to be small, such as processed waters. The advantages and disadvantages of each method are discussed.

TM-103593 July 1992

Analysis of Debris From Spacelab Space Life Sciences-1. S.V. Caruso, E.B. Rodgers, and T.L. Huff. Materials and Processes Laboratory. N92-32148

Airborne microbiological and particulate contamination generated aboard Spacelab modules is a potential safety hazard. In order to shed light on the characteristics of these contaminants, microbial and chemical/particulate analyses were performed on debris vacuumed from cabin and avionics air filters in the Space Life Sciences-1 (SLS-1) module of the Space Transportation System 40 (STS-40) mission 1 month after landing. The debris was sorted into categories (e.g., metal, nonmetal, hair/fur, synthetic fibers, food particles, insect fragments, etc.). Elemental analysis of particles was done by energy dispersive analysis of x rays (metals) and Fourier

transform infrared spectroscopy (nonmetals). Scanning electron micrographs were done of most particles. Microbiological samples were grown on R2A culture medium and identified. Clothing fibers dominated the debris by volume. Other particles, all attributed to the crew, resulted from abrasions and impacts during mission operations (e.g., paint chips, plastic, electronic scraps, clothing fibers). All bacterial species identified are commonly found in the atmosphere or on the human body. *Bacillus* sp. was the most frequently seen bacterium. One of the bacterial species, *Enterobacter agglomerans*, could cause illness in crew members with depressed immune systems.

TM-103594 July 1992

A Reduced Gravity Fiber Pulling Apparatus. D.S. Tucker. Materials and Processes Laboratory. N92-30971

A reduced gravity fiber pulling apparatus (FPA) has been constructed in order to study the effects of gravity on glass fiber formation. The apparatus was specifically designed and built for use on NASA's KC-135 aircraft. Four flights have been completed to date during which E-glass fiber was successfully produced in simulated lunar gravity.

TM-103595 August 1992

A Study of Enhancing Critical Current Densities (J_c) and Critical Temperature (T_c) of High-Temperature Superconductors—Center Director's Discretionary Fund Final Report (Project 90-N26). M. Vlasse, Space Science Laboratory. N92-30902

The development of pure phase 123 and Bi-based 2223 superconductors has been optimized. The preheat processing appears to be a very important parameter in achieving optimal physical properties. The synthesis of pure phases in the Bi-based system involves effects due to oxygen partial pressure, time, and temperature. Orientation/melt-sintering effects include the extreme c-axis orientation of Yttrium 123 and the Bismuth 2223, 2212, and 2201 phases. This orientation is conducive to increasing critical currents. A procedure was established to substitute Sr for Ba in Y-123 single crystals.

TM-103596 July 1992

Wear Mechanisms Found in Angular Contact Ball Bearings of the SSME's Lox Turbopumps. T.J. Chase. Propulsion Laboratory.

Extensive experimental investigation has been carried out on used flight bearings of the phase II high-pressure oxygen turbopump (HPOTP) of the space shuttle main engine (SSME) in order to determine the wear mechanisms, dominant wear modes, and their extent and causes. The report shows methodology, surface analysis techniques used, results, and discussion. The mode largely responsible for heavy bearing wear in lox has been identified as adhesive/shear peeling of the upper layers of bearing balls and rings. The mode relies on the mechanisms of scale formation, breakdown, and removal, all of which are greatly enhanced by the heavy oxidation environment of the HPOTP. Major causes of the high wear in bearings appear to be lubrication and cooling, both inadequate for the imposed conditions of operation. Numerous illustrations and evidence are given.

TM-103597 August 1992

NASA Marshall Space Flight Center Solar Observatory Report—January–June 1992. J.E. Smith. Space Science Laboratory. N92-32478

This report provides a description of the NASA Marshall Space Flight Center's Solar Vector Magnetograph Facility and gives a summary of its observations and data reduction during January–June 1992. The systems that make up the facility are a magnetograph telescope, an H-alpha telescope, a Questar telescope, and a computer code.

TM-103598 August 1992

Development of Static System Procedures to Study Aquatic Biofilms and Their Responses to Disinfection and Invading Species. G.A. Smithers. Materials and Processes Laboratory.

The microbial ecology facility in the Analytical and Physical Chemistry Branch at Marshall Space Flight Center is tasked with anticipation of potential microbial problems (and opportunities to exploit microorganisms) which may occur in partially closed systems such as space stations/vehicles/habitats and in water reclamation systems therein, with particular emphasis on the degradation of materials. Within this context, procedures for microbial biofilm research are being developed. Reported here is the development of static system procedures to study aquatic biofilms and their responses to disinfection and invading species. Preliminary investigations have been completed. As procedures are refined, it will be possible to focus

more closely on the elucidation of biofilm phenomena.

