FY 1991 SCIENTIFIC AND TECHNICAL REPORTS, ARTICLES, PAPERS, AND PRESENTATIONS

Compiled by Joyce E. Turner
Management Operations Office

October 1991
A compendium of bibliographic references to papers presented by Marshall Space Flight Center (MSFC) personnel and contractors during FY 1989 is provided. The papers include formal NASA technical reports, memoranda, papers which were published in technical journals, and presentations by MSFC personnel. The formal NASA technical reports and memoranda have abstracts included. Sources for obtaining these documents are also included.
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.
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 1991 SCIENTIFIC AND TECHNICAL REPORTS, ARTICLES, PAPERS, AND PRESENTATIONS

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The recognition of defects in materials properties still presents a number of problems for nondestructive testing in aerospace systems. This project attempts to utilize current capabilities in eddy current instrumentation, artificial intelligence, and robotics in order to provide insight into defining geometrical aspects of flaws in composite materials which are capable of being evaluated using eddy current inspection techniques. The unique capabilities of E-probes and horseshoe probes for inspecting graphite fiber materials have been evaluated and appear to hold great promise once the technology development matures.

This preliminary phase report describes the initial results of modeling eddy current interactions with certain flaws in graphite fiber samples.

This report presents the correlation of the static loads testing and finite element modeling for the fiberglass pedestal used on the Atmospheric Emission Photometric Imaging (AEPI) experiment. This payload is to be launched in the space shuttle as part of the ATLAS-1 experiment. Strain gauge data from rosettes around the highly loaded base are compared to the same load case run for the Spacelab 1 testing done in 1981. Correlation of the model and test data was accomplished through comparison of the composite stress invariant utilizing the expected flight loads for the ATLAS-1 mission. Where appropriate, the Tsai-Wu failure criteria was utilized in the development of the key margins of safety. Margins of safety are all positive for the pedestal and are reported.

This report documents the development of a heuristic procedure for the solution of pure integer linear programming problems. The procedure draws its methodology from the ideas of the Hooke and Jeeves type I and type II exploratory searches, greedy procedures, and neighborhood searches. It utilizes an efficient rounding procedure to obtain its first feasible integer point from the optimal continuous solution obtained via the simplex method. Since this procedure is based entirely on simple addition or subtraction of one to each variable of a point in \( n \)-space and the subsequent comparison of candidate solutions to a given set of constraints, it facilitates significant complexity improvements over existing techniques. It also obtains the same optimal solution found by the branch-and-bound technique in 44 out of 45 small to moderate size test problems. Two example problems are worked in detail to show the inner workings of the procedure.
Furthermore, using an established weighted scheme for comparing computational effort involved in an algorithm, a comparison of this algorithm is made to the more established and rigorous branch-and-bound method. A computer implementation of the procedure, in PC-compatible Pascal, is also presented and discussed. This procedure for finding optimal solutions to integer-type problems may be applied to various systems engineering situations in the conceptual, preliminary, and detail design phases of the system development cycle.

TM-103518 November 1990
S.N. Tewari, M.V. Kumar, J.E. Lee, and P.A. Curreri. Materials and Processes Laboratory. N91-15391

Primary dendrite spacings, secondary dendrite spacings, and microsegregation have been examined in PWA-1480 single crystal specimens which were directionally solidified during parabolic maneuvers on the KC-135 aircraft. Experimentally observed growth rate and thermal gradient dependence of primary dendrite spacings are in good agreement with predictions from dendrite growth models for binary alloys. Secondary dendrite coarsening kinetics show a reasonable fit with the predictions from an analytical model proposed by Kirkwood for a binary alloy. The partition coefficients of tantalum, titanium, and aluminum are observed to be less than unity; while that for tungsten and cobalt are greater than unity. This is qualitatively similar to their nickel base binaries. Microsegregation profiles experimentally observed for PWA-1480 superalloy show a good fit with Bower, Brody, and Flemings models developed for binary alloys. Transitions in gravity levels do not appear to affect primary dendrite spacings. A trend of decreased secondary arm spacings with transition from high gravity to the low gravity period was observed at a growth speed of 0.023 cm s$^{-1}$. However, definite conclusions can only be drawn by experiments at lower growth speeds which make it possible to examine the side-branch coarsening kinetics over a longer duration. Such experiments, not possible due to the insufficient low-gravity time of the KC-135, may be carried out in the low-gravity environment of space.

