FY 1998 Scientific and Technical Reports, Articles, Papers, and Presentations

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National Aeronautics and Space Administration

Marshall Space Flight Center

March 1999
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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Investigation of the Springback Associated With Composite Material Component Fabrication (MSFC Center Director’s Discretionary Fund Final Report, Project No. 94–09). M.A. Benzie. Materials and Processes Laboratory.

The objective of this research project was to examine processing and design parameters in the fabrication of composite components to obtain a better understanding and attempt to minimize springback associated with composite materials. To accomplish this, both processing and design parameters were included in a Taguchi-designed experiment. Composite angled panels were fabricated, by hand layup techniques, and the fabricated panels were inspected for springback effects. This experiment yielded several significant results. The confirmation experiment validated the reproducibility of the factorial effects, error recognized, and experiment as reliable. The material used in the design of tooling needs to be a major consideration when fabricating composite components, as expected. The factors dealing with resin flow, however, raise several potentially serious material and design questions. These questions must be dealt with up front in order to minimize springback: viscosity of the resin, vacuum bagging of the part for cure, and the curing method selected. These factors directly affect design, material selection, and processing methods.

Low velocity dropweight impact tests were conducted on carbon/epoxy laminates under various boundary conditions. The composite plates were 8-ply (+45.0,−45.90)s laminates supported in a clamped-clamped/free-free configuration with varying amounts of in-plane load, Nx, applied. Specimens were impacted at energies of 3.4, 4.5, and 6 Joules (2.5, 3.3, and 4.4 ft-lb). The amount of damage induced into the specimen was evaluated using instrumented impact techniques, x-ray inspection, and cross-sectional photomicroscopy. Some static indentation tests were performed to examine if the impact events utilized in this study were of a quasi-static nature and also to gain insight into the shape of the deflected surface at various impact load combinations. Load-displacement curves from these tests were compared to those of the impact tests, as was damage determined from x-ray inspection.

The International Space Station (ISS) incorporated elements designed and developed by an international consortium led by the United States (U.S.), and by Russia. For this cooperative effort to succeed, it is crucial that the designs and methods of design of the other partners are understood sufficiently to ensure compatibility. Environmental Control and Life Support (ECLS) is one system in which functions are performed independently on the Russian Segment (RS) and on the U.S./international segments. This document describes, in two volumes, the design and operation of the ECLS Systems (ECLSS) on board the ISS. Volume I is divided into three chapters. Chapter I is a general overview of the ISS, describing the configuration, general requirements, and distribution of systems as related to the ECLSS, and includes discussion of the design philosophies of the partners and methods of verification of equipment. Chapter II describes the U.S. ECLSS and technologies in greater detail. Chapter III described the ECLSS in the European Attached Pressurized Module (APM), Japanese Experiment Module (JEM), and Italian Mini-Pressurized Logistics Module (MPLM). Volume II describes the Russian ECLSS and technologies in greater detail. These documents present thorough, yet concise, descriptions of the ISS ECLSS.


A test program to determine the tribological properties of several self-lubricating composites was performed. Testing was done using an LFW-1 Friction and Wear machine. Each material was tested at four load levels (66 N, 133 N, 266 N, and 400 N) under ambient conditions. The coefficient of friction and wear rate was determined for each material, and a relative ranking of the composites was made.

Measurement of Damping of Composite Materials for Turbomachinery Applications (MSFC Center Director’s Discretionary Fund Final Report, Project No. 94–05). D.L. Harris. Structures and Dynamic Laboratory. 19980137576N

Many spacecraft systems have ambitious objectives that place stringent requirements on control systems. Achievable performance is often limited because of difficulty of obtaining accurate models for flexible space structures. To achieve sufficiently high performance to accomplish mission objectives may require the ability to refine the control design model based on closed-loop test data and tune the controller based on the refined model. A control system design procedure is developed based on mixed $H_2/H_\infty$ optimization to synthesize a set of controllers explicitly trading between nominal
performance and robust stability. A homotopy algorithm is presented which generates a trajectory of gains that may be implemented to determine maximum achievable performance for a given model error bound. Examples show that a better balance between robustness and performance is obtained using the mixed $H_\infty$ design method than either $H_\infty$ or mu-synthesis control design. A second contribution is a new procedure for closed-loop system identification which refines parameters of a control design model in a canonical realization. Examples demonstrate convergence of the parameter estimation and improved performance realized by using the refined model for controller redesign. These developments result in an effective mechanism for achieving high-performance control of flexible space structures.