TM-103600 August 1992
Fabrication of High T_c Superconductor Thin Film Devices—Center Director's Discretionary Fund Final Report (Project No. P17). R.C. Sisk. Space Science Laboratory.

This report describes a technique for fabricating superconducting weak link devices with micron-sized geometries etched in laser ablated $Y_1Ba_2Cu_3O_x$ (YBCO) thin films. Careful placement of the weak link over naturally occurring grain boundaries exhibited in some YBCO thin films produces Superconducting Quantum Interference Devices (SQUID's) operating at 77 K.

TM-103601 August 1992
A Comparison of High Cycle Fatigue Methodologies. D.A. Herda. Structures and Dynamics Laboratory.

To evaluate alternate turbopump development (ATD) high cycle fatigue (HCF) methodology, a comparison was made with the space shuttle main engine (SSME) methodology. This report documents the comparison and evaluates ATD's HCF system.

TM-103602 September 1992
The Effect of Weld Porosity on the Cryogenic Fatigue Strength of ELI Grade Ti-5Al-2.5Sn. P.R. Rogers, R.C. Lambdin, and D.E. Fox. Materials and Processes Laboratory.

The effect of weld porosity on the fatigue strength of ELI grade Ti-5Al-2.5Sn at cryogenic temperature was determined. A series of high cycle fatigue (HCF) and tensile tests were performed at −320 °F on specimens made from welded sheets of the material. All specimens were tested with weld beads intact and some amount of weld offset. Specimens containing porosity and control specimens containing no porosity were tested. Results indicate that for the weld configuration tested, the fatigue life of the material is not affected by the presence of spherical embedded pores.

TM-103603 September 1992
Atmospheric Environment for Space Shuttle *Atlantis* (STS-43) Launch. G.L. Jasper and G.W. Batts. Space Science Laboratory.

This report presents a summary of selected atmospheric conditions observed near Space Shuttle *Atlantis* (STS-43) launch time on August 2, 1991, at Kennedy Space Center, FL. Values of ambient pressure, temperature, moisture, ground winds, visual observations (cloud), and winds aloft are included. The sequence of prelaunch Jimsphere-measured vertical wind profiles is given in this report. The final atmospheric profile, which consists of wind and thermodynamic parameters versus altitude, for STS-43 vehicle ascent has been constructed. The STS-43 ascent atmospheric data profile has been constructed by Marshall Space Flight Center's Earth Science and Applications Division to provide an internally consistent data set for use in postflight performance assessments and represents the best estimate of the launch environment to the 400,000-ft altitude that was traversed by the STS-43 vehicle.

TM-103604 August 1992
Space Station *Freedom* Seal Leakage Rate Analysis and Testing Summary: Air Leaks in Ambient Pressure Versus Vacuum Exit Conditions. P.I. Rodriguez and R. Markovitch. Structures and Dynamics Laboratory.

This report is intended to reveal the apparent relationship of air seal leakage rates between 2 atmospheres (atm) to 1 atm and 1 atm to vacuum conditions. Gas dynamic analysis is provided as well as data summarizing MSFC test report, "Space Station *Freedom* (S.S. *Freedom*) Seal Flaw Study With Delta Pressure Leak Rate Comparison Test Report," SSF/DEV/ED91-008.

TM-108373 April 1992
Hubble Space Telescope Thermal Cycle Test Report for Large Solar Array Samples With BSFR Cells (Sample Numbers 703 and 704). D.W. Alexander. Information and Electronic Systems Laboratory.

The Hubble space telescope (HST) solar array was designed to meet specific output power requirements after 2 years in low-Earth orbit, and to remain operational for 5 years. The array, therefore, had to withstand 30,000 thermal cycles between approximately +100 and −100 °C. The ability of the array to meet this requirement was evaluated by thermal cycle testing, in vacuum, two 128-cell solar cell modules that exactly duplicated the flight HST solar array design. Also, the ability of the flight array to survive an emergency deployment during

the dark (cold) portion of an orbit was evaluated by performing a cold-roll test using one module.

TM-108374 September 1992

An Impact Investigation of the TOS–2 Case Damage. A.T. Nettles and D.G. Lance. Materials and Processes Laboratory.