TM-103519 October 1990

The design of engineering structures can be based on risk when enough information about the structure is available. This report compares designing by risk to the more commonly used approach of designing by an engineering factor of safety. The safety factor concept of providing structural assurance is challenged within this report. New methods are developed to assist in determining structural risk in an engineering design when the design is based on the interference of two normally distributed engineering phenomena. The risk factor ($R_F$) approach is offered as an alternate method of establishing engineering design criteria. The engineering risk equation is developed which allows a simple determination of risk when coefficients of variation are known. Several curves were developed that relate $R_F$ to coefficients of variation for various reliabilities. The author concluded that designs and redesigns should be based on risk whenever possible.

TM-103520 October 1990

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After being announced in STAR, all of the NASA series reports may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

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.
Lightning measurements acquired principally by a ground-based network of magnetic direction finders are used to diagnose and predict the existence, temporal evolution, and decay of thunderstorms over a wide range of space and time scales extending over four orders of magnitude. The nonlinear growth and decay of thunderstorms and their accompanying cloud-to-ground lightning activity is described by the three parameter logistic growth model. The growth rate is shown to be a function of the storm size and duration, and the limiting value of the total lightning activity is related to the available energy in the environment. A new technique is described for removing systematic bearing errors from direction finder data where radar echoes are used to constrain site error correction and optimization (best point estimate) algorithms. A nearest neighbor pattern recognition algorithm is employed to cluster the discrete lightning discharges into storm cells, and the advantages and limitations of different clustering strategies for storm identification and tracking are examined.

An instrument for biochemical studies, called the rotating spectrometer, separates previously inseparable cell cultures. The rotating spectrometer is intended for use in pharmacological studies which require fractional splitting of heterogeneous cell cultures based on cell morphology and swimming behavior. As a method to separate and concentrate cells in free solution, the rotating method requires active organism participation and can effectively split the large class of organisms known to form spontaneous patterns. Examples include the biochemical "star," an organism called *Tetrahymena pyriformis*. Following focusing in a rotated frame, the separation is accomplished using different radial dependencies of concentrated algal and protozoan species. The focusing itself appears as concentric rings and arises from the coupling between swimming direction and Coriolis forces. A dense cut is taken at varying radii and extraction is replenished at an inlet. Unlike standard separation and concentrating techniques such as filtration or centrifugation, the instrument is able to separate motile from immotile fractions. For a single pass, typical split efficiencies can reach 200 to 300 percent compared to the inlet concentration.
ones made of silicon nitride in 57-mm HPOTP bearings. The bearings were then installed in a test rig and run at near turbopump operating conditions. The results from this test series have been encouraging, with silicon nitride showing good wear resistance and thermal stability.

**TM-103525** November 1990

This report presents a summary of selected atmospheric conditions observed near space shuttle STS-41 launch time on October 6, 1990, 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-41 vehicle ascent has been constructed. The STS-41 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-41 vehicle.

**TM-103526** February 1991

A damage tolerance study of two new toughened carbon fiber/epoxy resin systems was undertaken as a continuation of ongoing work into screening new opposites for resistance to foreign object impact. This report is intended to be a supplement to NASA TP 3029 in which four new fiber/resin systems were tested for damage tolerance. Instrumented drop weight impact testing was used to inflict damage to 16-ply quasi-isotropic specimens. Instrumented output data and cross-sectional examination of the damage zone were utilized to quantify the damage. It was found that the two fiber/resin systems tested in this study were much more impact resistant than an untoughened composite such as T300/934, but were not as impact resistant as other materials previously studied.

**TM-103527** March 1991

Various bearing configurations were tested using the Marshall Space Flight Center single bearing tester with LN$_2$ as the cryogenic coolant. The baseline was one Rocketdyne phase I high pressure oxidizer turbopump (HPOTP) pump end 45-mm bore bearing. The bearing configurations that were tested included a Salox/M cage configuration, a silicon nitride ball configuration, an elongated cage configuration, and a Bray 601 grease configuration.