**TM—1998–207979 May 1998**


Conditions under which molten metal detachments might occur in a space welding environment are analyzed. A weld pool detachment parameter specifying conditions for pool detachment by impact is derived and corroborated by experimental evidence. Impact detachment for the pool is unlikely. Impact detachment for a drop of metal on the end of the weld wire may be possible under extreme conditions. Other potential causes of molten metal detachment considered, vaporization pressure forces and wire flickout from the pool, did not appear to present significant detachment threats.

**TM—1998–208181 May 1998**


This technical memorandum reports on the mirror material properties that were compiled by NASA Marshall Space Flight Center (MSFC) from April 1996 to June 1997 for preliminary design of the Next Generation Space Telescope (NGST) study. The NGST study began in February 1996, when the Program Development Directorate at NASA MSFC studied the feasibility of the NGST and developed the prephase A program for it. After finishing some initial studies and concepts development work on the NGST, MSFC’s Program Development Directorate handed this work to the Observatory Projects Office at MSFC and then to NASA Goddard Space Flight Center (GSFC). This technical memorandum was written by MSFC’s Preliminary Design Office and Materials and Processes Laboratory for the NGST Optical Telescope Assembly (OTA) team, in support of NASA GSFC. It contains material properties for 9 mirror substrate materials, using information from at least 6 industrial suppliers, 16 textbooks, 44 technical papers, and 130 technical abstracts.

**TM—1998–208194 May 1998**

Thruster Injector Faceplate Testing in Support of the Aerojet Rocket-Based Combined Cycle (RBCC) Concept. M.M. Fazah and J.M. Cramer. Propulsion Laboratory. 19980201177N

To satisfy RBCC rocket thruster requirements of high performance and a minimum amount of free hydrogen at plume boundary, a new impinging injector element using gaseous hydrogen and gaseous oxygen as the propellants has been designed. Analysis has shown that this injector design has potential to provide a high specific impulse (Isp) while minimizing the amount of free hydrogen that is available to be burned with incoming secondary flow. Past studies and test programs have shown that gas/gas-impinging elements typically result in high injector face temperatures due to combustion occurring close to the face. Since this design is new, there is no hot fire experience with this element. Objectives of this test program were to gain experience and hot fire test data on this new rocket thruster element design and injector faceplate pattern.

Twenty-two hot fire tests were run with maximum mixture ratio (MR) and chamber pressure (Pc) obtained at 7.25 and 1,822 psia, respectively. Posttest scanning microscope (SEM) images show only slight faceplate erosion during testing. This injector element design performed well and can be operated at design conditions: (1) Pc of 2,000 psia and MR of 7.0 and (2) Pc of 1,000 psia and MR of 5.0.


The Fiscal Year 1997 Annual Report describes key elements of the NASA Microgravity Research Program. The Program’s goals, approach taken to achieve those goals, and program resources are summarized. A review of the Program’s status at the end of FY97 and highlights of the ground- and flight-based research are provided.

To calculate structural loads of in-line launch vehicles for preliminary design, a very useful computer program is VLOADS 1.4. This software may also be used to calculate structural loads for upper stages and planetary transfer vehicles. Launch vehicle inputs such as aerodynamic coefficients, mass properties, propellants, engine thrusts, and performance data are compiled and analyzed by VLOADS to produce distributed shear loads, bending moments, axial forces, and vehicle line loads as a function of X-station along the vehicle’s length. Interface loads, if any, and translational accelerations are also computed. The major strength of the software is that it enables quick turnaround analysis of structural loads for launch vehicles during the preliminary design stage of its development. This represents a significant improvement over the alternative—the time-consuming and expensive chore of developing finite element models. VLOADS was developed as a Visual BASIC macro in a Microsoft Excel 5.0 workbook on a Macintosh. VLOADS has also been implemented on a PC computer using Microsoft Excel 7.0a for Windows 95. VLOADS was developed in 1996, and the current version was released to COSMIC, NASA's Software Technology Transfer Center, in 1997. The program is a copyrighted work with all copyright vested in NASA.