An impact investigation was performed on segments of a transfer-to-orbit stage (TOS) Kevlar/epoxy pressure vessel to assist in the evaluation of the damage sustained by a TOS–2 motor case during a handling accident. The impact conditions were replicated using an instrumented drop weight tower with a modified impactor. No. 10 bolts were used as impact tups to better simulate the accident. The similarities of the surface damage between the specimens and the actual case were observed before the specimens were cross-sectionally cut and examined. The results showed that, while no significant subsurface damage was observed in the test specimens, the damage was subtle and could not be predicted by visual examination of the external surface or by available NDE methods.

TM-4340 February 1992

Space Station *Freedom* Environmental Control and Life Support System Regenerative Subsystem Selection. R.L. Carrasquillo, D.L. Carter, D.W. Holder, Jr., C.F. McGriff, and K.Y. Ogle. Materials and Processes Laboratory. X92-10278

In support of Space Station *Freedom* phase C/D environmental control and life support systems (ECLSS) regenerative systems development, comparative testing was performed on predevelopment hardware of competing technologies for each regenerative function. This testing was conducted by the Boeing Aerospace and Electronics Company (BAE) at Marshall Space Flight Center (MSFC) from late 1989 through early 1990. The purpose of the test program was to collect data on latest generation hardware in order to make final technology selections for each subassembly in the oxygen recovery and water reclamation strings. This report discusses the testing performed, test results, and evaluation of these results relative to subsystem selections for CO_2 reduction, O_2 generation, potable water processing, hygiene water processing, and urine processing.

TM-4350 February 1992

Lightning Imaging Sensor (LIS) for the Earth Observing System. H.J. Christian, R.J. Blakeslee, and S.J. Goodman. Space Science Laboratory. N92-20036

This document describes scientific objectives and instrument characteristics of a calibrated optical lightning imaging sensor (LIS) for the Earth observing system (EOS) and the tropical rainfall measuring mission (TRMM) designed to acquire and investigate the distribution and variability of total lightning on a global basis. The LIS is an EOS instrument, whose lineage can be traced to a lightning mapper sensor planned for flight on the GOES series of operational meteorological satellites. The LIS is conceptually a simple device, consisting of a staring imager optimized to detect and locate lightning. The LIS will detect and locate lightning with storm scale resolution (i.e., 5 to 10 km) over a large region of the Earth's surface along the orbital track of the satellite, mark the time of occurrence of the lightning, and measure the radiant energy. The LIS will have a nearly uniform 90-percent detection efficiency within the area viewed by the sensor, and will detect intracloud and cloud-to-ground discharges during day and night conditions. In addition, the LIS will monitor individual storms and storm systems long enough (i.e., 2 min) to obtain a measure of the lightning flashing rate in these storms when they are within the field of view of the LIS. The LIS attributes include low cost, low weight and power (15 kg, 30 W), low data rate (6 kb/s), and important science. The LIS will contribute to studies of the hydrological cycle, general circulation and sea-surface temperature variations, investigations of the electrical coupling of thunderstorms with the ionosphere and magnetosphere, and observations and modeling of the global electric circuit. It will provide a global lightning climatology from which changes, caused perhaps by subtle temperature variations, will be readily detected.

TM-4353 February 1992

First International Microgravity Laboratory Experiment Descriptions—First Edition. T.Y. Miller, Editor. Space Science Laboratory. N92-23600

This document contains brief descriptions of the experiments for the first international microgravity laboratory (IML–1) which is scheduled for launch from the Kennedy Space Center aboard the orbiter *Discovery* in early 1992.

TM-4388 June 1992

Functional Requirements Document for NASA/MSFC Earth Science and Applications Division—Data and Information System (ESAD-DIS) Interoperability, 1992. J.B. Stephens, and G.W. Grider. Space Science Laboratory. N92-26905

These ESAD-DIS interoperability requirements are designed to quantify the Earth Science and Applications Division's hardware and software requirements in terms of communications between personal and visualization workstation and mainframe computers. The electronic mail requirements and LAN requirements are addressed. These interoperability requirements are top-level requirements framed around defining the existing ESAD-DIS interoperability and projecting known near-term requirements for both operational support and for management planning. Detailed requirements will be submitted on a case-by-case basis. This document is also intended as an overview of ESAD-DIS interoperability for newcomers and management not familiar with these activities. It is intended as background documentation to support requests for resources and support requirements.