**TM-103528** February 1991

A numerical model which simulates geophysical fluid flow in a wide range of problems is described in detail, and comparisons of some of the model's results are made with previous experimental and numerical studies. The model is based upon the Boussinesq Navier-Stokes equations in spherical coordinates, which can be reduced to a cylindrical system when latitudinal walls are used near the pole and the ratio of latitudinal length to the radius of the sphere is small. The equations are approximated by finite differences in the meridional plane and spectral decomposition in the azimuthal direction. The user can specify a variety of boundary and initial conditions, and there are five different spectral truncation options. The results of five validation cases are presented: (1) the transition between axisymmetric flow and baroclinic wave flow in the side-heated annulus; (2) the steady baroclinic wave of the side-heated annulus; (3) the wave-amplitude vacillation of the side-heated annulus; (4) transition to baroclinic wave flow in a bottom-heated annulus; and (5) the Spacelab Geophysical Fluid Flow Cell (spherical) experiment.

Mechanical properties have been evaluated to determine statistically whether the pulsed current gas tungsten arc welding (GTAW-P) process produces welds in alloy 718 with room temperature structural performance equivalent to current space shuttle main engine (SSME) welds manufactured by the constant current gas tungsten arc welding (GTAW) process. Evaluations were conducted on two base metal lots, two filler metal lots, two heat input levels, and two welding processes. The material form was 0.125-inch (3.175-mm) alloy 718 sheet. Prior to welding, sheets were heat treated to either the ST or STA-1 condition. After welding, panels were left as welded or heat treated to the STA-1 condition, and weld beads were left intact or machined flush. Statistical analyses were performed on yield strength (YS), ultimate tensile strength (UTS), and high cycle fatigue (HCF) properties for all the post welded material conditions. Analyses of variance (ANOVA) were performed on the data to determine if there were any significant effects on UTS or HCF life due to variations in base metal, filler metal, heat input level, or welding process.

Statistical analyses have shown that the GTAW-P process does produce welds with room temperature structural performance equivalent to current SSME welds manufactured by the GTAW process, regardless of prior material condition or post welding condition.


This report presents a summary of selected atmospheric conditions observed near space shuttle STS-38 launch time on November 15, 1990, at Kennedy Space Center, Florida. STS-38 carried a Department of Defense payload and the flight azimuth in this report will be denoted by a reference flight azimuth, since the actual flight azimuth is not known. Values of ambient pressure, temperature, moisture, ground winds, visual observations (cloud), and winds aloft are included. The sequence of prelaunch Jimosphere-measured vertical wind profiles is given in this report. The final atmospheric tape, which consists of wind and thermodynamic parameters versus altitude, for STS-38 vehicle ascent has been constructed. The STS-38 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-38 vehicle.

TM-103530

This report presents a summary of selected atmospheric conditions observed near space shuttle STS-38 launch time on November 15, 1990, at Kennedy Space Center, Florida. STS-38 carried a Department of Defense payload and the flight azimuth in this report will be denoted by a reference flight azimuth, since the actual flight azimuth is not known. Values of ambient pressure, temperature, moisture, ground winds, visual observations (cloud), and winds aloft are included. The sequence of prelaunch Jimosphere-measured vertical wind profiles is given in this report. The final atmospheric tape, which consists of wind and thermodynamic parameters versus altitude, for STS-38 vehicle ascent has been constructed. The STS-38 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-38 vehicle.

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–September 1990. The systems that make up the facility are a magnetograph telescope, an H-alpha telescope, a Questar telescope, and a computer code. The data are represented by longitudinal contours with azimuth plots.

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 October–December 1990. The systems that make up the facility are a magnetograph telescope, an H-alpha telescope, a Questar telescope, and a computer code. The data are represented by longitudinal contours with azimuth plots.
This document represents an evaluation of the NASA's Marshall Space Flight Center (MSFC) strategy to implement total quality management (TQM) in the advanced solid rocket motor (ASRM) project. The evaluation of the implementation strategy reflected the Civil Service personnel perspective at the project level. The external and internal environments at MSFC were analyzed for their effects on the ASRM TQM strategy. Organizational forms, cultures, management systems, problem solving techniques and training were assessed for their influence on the implementation strategy. The influence of ASRM’s effort was assessed relative to its impact on mature projects as well as future projects at MSFC.