Accounting for variability of structures in analysis has been a topic of considerable research, with one of the primary goals being able to determine quantifiable measures of statistical probability of a desired response variable to replace experience-based “safety factors.” Several problems with the satisfactory application of this research to realistic structures, though, include accurate definition of the input random variables, the large size of finite element models, and accurate generation of the Cumulative Distribution Function (CDF) of the response variable. A new method called “probabilistic dynamic synthesis” (PDS) is presented here that addresses these problems. The PDS method uses dynamic characteristics of substructures measured from modal test as input random variables, which accurately account for the entire random character of the substructure, rather than “primitive” random variables representing material or geometric uncertainties. Using the residual flexibility method of component mode synthesis, these dynamic characteristics are used to generate reduced-size sample models of the substructures, which are then used in a Monte Carlo simulation or in the response surface reliability method to obtain the CDF. Both free and forced analyses have been performed, and the results indicate that the method produces usable and more representative solutions for the design of realistic structures with a substantial savings in computer time.


Probabilistic method is not a universally accepted approach for the design and analysis of aerospace structures. The validity of this approach must be demonstrated to encourage its acceptance as a viable design and analysis tool to estimate structural reliability. The objective of this study is to develop a well characterized finite population of similar aerospace structures that can be used to (1) validate probabilistic codes, (2) demonstrate the basic principles behind probabilistic methods, (3) formulate general guidelines for characterization of material drivers (such as elastic modulus) when limited data is available, and (4) investigate how the drivers affect the results of sensitivity analysis at the component/failure mode level.


The purpose of the 1997 NASA Microgravity Technology Report is to update the Microgravity Research Program's technology development policy and to present and assess current technology related activities and requirements identified within its research and technology disciplines.
TECHNICAL MEMORANDUM

July 1998


This paper provides information for trajectory designers and mission planners to determine Earth-Mars and Mars-Earth mission opportunities for the years 2009–2024. These studies were performed in support of a human Mars mission scenario that will consist of two cargo launches followed by a piloted mission during the next opportunity approximately 2 years later. "Porkchop" plots defining all of these mission opportunities are provided which include departure energy, departure excess speed, departure declination, arrival excess speed, and arrival declinations for the mission space surrounding each opportunity. These plots are intended to be directly applicable for the human Mars mission scenario described briefly herein. In addition, specific trajectories and several alternate trajectories are recommended for each cargo and piloted opportunity. Finally, additional studies were performed to evaluate the effect of various thrust-to-weight ratios on gravity losses and total time-of-flight tradeoff, and the resultant propellant savings and are briefly summarized.

July 1998


This document lists the significant publications and presentations of the Space Sciences Laboratory during the period January 1–December 31, 1997. 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 page number) listing preprints issued by the Laboratory during this reporting period. Some of the preprints have not been published; those already published are so indicated. Most of the articles listed under Open Literature have appeared in refereed professional journals, books, monographs, 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 Gregory S. Wilson (ES01: 544–7579) or to one of the authors. The organizational code of the cognizant SSL branch or office is given at the end of each entry.

August 1998


Wastewater and urine generated on the International Space Station will be processed to recover pure water using vapor compression distillation (VCD). To verify the long-term reliability and performance of the VCD Urine Processor Assembly (UPA), life testing was performed at the Marshall Space Flight Center (MSFC) from January 1993 to April 1996. Two UPAs', the VCD-5 and VCD-5A, were tested for 204 days and 665 days, respectively. The compressor gears and the distillation centrifuge drive belt were found to have operating lives of approximately 4,800 hours, equivalent to 3.9 years of operation on ISS for a crew of three at an average processing rate of 1.76 kg/h (3.87 lb/h). Precise alignment of the flex-splines of the fluids and purge pump motor drives is essential to avoid premature failure after about 400 hours of operation. Results indicate that, with some design and procedural modifications and suitable quality control, the required performance and operational life can be met with the VCD/UPS.
Comprehensive Structural Dynamic Analysis of the SSME/AT Fuel Pump First-Stage Turbine Blade.
A.M. Brown.

A detailed structural dynamic analysis of the Pratt & Whitney high-pressure fuel pump first-stage turbine blades has been performed to identify the cause of the tip cracking found in the turbomachinery in November 1997. The analysis was also used to help evaluate potential fixes for the problem. Many of the methods available in structural dynamics were applied, including modal displacement and stress analysis, frequency and transient response to tip loading from the first-stage blade outer gas seals (BOGS), fourier analysis, and shock spectra analysis of the transient response. The primary findings were that the BOGS tip loading is impulsive in nature, thereby exciting many modes of the blade that exhibit high stress at the tip cracking location. Therefore, a proposed BOGS count change would not help the situation because a clearly identifiable resonance situation does not exist. The recommendations for the resolution of the problem are to maintain the existing BOGS count, eliminate the stress concentration in the blade due to its geometric design, and reduce the applied load on the blade by adding shiplaps in the BOGS.