TM-4392 June 1992

Functional Requirements Document for the Earth Observing System Data and Information System (EOS DIS) Scientific Computing Facilities (SCF) of the NASA/MSFC Earth Science and Applications Division, 1992. M.E. Botts, R.J. Phillips, J.V. Parker, and P.D. Wright. Space Science Laboratory. N92-28899

Five scientists at MSFC/ESAD have EOS SCF investigator status. Each SCF has unique tasks which require the establishment of a computing facility dedicated to accomplishing those tasks. An SCF Working Group was established at ESAD with the charter of defining the computing requirements of the individual SCF's and recommending options for meeting these requirements. The primary goal of the working group was to determine which computing needs can be satisfied using either shared resources or separate but compatible resources, and which needs require unique individual resources. The requirements investigated included CPU-intensive vector and scalar processing, visualization, data storage, connectivity, and I/O peripherals. A review of computer industry directions and a market survey of computing hardware provided information regarding important industry standards and candidate computing platforms. It was determined that the total SCF computing requirements might be most effectively met using a hierarchy consisting of shared and individual resources. This hierarchy is composed of five major system types: (1) a supercomputer class vector processor, (2) a high-end scalar multiprocessor workstation, (3) a file server, (4) a few medium- to high-end visualization workstations, and (5) several low- to medium-range personal graphics workstations. Specific recommendations for meeting the needs of each of these types are presented.

TP-3160 October 1991

An Examination of the Damage Tolerance Enhancement of Carbon/Epoxy Using an Outer Lamina of Spectra®. D.G. Lance and A.T. Nettles. Materials and Processes Laboratory. N92-11142

Low-velocity instrumented impact testing was utilized to examine the effects of an outer lamina of ultra-high molecular-weight polyethylene (Spectra) on the damage tolerance of carbon/epoxy composites. Four types of 16-ply quasi-isotropic panels, $(0, +45, 90, -45)_{S2}$ were tested. Some panels contained no Spectra, while others had a lamina of Spectra bonded to the top (impacted side), bottom, or both surfaces of the composite plates. The specimens were impacted with energies up to 8.5 J. Force-time plots and maximum force versus impact energy graphs were generated for comparison purposes. Specimens were also subjected to cross-sectional analysis and compression-after-impact tests. The results show that while the Spectra improved the maximum load that the panels could withstand before fiber breakage, the Spectra seemingly reduced the residual strength of the composites.

TP-3161 October 1991

Automating a Spacecraft Electrical Power System Using Expert Systems. L.F. Lollar. Information and Electronic Systems Laboratory. N92-12052

Since Skylab, Marshall Space Flight Center (MSFC) has recognized the need for large electrical power systems (EPS's) in upcoming spacecraft. The operation of the spacecraft depends on the EPS. Therefore, it must be efficient, safe, and reliable. In 1978, as a consequence of having to supply a large number of EPS personnel to monitor and control Skylab, the Electrical Power Branch of MSFC began the autonomously managed power system (AMPS) project. This project resulted in the assembly of a 25-kW high-voltage dc test facility and provided the means of getting man out of the loop as much as possible. AMPS includes several embedded controllers which allow a significant level of autonomous operation. More recently, the Electrical Division at MSFC has developed the space station module power management and distribution (SSM/PMAD) breadboard to investigate managing and distributing power in the Space Station *Freedom* habitation and laboratory modules. Again, the requirement for a high level of autonomy for efficient operation over the lifetime of the station and for the benefits of enhanced safety has been demonstrated. This paper describes the two breadboards and the hierarchical approach to automation which was developed through these projects.

TP-3163 October 1991

A Generalized Method for Multiple Robotic Manipulator Programming Applied to Vertical-Up Welding. K.R. Fernandez, G.E. Cook, K. Andersen, R.J. Barnett, and S. Zein-Sabattou. Information and Electronic Systems Laboratory. N92-11218

This paper describes the application of a weld programming algorithm for vertical-up welding, which is frequently desired for variable polarity plasma arc welding (VPPAW). The Basic algorithm performs three tasks simultaneously: control of the robotic mechanism so that proper torch motion is achieved while minimizing the sum-of-squares of joint displacement; control of the torch while the part is maintained in a desired orientation; and control of the wire feed mechanism location with respect to the moving welding torch. This algorithm has been presented and demonstrated in earlier reports as applied to downhand welding, such as is required for gas tungsten arc welding (GTAW).

This paper also presents a modification of this algorithm which permits it to be used for vertical-up welding. The details of this modification are discussed and simulation examples are provided for illustration and verification.