**TM-103534**

**April 1991**

Parametric Study in Weld Mismatch of Longitudinally Welded SSME HPFTP Inlet. 
J.B. Min, K.L. Spanyer, and R.M. Brunair. 
Structures and Dynamics Laboratory. 
N91-23502

Welded joints are an essential part of pressure vessels such as the space shuttle main engine (SSME) turbopumps. Defects produced in the welding process can be detrimental to weld performance. Recently, review of the SSME high pressure fuel turbopump (HPFTP) titanium inlet x rays revealed several weld discrepancies such as penetrant density issues, film processing discrepancies, weld width discrepancies, porosity, lack of fusion, and weld offsets. Currently, the sensitivity of welded structures to defects is of concern. From a fatigue standpoint, weld offset may have a serious effect since local yielding, in general, aggravates cyclic stress effects. Therefore, the weld offset issue is considered in this report. Using the finite element method and mathematical formulations, parametric studies were conducted to determine the influence of weld offsets and a variation of weld widths in longitudinally welded cylindrical structures with equal wall thicknesses on both sides of the joint. From the study, the finite element results and theoretical solutions are presented.

**TM-103535**

**April 1991**

Effects of Water on the Strength of Zerodur. 
D. Tucker and A. Setzer. Materials and Processes Laboratory. 
N91-24430

An experimental design matrix was constructed to determine the effects of time and temperature water soak on the strength of Zerodur glass-ceramic. It was found that strength does increase in a nonlinear manner which is consistent with existing theories of crack tip blunting and residual stress reduction.

**TM-103536**

**May 1991**

Effect of Flange Bolt Preload on Space Shuttle Main Engine High Pressure Oxidizer Turbopump Housing Analysis. J.B. Min, L.M. Johnston, and B. Czekalski. Structures and Dynamics Laboratory. 
N91-24584

Cracks at the seal fillet flange and the strut pilot groove of primary turbine drain passage of the space shuttle main engine (SSME) high pressure oxidizer turbopump (HPOTP) have been observed and reported. Stress information for critical structural components in the SSME under actual conditions is necessary for design and life prediction analysis. However, little information is available about the stress distribution at this location under various combinations of loadings and environments. Thus, a stress analysis was conducted to determine an influence of the various operation and installation loads on the stresses of the HPOTP main mounting flange. To do this, a three-dimensional (3-D) finite element model of the HPOTP housing was generated. A fairly comfortable margin of stresses at the flange fillet with respect to the yield stress of Inconel 718 is shown in this analysis. However, it was revealed that the bending stress arising from the housing flange bolt preloads could significantly affect the stress distribution at the strut pilot groove of primary turbine drain passage in the HPOTP housing. Consequently, the information obtained from the present 3-D analysis results should be useful in guiding the development of the SSME HPOTP.

**TM-103537**

**May 1991**

The Effect of Stress on Hydrogen Uptake and Desorption by A-286. M.D. Danford. 
Materials and Processes Laboratory. 
N91-28341
The uptake and desorption of hydrogen by A-286 as a function of stress has been studied using electrochemical methods. It was found that the apparent surface hydrogen concentration $C_0$, the mean hydrogen concentration $C$, and the hydrogen distribution uniformity all increased up to a stress level 50-percent of yield and decreased thereafter. The value of the hydrogen diffusion coefficient $D$ was relatively unaffected by stress while the percent of trapped hydrogen appeared to decrease with increasing stress.

TM-103538 June 1991

This report presents a summary of selected atmospheric conditions observed near space shuttle STS-35 launch time on December 2, 1990, 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-35 vehicle ascent has been constructed. The STS-35 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-35 vehicle.

TM-103539 April 1991
Analysis of Lightning Field Changes Produced by Florida Thunderstorms. W.J. Koshak. Space Science Laboratory.

A new method is introduced for inferring the charges deposited in a lightning flash. Previous nonlinear least-squares methods have used simple point charge ($Q$) and point dipole ($P$) models to describe ground-based observations of lightning-caused field changes ($\Delta E$). In the new approach, the $\Delta E$'s are described by a more general volume charge distribution that is defined on a large cartesian grid system centered above the measuring network. We show that a linear system of equations can be used to relate the $\Delta E$'s at the ground to the values of charge on this grid. With this approach, it is possible to apply more general physical constraints to the charge solutions, and it is possible to access the information content of the $\Delta E$ data. Computer-simulated $\Delta E$ inversions show that the location and symmetry of the charge retrievals are usually consistent with the known test sources. Analyses of three natural lightning events show that the linear method provides source distributions that are in reasonable agreement with $Q$- and $P$-model results.