Second United States Microgravity Laboratory. One Year Report, Volume 1.
M. Vlasse, D. McCauley, and C. Walker.

This document reports the one year science results for the important and highly successful Second United States Microgravity Laboratory (USML–2). The USML–2 mission consisted of a pressurized Space lab module where the crew performed experiments. The mission also included a Glovebox where the crew performed additional experiments for the investigators. Together, about 36 major scientific experiments were performed, advancing the state of knowledge in fields such as fluid physics, solidification of metals, alloys, and semiconductors, combustion, and the growth of protein crystals. The results demonstrate the range of quality science that can be conducted utilizing orbital laboratories in microgravity and provide a look forward to a highly productive Space Station era.

Second United States Microgravity Laboratory. One Year Report, Volume 2.
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This document reports the one year science results for the important and highly successful Second United States Microgravity Laboratory (USML–2). The USML–2 mission consisted of a pressurized Space lab module where the crew performed experiments. The mission also included a Glovebox where the crew performed additional experiments for the investigators. Together, about 36 major scientific experiments were performed, advancing the state of knowledge in fields such as fluid physics, solidification of metals, alloys, and semiconductors, combustion, and the growth of protein crystals. The results demonstrate the range of quality science that can be conducted utilizing orbital laboratories in microgravity and provide a look forward to a highly productive Space Station era.

J.E. Turner Waits, Compiler.

This document presents formal NASA technical reports, papers published in technical journals, and presentations by MSFC personnel in FY97. It also includes papers of MSFC contractors.

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.

Model-Based Diagnosis in a Power Distribution Test-Bed. E. Scarl* and K. McCall.

The Rodon model-based diagnosis shell was applied to a breadboard test-bed, modeling an automated power distribution system. The constraint-based modeling paradigm and diagnostic algorithm were found to adequately represent the selected set of test scenarios.
Inherent Conservatism in Deterministic Quasi-Static Structural Analysis. V. Verderaime. Structures and Dynamics Laboratory.

The cause of the long-suspected excessive conservatism in the prevailing structural deterministic safety factor has been identified as an inherent violation of the error propagation laws when reducing statistical data to deterministic values and then combining them algebraically through successive structural computational processes. These errors are restricted to the applied stress computations, and because mean and variations of the tolerance limit format are added, the errors are positive, serially cumulative, and excessively conservative. Reliability methods circumvent these errors and provide more efficient and uniform safe structures. The document is a tutorial on the deficiencies and nature of the current safety factor and of its improvement and transition to absolute reliability.

The Corrosion Protection of Magnesium Alloy AZ31B have been measured. Two Coatings, Dow-23™ and Tagnite™ have been tested by electrochemical methods and their effectiveness determined. Electrochemical methods employed were the scanning reference electrode technique (SRET), the polarization resistance technique (PR) and the electrochemical impedance spectroscopy technique (EIS). In addition, general corrosion and stress corrosion methods were employed to examine the effectiveness of the above coatings in 90 percent humidity. Results from these studies are presented.

The Small Expandable Deployer System (SEDS) was designed to deploy an endmass at the end of a 20-km-long tether which acts as an upper stage rocket, and the threats from the meteoroid and orbital debris (M/OD) particle environments on SEDS components are important issues for the safety and success of any SEDS mission. However, the possibility of severing the tether due to M/OD particle impacts is an even more serious concern, since the SEDS tether has a relatively large exposed area to the M/OD environments although its diameter is quite small. The threats from the M/OD environments became a very important issue for the third SEDS mission, since the project office proposed using the shuttle orbiter as a launch platform instead of the second stage of a Delta II expendable rocket, which was used for the first two SEDS missions.