TP-3177 December 1991

Optical Measurements on Solid Specimens of Solid Rocket Motor Exhaust and Solid Rocket Motor Slag. F.E. Roberts, III. Materials and Processes Laboratory. N92-20949

Samples of alumina slag were investigated to aid the Earth Science and Applications Division at Marshall Space Flight Center (MSFC). Alumina from space motor propellant exhaust and space motor propellant slag was examined as a component of space refuse. Thermal emittance and solar absorptivity measurements were taken to support their comparison with reflectance measurements derived from actual debris. To determine the similarity between the samples, and space motor exhaust or space motor slag, emittance and absorbance results were correlated with an examination of specimen morphology.

TP-3178 December 1991

A Nonlinear Estimator for Reconstructing the Angular Velocity of a Spacecraft Without Rate Gyros. M.E. Polites and W.D. Lightsey. Structures and Dynamics Laboratory. N92-13343

This paper presents a new scheme for estimating the angular velocity of a spacecraft without rate gyros. It is based upon a nonlinear estimator whose inputs are measured inertial vectors and their calculated time-derivatives relative to vehicle axes. It works for all spacecraft attitudes and requires no knowledge of attitude. It can use measurements from a variety of onboard sensors like Sun sensors, star trackers, or magnetometers, and in concert. It can also use look angle measurements from onboard tracking antennas for tracking and data relay satellites or global positioning system satellites. In this paper, it is applied to a Sun point scheme on the Hubble space telescope assuming all or most of its onboard rate gyros have failed. Simulation results are presented which verify it.

TP-3179 December 1991

A Statistical Comparison of Two Carbon Fiber/Epoxy Fabrication Techniques. A.J. Hodge. Materials and Processes Laboratory. N92-20950

A statistical comparison of the compression strengths of specimens that were fabricated by either a platen press or an autoclave were performed on IM6/3501-6 carbon/epoxy composites of 16-ply $(0,+45,90,-45)_{S2}$ lay-up configuration. The samples were cured with the same parameters and processing materials. It was found that the autoclaved panels were thicker than the platen press-cured samples. Two hundred samples of each type of cure process were compression tested. The autoclaved samples had an average strength of 450 MPa (65.5 ksi), while the press-cured samples had an average strength of 370 MPa (54.0 ksi). A Weibull analysis of the data showed that there is only a 30-percent probability that the two types of cure systems yield specimens that can be considered from the same family.

TP-3181 December 1991

Limit Cycle Vibrations in Turbomachinery. S.G. Ryan. Structures and Dynamics Laboratory. N92-14108

High-performance turbomachinery is susceptible to a wide variety of vibration problems. Some of these problems are rotor unbalance vibration, dynamic instability, and subharmonic response to unbalance excitation. Understanding these problems is complicated when nonlinearities are present, as they almost always are in actual hardware. For example, dynamic instabilities may manifest themselves as limit cycle vibrations. In some cases, the vibration levels are so high that the distinction between a divergent instability and a limit cycle is meaningless. This is because the machinery would be destroyed in either case. In other cases, the limit cycle may appear at relatively small levels. These cases may appear to be benign; however, the presence of the limit cycle may be an indication of an impending divergent instability. This matter is complicated by the fact that the frequency of the limit cycle instability is frequently near one-half of the unbalance excitation synchronous frequency. This makes it difficult to distinguish between the limit cycle and a subharmonic response.

The focus of this work is an examination of rotordynamic systems which are simultaneously susceptible to limit cycle instability and subharmonic response. Characteristics of each phenomenon are determined as well as their interrelationship. A normalized, single mass rotor model is examined as well as a complex model of the high-pressure fuel turbopump (HPFTP) of the space shuttle main engine (SSME). Entrainment of limit cycle instability by subharmonic response is demonstrated for both models. The nonuniqueness of the solution is also demonstrated.

TP-3203 February 1992

Structural Deterministic Safety Factors Selection Criteria and Verification. V. Verderaime. Structures and Dynamics Laboratory. N92-19355

Though current deterministic safety factors are arbitrarily and unaccountably specified, its ratio is rooted in resistive and applied stress probability distributions. This study approached the deterministic method from a probabilistic concept leading to a more systematic and coherent philosophy and criterion for designing more uniform and reliable high-performance structures. The deterministic method was noted to consist of three safety factors—a standard deviation multiplier of the applied stress distribution, a K-factor for the A- or B-basis material ultimate stress, and the conventional safety factor to ensure that the applied stress does not operate in the inelastic zone of metallic materials. The conventional safety factor is specifically defined as the ratio

of ultimate to yield stresses. A deterministic safety index of the combined safety factors was derived from which the corresponding reliability proved the deterministic method is not reliability sensitive. Bases for selecting safety factors are presented, and verification requirements are discussed. The suggested deterministic approach is applicable to all NASA, DOD, and commercial high-performance structures under static stresses.