TM-103540 June 1991
The Corrosion Protection of 2219-T87 Aluminum by Anodizing. M.D. Danford. Materials and Processes Laboratory.

Various types of anodized coatings have been studied for 2219-T87 aluminum. These include both type II and type III anodize coats which have been water sealed and a newly developed and proprietary Magnaplate HCR™ coat. Results indicate that type III anodizing is not much superior to type II anodizing as far as corrosion protection for 2219-T87 aluminum is concerned. Magnaplate HCR™ coatings should provide superior corrosion protection over an extended period of time using a coating thickness of 51 microns (2.0 mils).

TM-103541 June 1991

Preliminary results of research conducted in the late 1970's indicate that perceptual qualities of an enclosure can be influenced by the distribution of illumination within the enclosure. Subjective impressions such as spaciousness, perceptual clarity, and relaxation or tenseness, among others, appear to be related to different combinations of surface luminance. A prototype indirect ambient illumination system was developed which will allow crew members to alter surface luminance distributions within an enclosed module, thus modifying perceptual cues to match crew preferences. A traditional lensed
direct lightning system was compared to the prototype utilizing the full-scale mockup of Space Station Freedom developed by Marshall Space Flight Center. The direct lensed system was installed in the habitation module with the indirect prototype deployed in the U.S. laboratory module. Analysis centered on the illuminance and luminance distributions resultant from these systems and the implications of various luminaire spacing options. All test configurations were evaluated for compliance with NASA Standard 3000, "Man-System Integration Standards."

TM-103542 June 1991
Vacuum Vapor Deposition—A Spinoff of Space Welding Development. R.M. Poorman. Materials and Processes Laboratory. N91-27330

A vapor deposition process has been defined through a spinoff effort of space welding development. In this development for welding in a space environment, a hollow electrode was used to add gas precisely at the welding arc. This provides gas for ionization which carries the welding arc current. During this welding development metal vapor coatings were observed. These coatings are unique in that they are produced by a new process. This report characterizes some coatings produced and the potential of this new and innovative vapor deposition process. Advantages over prior art are discussed.

TM-103543 June 1991

Proof test diagrams for Zerodur glass-ceramic are calculated from available fracture mechanics data. It is shown that the environment has a large effect on minimum time-to-failure as predicted by proof test diagrams.

TM-103544 June 1991

This report investigates several applications of low lift to drag ratio aerobrakes which use angle-of-attack variation for control. These applications are: return from geosynchronous or lunar orbit to low Earth orbit and planetary aerocapture at Earth and Mars. A number of aerobrake design considerations are reviewed. It was found that the flow impingement behind the aerobrake and the aerodynamic heating loads are the primary factors that control the sizing of an aerobrake. The heating loads and other loads, such as maximum acceleration, are determined by the vehicle ballistic coefficient, the atmosphere entry conditions, and the trajectory design. Several formulations for defining an optimum trajectory are reviewed, and the various performance indices that can be used are evaluated. The "nearly grazing" optimal trajectory was found to provide the best compromise between the often conflicting goals of minimizing the vehicle propulsive requirements and minimizing vehicle loads. The relationship between vehicle and trajectory design is investigated further using the results of numerical simulations of trajectories for each aerobrake application. The data show the sensitivity of the trajectories to several vehicle parameters and atmospheric density variations. The results of the trajectory analysis show that low lift to drag ratio aerobrakes, which use angle-of-attack variation for control, can potentially be used for a wide range of aerobrake applications.

TM-103546 July 1991

The Burst and Transient Source Experiment (BATSE) on the Gamma Ray Observatory (GRO) has detected a large number of terrestrial electron precipitation events. Bremsstrahlung is generated as the precipitating electrons interact in the atmosphere, or at the spacecraft, and this radiation is detected by the gamma ray detectors onboard. Several examples of such events are presented here, and the different classes of events are described. A correlation of events to strong magnetospheric activity is presented, and the association of a subset of events to a powerful VLF transmitter on the western coast of Australia is described.