A series of hypervelocity impact tests were performed at the Johnson Space Center and Arnold Engineering Development Center to help determine the critical particle sizes required to sever the tether. The computer hydrodynamic code or hydrocode called CTH, developed by the Sandia National Laboratories, was also used to simulate the damage on the SEDS tether caused by both the orbital debris and test particle impacts. The CTH hydrocode simulation results provided the much needed information to help determine the critical particle sizes required to sever the tether. The M/OD particle sizes required to sever the tether were estimated to be less than 0.1 cm in diameter from these studies, and these size particles are more abundant in low-Earth orbit than larger size particles. Finally, the authors performed the M/OD damage analyses for the three SEDS missions: i.e., SEDS-1, -2, and -3 missions, by using the information obtained from the hypervelocity impact test and hydrocode simulations results.

Corrosion Studies of 2195 Al-Li Alloy and 2219 Al Alloys have been conducted using the scanning reference electrode technique (SRET) and the polarization resistance (PR) technique. The SRET was used to study corrosion mechanisms, while corrosion rate measurements were studied with the PR technique. Plates of Al₂O₃ blasted, soda blasted and conversion coated 2219 Al were coated with Deft primer and the corrosion rates studied with the EIS technique. Results from all of these studies are presented.

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The projected traffic to geostationary earth orbit (GEO) is expected to increase over the next few decades. At the same time, the cost of delivering payloads from the Earth's surface to low earth orbit (LEO) is projected to decrease, thanks in part to the Reusable Launch Vehicle (RLV). A comparable reduction in the cost of delivering payloads from LEO to GEO is sought. The use of in-space tethers, eliminating the requirement for traditional chemical upper stages and thereby reducing the launch mass, has been identified as such an alternative.

Spinning tethers are excellent kinetic energy storage devices for providing the large delta vee's required for LEO to GEO transfer. A single-stage system for transferring payloads from LEO to GEO was proposed some years ago. The study results presented here contain the first detailed analyses of this proposal, its extension to a two-stage system, and the likely implementation of the operational system.

Probability and Statistics in Aerospace Engineering.
M.H. Rheinfurth and L.W. Howell. Systems Analysis and Integration Laboratory. 19980045313N

This monograph was prepared to give the practicing engineer a clear understanding of probability and statistics with special consideration to problems frequently encountered in aerospace engineering. It is conceived to be both a desktop reference and a refresher for aerospace engineers in government and industry. It could also be used as a supplement to standard texts for in-house training courses on the subject.

A Study of Friction Stir Welded 2195 Al-Li Alloy by the Scanning Reference Electrode Technique.
M.D. Danford and M.J. Mendrek. Materials and Processes Laboratory. 19980046577N

A study of the corrosion of friction stir welded 2195 Al-Li alloy has been carried out using the scanning reference electrode technique (SRET). The results are compared to those obtained from a study of heterogeneously welded samples.

TP—1998–207686 April 1998

The corrosion and stress corrosion cracking (SCC) characteristics of annealed and hardened 440C stainless steel were evaluated in high humidity and 3.5-percent NaCl solution. Corrosion testing consisted of an evaluation of flat plates, with and without grease, in high humidity, as well as electrochemical testing in 3.5-percent NaCl. Stress corrosion testing consisted of conventional constant strain, smooth bar testing in high humidity in addition to two relatively new techniques under evaluation at MSFC. These techniques involve either incremental or constant rate increases in the load applied to a precracked SE(B) specimen, monitoring the crack-opening-displacement response for indications of crack growth. The electrochemical corrosion testing demonstrated an order of magnitude greater general corrosion rate in the annealed 440C. All techniques for stress corrosion testing showed substantially better SCC resistance in the annealed material. The efficacy of the new techniques for stress corrosion testing was demonstrated both by the savings in time and the ability to better quantify SCC data.

Application of Rapid Prototyping Methods to High-Speed Wind Tunnel Testing (MSFC Center Director’s Discretionary Fund Final Report, Project No. 96–21). A.M. Springer. Structures and Dynamics Laboratory. 19980201248 N

This study was undertaken in MSFC’s 14-Inch Trisonic Wind Tunnel to determine if rapid prototyping methods could be used in the design and manufacturing of high speed wind tunnel models in direct testing applications, and if these methods would reduce model design/fabrication time and cost while providing models of high enough fidelity to provide adequate aerodynamic data, and of sufficient strength to survive the test environment. Rapid prototyping methods utilized to construct wind tunnel models in a wing-body-tail configuration were: fused deposition method using both ABS plastic and PEEK as building materials, stereolithography using the photopolymer SL–5170, selective laser sintering using glass reinforced nylon, and laminated object manufacturing using plastic reinforced with glass and “paper.”