TP-3213 March 1992

The Role of Failure/Problems in Engineering: A Commentary on Failures Experienced—Lessons Learned. R.S. Ryan. Structures and Dynamics Laboratory. N92-22235

This report presents the written version of a series of seminars given to several aerospace companies and three National Aeronautics and Space Administration (NASA) Centers. The results are lessons learned through a study of the problems experienced in 35 years of engineering. The basic conclusion is that the primary cause of problems has not been missing technologies, as important as technology is, but the neglect of basic principles. Undergirding this is the lack of a systems focus from determining requirements through design, verification, and operations phases. Many of the concepts discussed are fundamental to total quality management (TQM) and can be used to augment this product enhancement philosophy. Fourteen principles are addressed in this report with problems experienced used as examples. Included is a discussion of the implication of constraints, poorly defined requirements, and schedules. Design guidelines, lessons learned, and future tasks are listed. Two additional sections are included that deal with personal lessons learned and thoughts on future thrusts (TQM). A separate report, to be published later, will contain synopses of the problems experienced. They will be documented by project and cause. Approximately 175 problems have been treated to date.

TP-3215 March 1992

Time-Frequency Representation of a Highly Nonstationary Signal Via the Modified Wigner Distribution. T.F. Zoladz, J.H. Jones, and J. Jong. Structures and Dynamics Laboratory. N92-20492

This report presents a new signal analysis technique called the modified Wigner distribution (MWD). The MWD has been developed for the Structures and Dynamics Laboratory at MSFC by Dr. Jen-Yi Jong of Wyle Laboratories. The new signal processing tool has proven very successful in determining time-frequency representations of highly nonstationary multicomponent signals in both simulation and trials involving actual space shuttle main engine high-frequency data. The MWD departs from the classic Wigner distribution (WD) in that it effectively eliminates the cross coupling among positive frequency components in a multiple component signal. This attribute of the MWD, which prevents the generation of "phantom" spectral peaks, will undoubtedly increase the utility of the WD for real-world signal analysis applications which more often than not involve multicomponent signals.

TP-3218 April 1992

The Effect of Acceleration Versus Displacement Methods on Steady-State Boundary Forces. D.S. McGhee. Structures and Dynamics Laboratory. N92-21457

When a substructure model is reduced by the Craig-Bampton method, a number of degrees-of-freedom (DOF's) are retained as physical DOF's to provide interface to other substructures. When more DOF's are retained in this interface than are actually required, the model is said to be over constrained. The result of this, when using the displacement method, is typically an inaccurate distribution of boundary forces. This inaccuracy also occurs when there are justifiably many interface DOF's which result in an indeterminate interface. When the acceleration method is used, this inaccuracy is overcome. However, many people do not fully understand this method and the many ways of implementing it, and so its implementation is sometimes haphazard.

This study describes the acceleration and displacement methods for use in the recovery of coupled system boundary forces. A simple 2-DOF system has been used for illustration. The effect of the choice of method for use with indeterminate or over-constrained boundaries has been investigated. It has specifically looked at results from a simple two-dimensional beam problem using both methods.

In the space shuttle payload community, there has been an increase in the use of over-constrained payload models. This has been, mainly, to afford easy recovery of relative deflection data between the payload and the shuttle. While there has also been an increase in the use of the acceleration method for the recovery of payload displacements and forces, the displacement method remains the method used for recovering system displacements and forces. Much

work has been done on the effects of Craig-Bampton modal truncation on system displacements and forces; however, little work has been done on system modal truncation (i.e., modes across the boundary). The findings of this study indicate the effect of this system level truncation is significant. This may be particularly true for the 35-Hz system cutoff frequency that is required by the space shuttle. From this study's findings, recommendations for areas of study with space shuttle payload systems are made.

TP-3220 April 1992
Technique to Eliminate Computational Instability in Multibody Simulations Employing the Lagrange Multiplier. G. Watts. Structures and Dynamics Laboratory. N92-23436

This paper presents a programming technique to eliminate computational instability in multibody simulations that use the Lagrange multiplier. The computational instability occurs when the attached bodies drift apart and violate the constraints. The programming technique uses the constraint equation, instead of integration, to determine the coordinates that are not independent. Although the equations of motion are unchanged, a complete derivation of the incorporation of the Lagrange multiplier into the equation of motion for two bodies is presented. A listing of a digital computer program which uses the programming technique to eliminate computational instability is also presented. The computer program simulates a solid rocket booster and parachute connected by a frictionless swivel.