NASA has recently completed a shuttle-borne stellar ultraviolet astronomy mission known as Astro-1. A three-axis instrument pointing system (IPS) was employed to accurately point the science instruments. In order to analyze the pointing control system and verify pointing performance, a simulation of the IPS has been developed using the multibody dynamics software TREETOPS. The TREETOPS IPS simulation is capable of accurately modeling the multibody IPS system undergoing large angle, nonlinear motion. This report documents the simulation and presents example cases demonstrating disturbance rejection, fine pointing operations, and multiple target pointing and slewing of the IPS.


During the summer of 1990, space shuttle Columbia experienced both an external tank/orbiter disconnect hydrogen leak and multiple internal aft compartment hydrogen leaks. After the third scrub of STS-35, a leak investigation team was organized. In support of this team, an analysis of the data obtained during scrub 3 was performed. Based on this analysis, the engine 2 prevalve was concluded to be the most likely leak location and to account for most of the observed leakage.

Evaluation of Chemical Conversion and Sulfuric Acid Type II Anodize Coatings on 7075-T73 and 2219-T87 Aluminum Alloys. V.C. McMillan. Materials and Processes Laboratory.

Corrosion evaluation studies were conducted on chemical conversion coated and anodized 7075-T73 and 2219-T87 aluminum alloys. The corrosive environments ranged from a 95-percent relative humidity combined with 35 °C (95 °F) to a 5-percent salt fog environment at 35 °C (95 °F). An evaluation of the effect of temperature on corrosion protection and adhesion properties was conducted by exposing test samples to various temperatures for specified time periods followed by environmental exposure and adhesion testing.


This report describes a family of user-friendly, DOS PC based, Microsoft BASIC programs written to provide spacecraft designers with empirical predictions of space debris damage to orbiting spacecraft. The spacecraft wall configuration is assumed to consist of multilayer insulation (MLI) placed between a Whipple style bumper and the pressure wall. Predictions are based on data sets of experimental results obtained from simulating debris impacts on spacecraft using light gas guns on Earth. A module of the program facilitates the creation of the data base of experimental results that are used by the damage prediction modules of the code. The user has the choice of three different prediction modules to predict damage to the bumper, the MLI, and the pressure wall. One prediction module is based on fitting low order polynomials through subsets of the experimental data. Another prediction module fits functions based on nondimensional parameters through the data. The last prediction technique is a unique approach that is based on weighting the experimental data according to the distance from the design point.

Electrodeposited Zinc-Nickel as an Alternative to Cadmium Plating for Aerospace Application. V.C. McMillan. Materials and Processes Laboratory.

Corrosion evaluation studies were conducted on 4130 alloy steel samples coated with electrodeposited zinc-nickel and samples coated with electrodeposited cadmium. The zinc-nickel was deposited by the selection electrochemical metallizing process. These coated samples were exposed to a 5-percent salt fog environment at 35±2 °C (95±5 °F). The exposure period ranged from 96 to 240 hours. An evaluation of the effect of dichromate coatings on the performance of each plating was conducted. The protection
afforded by platings with a dichromate seal was compared to platings without the seal. During the later stages of testing, deposit adhesion and potential for hydrogen entrapment were also evaluated.

TM-103552 August 1991
Multiplexing Readout Channels in Proportional Counters. J. Caristi. Space Science Laboratory.

Proportional counters are important instruments used in sensing "hard" x rays. This document describes the possibility of doubling the number of readout channels in the detector without increasing the electronics needed to amplify channel signals. This suggests that it should be possible, conversely, to reduce the number of amplifiers, thereby reducing the weight and energy budget of the instrument. Various numerical multiplexing schemes are analyzed, and a computer program is presented that can reconstruct multiplexed channel outputs with very good accuracy.

TM-103553 September 1991

In an effort to best utilize all areas of expertise within the Materials and Processes Laboratory, a Composite Materials Characterization Task Team was developed to help bring together the various branches within the Laboratory to develop a comprehensive data base on composite materials. A "test run" was performed on IM6/3501-6 carbon/epoxy in which the material was processed, machined into specimens, and tested for damage tolerance capabilities. Nondestructive test data played a major role in this element of composite characterization. A time chart was produced showing the time the composite material spent within each Branch or Division in order to identify those areas which produce a long turnaround time. Instrumented drop weight testing was performed on the specimens with nondestructive evaluation (NDE) being performed before and after the impacts. Destructive testing in the form of cross-sectional photomicrography and compression-after-impact (CAI) testing were used. Results show that the processing and machining steps needed to be performed more rapidly if data on a composite material is to be collected within a reasonable timeframe. The results of the damage tolerance testing showed that IM6/3501-6 is a brittle material that is very susceptible to impact damage.