This study revealed good agreement between the SLA model, the metal model with an FDM–ABS nose, and SLA nose, and the metal model for most operating conditions, while the FDM–ABS data diverged at higher loading conditions. Data from the initial SLS model showed poor agreement due to problems in post-processing, resulting in a different configuration. A second SLS model was tested and showed relatively good agreement.
It can be concluded that rapid prototyping models show promise in preliminary aerodynamic development studies at subsonic, transonic, and supersonic speeds.

TP—1998–208475
19980203952N

The results of a study performed to evaluate the feasibility and merits of using an electrodynamic tether for propulsion and power generation for a spacecraft in the Jovian system are presented. The environment of the Jovian system has properties which are particularly favorable for utilization of an electrodynamic tether. Specifically, the planet has a strong magnetic field and the mass of the planet dictates high orbital velocities which, when combined with the planet's rapid rotation rate, can produce very large relative velocities between the magnetic field and the spacecraft. In a circular orbit close to the planet, tether propulsion forces are found to be as high as 50 N and power levels as high as 1 MW.

TP—1998–208528
An Assessment of the Technology of Automated Rendezvous and Capture in Space. M.E. Polites. Astrionics Laboratory. 19980219470N

This paper presents the results of a study to assess the technology of automated rendezvous and capture (AR&C) in space. The outline of the paper is as follows. First, the history of manual and automated rendezvous and capture and rendezvous and dock is presented. Next, the need for AR&C in space is established. Then, today's technology and ongoing technology efforts related to AR&C in space are reviewed. In light of these, AR&C systems are proposed that meet NASA's future needs, but can be developed in a reasonable amount of time with a reasonable amount of money. Technology plans for developing these systems are presented: cost and schedule are included.

TP—1998–208530
Reusable Rocket Engine Operability Modeling and Analysis. R.L. Christenson and D.R. Komar. Propulsion Laboratory. 19980218686N

This paper described the methodology, model, input data, and analysis results of a reusable launch vehicle engine operability study conducted with the goal of supporting design from an operations perspective. Parallelizing performance analyses in schedule and method, this requires the use of metrics in a validated operations model useful for design, sensitivity, and trade studies. Operations analysis in this view is one of several design functions.

An operations concept was developed given an engine concept and the predicted operations and maintenance processes incorporated into simulation models. Historical operations data at a level of detail suitable to model objectives were collected, analyzed, and formatted for use with the models, the simulations were run, and results collected and presented. The input data used included scheduled and unscheduled timeline and resource information collected into a Space Transportation System (STS) Space Shuttle Main Engine (SSME) historical launch operations database. Results reflect upon the importance not only of reliable hardware but upon operations and corrective maintenance process improvements.

TP—1998–208591

During the rise from sunspot minimum to maximum, the observed value of smoothed monthly mean sunspot number at maximum RM is found to correlate with increasing strength against the current value of smoothed monthly mean sunspot number R(t), where \( t \) is the elapsed time in months from minimum. On the basis of the modern era sunspot cycles (i.e., cycles 10–22), the inferred linear correlation is found to be statistically important (i.e., at the 95-percent level of confidence) from about 11 mo past minimum and statistically very important (i.e., at the 99-percent level of confidence) from about 15 mo past minimum; ignoring cycle 19, the largest cycle of the modern era, the inferred linear correlation is found to be statistically important from cycle onset. On the basis of \( R(t) \), estimates of RM can be gauged usually to within about ±30 percent during the first 2 yr past minimum and statistically very important (i.e., at the 99-percent level of confidence) from about 15 mo past minimum; ignoring cycle 19, the largest cycle of the modern era, the inferred linear correlation is found to be statistically important from cycle onset. For cycle 23, because controversy exists regarding the placement of its minimum (i.e., its onset), being either May 1996 or perhaps August 1996 (or shortly thereafter), estimates of its RM are divergent, being lower (more like a mean size cycle) when using the earlier epoch of minimum...
and higher (above average in size) when using the later-occurring minimum. For smoothed monthly mean sunspot number through October 1997 (t = 17 or 14 mo, respectively), having a provisional value of 32.0, the earlier minimum date projects an RM of 110.3 ± 33.1, while the later minimum date projects one of 137.2 ± 41.2. The projection is slowly decreasing in size using the earlier onset date, while it is slowly increasing in size using the later onset date.