TP-3248 June 1992
Effect of Type of Load on Stress Analysis of Thin-Walled Ducts. J.B. Min and P.K. Aggarwal. Structures and Dynamics Laboratory. N92-26669

The standard procedure for qualifying the design of duct (pipe) systems in the space shuttle main engine (SSME) has been fairly well defined. However, since pipe elbows are quite common and important in the SSME duct systems, a clear understanding of the detailed stress profile of the components is necessary for accurate structural and life assessments. This study was initiated to predict the stress profile at/near the tangent point along the cross section of the duct under various types of loads. Also, this study was further extended to understand the stiffening effect on stresses due to pressure at the tangent point. The intention of this study was to identify the importance of selecting proper locations for mounting strain gauges and to utilize the obtained results to anchor dynamic models for accurate structural and life assessments of the SSME ducts under dynamic environment. The finite element method was utilized in this study.

TP-3249 June 1992
Definition and Design of an Experiment to Test Raster Scanning With Rotating Unbalanced-Mass Devices on Gimbaled Payloads. W.D. Lightsey, D.C. Alhorn, and M.E. Polites. Structures and Dynamics Laboratory. N92-29677

This paper describes an experiment designed to test the feasibility of using rotating unbalanced-mass (RUM) devices for line and raster scanning gimbaled payloads, while expending very little power. The experiment is configured for ground-based testing, but the scan concept is applicable to ground-based, balloon-borne, and space-based payloads, as well as free-flying spacecraft. In this paper, the servos used in scanning are defined, the electronic hardware is specified, and a computer simulation model of the system is described. Simulation results are presented that predict system performance and verify the servo designs.

TP-3275 August 1992
Gibbs Free Energy of Reactions Involving Si-C, Si_3-N_4, H_2, and H_2-O as a Function of Temperature and Pressure. M.A. Isham. Materials and Processes Laboratory. N92-31278

Silicon carbide (Si-C) and silicon nitride (Si_3-N_4) are considered for application as structural materials and coating in advanced propulsion systems including nuclear thermal. Three-dimensional Gibbs free energy surfaces were constructed for reactions involving these materials in H_2 and H_2/H_2-O. Free energy plots are functions of temperature and pressure. Calculations used the definition of Gibbs free energy where the spontaneity of reactions is calculated as a function of temperature and pressure.

Silicon carbide decomposes to Si and CH_4 in pure H_2 and forms a Si-O_2 scale in a wet atmosphere. Silicon nitride remains stable under all conditions. There was no apparent difference in reaction thermodynamics between ideal and Van der Waals treatment of gaseous species.

TP-3277 August 1992

Applications of FEM and BEM in Two-Dimensional Fracture Mechanics Problems. J.B. Min, B.E. Steeve, and G.R. Swanson. Structures and Dynamics Laboratory. N92-31280

A comparison of the finite element method (FEM) and boundary element method (BEM) for the solution of two-dimensional plane strain problems in fracture mechanics is presented in this paper. Stress intensity factors (SIF's) were calculated using both methods for elastic plates with either a single-edge crack or an inclined-edge crack. In particular, two currently available programs, ANSYS for finite element analysis and BEASY for boundary element analysis, were used.

TP-3282 September 1992

Reconfiguring the RUM Experiment to Test Circular Scanning With Rotating Unbalanced-Mass Devices on Gimbaled Payloads. M.E. Polites and D.C. Alhorn. Structures and Dynamics Laboratory.

This paper describes a ground-based experiment designed to prove the concept of circular scanning a gimbaled payload with rotating unbalanced-mass (RUM) devices. The experiment is a modified version of a similar experiment which demonstrates line and raster scanning with RUM's. In this paper, a description of the experiment hardware is presented, and a detailed design of the servos used in scanning is given. A computer simulation model of the entire system is discussed, and simulation results are included. These verify the servo designs and show the RUM's to be an extremely power-efficient method for circular scanning.

TP-3289 September 1992

Spacecraft Flight Control System Design Selection Process for a Geostationary Communication Satellite. C. Barret. Structures and Dynamics Laboratory.

The Earth's first artificial satellite, Sputnik I, slowly tumbled in orbit. The first U.S. satellite, Explorer I, also tumbled out of control. Now, as we launch the Mars observer and the Cassini spacecraft, stability and control have become a higher priority. This paper reviews the flight control system design selection process using as an example a geostationary communication satellite which is to have a life expectancy from 10 to 14 years.