TM-4268, Part I April 1991

A new (1990) version of the NASA/MSFC Global Reference Atmospheric Model (GRAM-90) is presented and discussed. GRAM-90 incorporates extensive new data, mostly collected under the Middle Atmosphere Program (MAP), to produce a completely revised middle atmosphere model (20 to 120 km). Because of earlier data sparseness in this altitude region, previous versions of GRAM relied on a 6-month displacement of Northern Hemisphere data to represent the Southern Hemisphere. GRAM-90 alleviates this shortcoming by utilizing actual data from the Southern Hemisphere for each month. The NASA Marshall Engineering Thermosphere (MET) model has also been incorporated into the GRAM-90 program, at all orbital altitudes greater than 120 km. Part I of this report serves as a technical description of the GRAM-90 program, with extensive documentation on the program operation and usage. Sample results are presented, in the form of height-latitude and latitude-longitude plots. Comparisons are made between the empirically based GRAM-90 model and results from a "first principles" stratospheric circulation model (SCM) in the 20- to 80-km height region. Specific areas of improvement of GRAM-90 over the earlier GRAM model results are also noted. A test case example is also included. Part II of this report presents the entire GRAM-90 program listing along with the major data base listings.

TM-4268, Part II April 1991
The NASA/MSFC Global Reference Atmospheric Model—1990 Version (GRAM-90),
A new (1990) version of the NASA/MSFC Global Reference Atmospheric Model (GRAM-90) has been completed and the program and key data base listings are presented in this document. GRAM-90 incorporates extensive new data, mostly collected under the Middle Atmosphere Program (MAP), to produce a completely revised middle atmosphere model (20–120 km). At altitudes greater than 120 km, GRAM-90 uses the NASA Marshall Engineering Thermosphere (MET) model. This report (part II) serves as a supplementary report to the technical document of GRAM-90 (part I). Complete listings of all program and major data bases are presented herein. Also, a test case example is included.

PLT is a high level plotting package. A Programmer can create a default plot suited for the data being displayed. At run times, users can then interact with the plot overriding any or all of these defaults. The user is also provided the capability to fit functions to the displayed data. This ability to display, interact with, and to fit the data make PLT a useful tool in the analysis of data. The Quick and Dandy Plotter (QDP) program will read ASCII text files that contain PLT commands and data. Thus, QDP provides an easy way to use the PLT software. QDP files provide a convenient way to exchange data. The QDP/PLT software is written in standard Fortran 77 and has been ported to VAX VMS, SUN UNIX, IBM AIX, NeXT NextStep, and MS-DOS systems.
The effect of single salts, as well as multicomponent mixtures, on corrosion inhibition has been studied for type 1010 steel; for 5052, 1100, and 2219-T87 aluminum alloys; and for copper. Molybdate-containing inhibitors exhibit an immediate, positive effect for steel corrosion, but an incubation period may be required for aluminum before the effect of a given inhibitor can be determined. The absence of oxygen was found to provide a positive effect (smaller corrosion rate) for steel and copper, but a negative effect for aluminum. This is attributed to the two possible mechanisms by which aluminum can oxidize. Corrosion inhibition is generally similar for oxygen-rich and oxygen-free environments. The results of this study show that the electrochemical method is an effective means of screening inhibitors for the corrosion of single metals, with caution to be exercised in the case of aluminum.

Ultimate safety factors of high performance structures depend on stress behavior beyond the elastic limit—a region not too well understood. An analytical modeling approach was developed to gain fundamental insights into inelastic responses of simple structural elements. Nonlinear material properties were expressed in engineering stresses and strains variables and combined with strength of material stress and strain equations similar to numerical piece-wise linear method. Integrations are continuous which allows for more detailed solutions. Included with interesting results are the classical combined axial tension and bending load model and the strain gauge conversion to stress beyond the elastic limit. Material discontinuity stress factors in butt-welds were derived. This is a working-type document with analytical methods and results applicable to all industries of high reliability structures.