Volcanism, Cold Temperature, and Paucity of Sunspot Observing Days (1818–1858): A Connection?
R.M. Wilson. Space Sciences Laboratory.

During the interval of 1818–1858, several curious decreases in the number of sunspot observing days per year are noted in the observing record of Samuel Heinrich Schwabe, the discoverer of the sunspot cycle, and in the reconstructed record of Rudolf Wolf, the founder of the now familiar relative sunspot number. These decreases appear to be nonrandom in nature and often extended for 1–3 yr (or more). Comparison of these decreases with equivalent annual mean temperature (both annual means and 4-yr moving averages), as recorded at Armagh Observatory (Northern Ireland), indicates that the temperature during the years of decreased number of observing days trended downward near the start of each decrease and upward (suggesting some sort of recovery) just before the end of each decrease. The drop in equivalent annual mean temperature associated with each decrease, as determined from the moving averages, measured about 0.1–0.7 °C. The decreases in number of observing days are found to be closely related to the occurrences of large, cataclysmic volcanic eruptions in the tropics or northern hemisphere. In particular, the interval of increasing number of observing days at the beginning of the record (i.e., 1818–1819) may be related to the improving atmospheric conditions in Europe following the 1815 eruption of Tambora (Indonesia: 8°S), which previously has been linked to “the year without a summer” (in 1816) and which is the strongest eruption in recent history, while the decreases associated with the years of 1824, 1837, and 1847 may be linked, respectively, to the large, cataclysmic volcanic eruptions of Galunggung (Indonesia: 7°S) in 1822, Cosiguina (Nicaragua) in 1835, and, perhaps, Hekla (Iceland: 64°N) in 1845. Surprisingly, the number of observing days per year, as recorded specifically by Schwabe (from Dessau, Germany), is found to be linearly correlated against the yearly mean temperature at Armagh Observatory (r = 0.5 at the 2 percent level of significance); thus, years of fewer sunspot observing days in the historical record seem to indicate years of probable cooler climate, while years of many sunspot observing days seem to indicate years of probable warmer climate (and vice versa). Presuming this relationship to be real, one infers that the observed decrease in the number of observing days near 1830 (i.e., during “the lost record years” of 1825 to 1833) provides a strong indication that temperatures at Armagh (and, perhaps, most of Europe, as well) were correspondingly cooler. If true, then, the inferred cooling may have resulted from the eruption of Kliuchevskoi (Russia: 56°N) 1829.
Volume One of the General Public Space Travel and Tourism Workshop is a summary of the findings of the participants. This document provides an overview of the infrastructure requirements, policy and regulation needs, and potential near term activities.

Volume II contains the detailed findings of the multi-day workshop conducted at Georgetown University, Washington, DC.

This is a compilation of 25 papers presented at a tether technical interchange meeting in Huntsville, AL, on September 9–10, 1997. After each presentation, a technical discussion was held to clarify and expand the salient points. A wide range of subjects was covered including tether dynamics, electrodynamics, space power generation, plasma physics, ionospheric physics, towing tethers, tethered reentry schemes, and future tether missions.

This document reports the results and analyses presented at the Life and Microgravity Spacelab (LMS) One Year Science Review meeting. The science conference was held in Montreal, Canada, on August 20–21, 1997, and was hosted by the Canadian Space Agency. The LMS payload flew on the Space Shuttle Columbia (STS–78) from June 20–July 7, 1996. The LMS investigations were performed in a pressurized Spacelab module and the Shuttle middeck. Forty scientific experiments were performed in fields such as fluid physics, solidification of metals, alloys, and semiconductors, the growth of protein crystals, and animal, human, and plant life sciences. The results demonstrate the range of quality science that can be conducted utilizing orbital laboratories in microgravity.
CR—97-205192 July 1997

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- **Internal/External References:**
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- **Publication Dates:**
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- **Citations:**
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**Conference Details:**

- **STAIF-98**
  - Space Technology and Applications International Forum

**Journal Details:**

- **Astrophysical Journal**
- **Journal of Geophysical Research—Atmospheres**
- **International Astronomical Union (IAU) Circular**
- **Nature**
- **Mir Glovebox Facility**
- **Research Program Results Symposium**
- **12th Conference on Numerical Weather Prediction**

**Location Details:**

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