Disturbance torques including aerodynamic, magnetic, gravity gradient, solar, micrometeorite, debris, collision, and internal torques are assessed to quantify the disturbance environment so that the required compensating torques can be determined. Then control torque options including passive versus active, momentum control, bias momentum, spin stabilization, dual spin, gravity gradient, magnetic, reaction wheels, control moment gyros, nutation dampers, inertia augmentation techniques, three-axis control, reaction control system (RCS), and RCS sizing are considered. A flight control system design is then selected, and preliminary stability criteria met by the control gains selection.

TP-3303 September 1992

The Effects of Compressive Preloads on the Compression-After-Impact Strength of Carbon/Epoxy. MSFC Center Director's Discretionary Fund Final Report, Project No. P-11. A.T. Nettles and D.G. Lance. Materials and Processes Laboratory.

A preloading device was used to examine the effects of compressive prestress on the compression-after-impact (CAI) strength of 16-ply, quasi-isotropic carbon epoxy test coupons. T300/934 material was evaluated at preloads from 200 to 4,000 lb at impact energies from 1 to 9 joules. IM7/8551-7 material was evaluated at preloads from 4,000 to 10,000 lb at impact energies from 4 to 16 joules. Advanced design of experiments methodology was used to design and evaluate the test matrices. The results showed that no statistically significant change in CAI strength could be attributed to the amount of compressive preload applied to the specimen.

CP-3139 February 1992
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CP-3140 February 1992
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CP-3163 June 1992
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CP-
Advanced Earth-to-Orbit Propulsion Technology—1992, Volume I. R.J. Richmond and S.T. Wu, Editors.

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Advanced Earth-to-Orbit Propulsion Technology—1992, Volume II. R.J. Richmond and S.T. Wu, Editors.

CP- October 1992
Second Workshop on Hydrogen Effects on Materials in Propulsion Systems. B.N. Bhat, R.L. Dreshfield, and E.J. Vesely, Jr., Editors.

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Recommendations for a Wind Profiling Network to Support Space Shuttle Launches. R.J. Zamora. H-59348B. NOAA/Wave Propagation Laboratory. N92-17072

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Bivariate Extreme Value Distributions. M. Elshamy. NAS8-37585. The University of Alabama in Huntsville. N92-27588

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CR-184215 February 1990
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HARMON, B.A. ES62
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FINGER, M.H.
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LOVELACE, R.V.E.
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WANG, T.S. ED32
LUONG, V.
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CHYU, M.K.
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WATWOOD, M. EH23
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VESSELY, E.J., JR.
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WEGRICH, R.D. ED61
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WEISSKOPF, M.C. ES65
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WEISSKOPF, M.C. TA01
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WILKINS, N. (UAH)
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WEST, M.E. ED12
RAKOCZY, J.M.
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WHITAKER, A.F. EH11
KAMENETZKY, R.R.
FINCKENOR, M.M.
NORWOOD, J.K.
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TSAI, H.
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EMSLIE, A.G.
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Statistical Ballistic Limit Curve Regression for Space Station *Freedom* Meteoroid/Orbital Debris Shielding. For presentation at the 1992 Hypervelocity Impact Symposium, Austin, TX, November 17–20, 1992.

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WILLAMSEN, J.E. ED52
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HUNTRESS, W.T.
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BRYSON, C.C. EH13
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MONK, J.C.
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NUNES, A.C., JR. EH42
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MULQUEEN, J.A.
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GALLAGHER, D.L.
GREEN, J.L. (GSFC)
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POORMAN, R. EH42
LIAW, Y. (Rockwell)
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ZIMMERMAN, F.R. EH42
BRYANT, M.A.
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WILKES, D.R. (Arizona Tech)
MILLER, E.R.
GREGORY, J.C. (UAH)
Fluorescence Measurements of the Thermal Control Coatings on LDEF Experiments S0069 and A0114. For presentation at the Second LDEF Postretrieval Symposium, San Diego, CA, June 1–5, 1992.

APPROVAL

FY 1992 SCIENTIFIC AND TECHNICAL REPORTS, ARTICLES, PAPERS, AND PRESENTATIONS

Compiled by Joyce E. Turner

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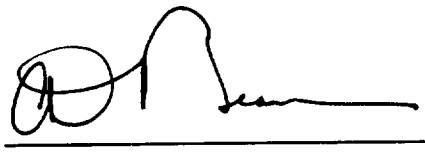

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