Sandwich composites of aluminum and glass/phenolic honeycomb core were tested for shear strength before and after impact damage. The assessment of shear strength was performed in two ways; by four-point bend testing of sandwich beams and by a novel "double lap shear" (DLS) test. This novel testing technique was developed so smaller specimens could be used thus making the use of common laboratory scale fabrication and testing possible. The two techniques yielded similar data. The DLS test gave slightly lower shear strength values of the two methods but were closer to the supplier's values for shear strength.

This paper presents a unique scheme for reconstructing tethered satellite skiprope motion by ground processing of satellite magnetometer measurements. The measurements are modified based on ground knowledge of the Earth's magnetic field and passed through bandpass filters tuned to the skiprope frequency. Simulation results are presented which verify the scheme and show it to be quite robust. The concept is not just limited to tethered satellites. Indeed, it can be applied wherever there is a need to reconstruct the coning motion of a body about a known axis, given measurements of a known vector in body-fixed axes.

Hydrogen diffusion coefficients have been measured for several alloys, and these have been determined to be about the same at 25 °C for all alloys investigated. The relation of structure, both metallurgical and crystallographic,
the observed hydrogen distribution on charging has been investigated, as well as the role of hydride formation in the hydrogen resistance of metal alloys. An attempt has been made to correlate the structures and compositions of metals alloys as well as other parameters with the ratios of their notched tensile strengths in hydrogen to that in helium, R(H₂/He), which are believed to represent a measure of their hydrogen resistance. Evidence supports the belief that hydrogen permeability and hydrogen resistance are increased by smaller grain sizes for a given alloy composition.

TP-3138 July 1991

The test program discussed in this report has potentially wide application to the testing and structural analysis of polymer materials and other materials generally characterized as being made of viscoelastic materials. A joint National Aeronautics and Space Administration, Jet Propulsion Laboratory, and Army program of test and analysis has been established in order to provide the nonlinear, viscoelastic biaxial characterization of the structural and mechanical properties of the space shuttle solid rocket motor (SRM) propellant and the advanced solid rocket motor (ASRM) propellant. This investigation will also endeavor to obtain a consistent and complete set of propellant materials failure data. The data base and accompanying theoretical characterization will be used to improve and revise finite element modeling for shuttle and ASRM-propellant motors.

TP-3139 August 1991

This document details seven proposed methods for creating resource envelopes for Space Station Freedom mission planning. Four reference science activity models are used to illustrate the effect of adding operational flexibility to mission timelines. For each method, a brief explanation is given along with graphs to illustrate the application of the envelopes to the power and crew resources. The benefits and costs of each method are analyzed in terms of resource utilization. In addition to the effect on individual activities, resource envelopes are analyzed at the experiment level.

TP-3148 September 1991

A stress corrosion cracking (SCC) evaluation of carburized AISI 9310 and carburized M-50 NiL steels was undertaken. AISI 9310 is a candidate substitute to 440C for the bearing inner race in the space shuttle main engine alternate turbopump development program, and M-50 NiL may also find applications as a bearing alloy. Round tensile specimens of these alloys at several stress levels, as well as corrosion samples of AISI 9310, were exposed to 100-percent relative humidity at 38 °C (100 °F). The maximum tensile stresses that produced no SCC failures in 1 year of exposure were 172 MPa (25 ksi) for AISI 9310 and 345 MPa (50 ksi) for M-50 NiL. Each AISI 9310 steel fracture showed a circumferential crack between the case and the core. Both alloys developed rust on the surface and pitting; however, AISI 9310 rusted to a greater extent than M-50 NiL. Thin, dense chrome (TDC) was also evaluated in this program as a corrosion barrier alternative; however, its protection was minimal. Corrosion spots visible to the naked eye appeared in less than 5 days of exposure. Although TDC plating on test specimens prevented the intensive corrosion attack which occurred in bare samples after a long time exposure, the TDC plating did not offer sufficient protection to avoid failures. The results obtained in this evaluation must be carefully considered when designing bearing components made of these materials.

TP-3161 September 1991

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.


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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

C.D. BEAN
Director
Administrative Operations Office