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The 1990 Johnson Space Center Bibliography of Scientific and Technical Papers

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The 1990 Johnson Space Center Bibliography of Scientific and Technical Papers

Compiled by
Management Services Division
Lyndon B. Johnson Space Center
Houston, Texas

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

December 1991

PREFACE

This listing of the Johnson Space Center's scientific and technical publications and presentations is grouped by subject categories and arranged alphabetically by author within each category. The category numbers and titles are those used in the Scientific and Technical Aerospace Reports (STAR) abstracts issued by NASA's Center for Aerospace Information (CASI). Authors include JSC employees, contractors, grantees, and independent collaborators. Abbreviations for authors' organizations are given in parentheses after the name(s) of the author(s). When two or more authors in sequence are from the same organization, the affiliation is given only after the name of the last person in that sequence.

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STAR Category 2 - Aerodynamics

Krech, R. H.; Gauthier, M. J.; Caledonia, G. E. (Physical Sciences Inc.): High Velocity Gas Surface Accommodation Final Report, NASA CR- 185629, August 1990.

The purpose of the Phase I effort was to demonstrate that Physical Sciences Inc.'s unique fast atom source could be used to measure the accommodation coefficients of hypersonic atmosphere species interacting with various material surfaces. All the goals of Phase I have been met, having demonstrated the ability to measure energy accommodation coefficients of 8 km/s oxygen atoms on selected materials. Preliminary measurements have been provided for three materials at normal incidence. Neglecting chemical energy, the accommodation coefficients for Ni, Au, and RCG are all $\sim 0.6 \pm 50$ percent. The beam source also has been characterized for fast nitrogen atom production at several velocities. Last, a series of diagnostics has been suggested for the measurement of momentum transfer characteristics of fast atom/material interactions. The techniques studied in Phase I show great promise for the Phase II development of an (until now) elusive data base to describe the aerodynamic interactions of fast atmospheric species with aerospace materials.

Simpson, D. B. (LESC): Aeroassist Flight Experiment (AFE) Aerodynamic Stability Derivative Extraction (ASDE) Results. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

This presentation will show the results of recent studies completed in support of the AFE Aerodynamic Performance Experiment (APEX). The process used in extracting the AFE aerodynamic stability derivatives and its major sources of error will be addressed. In particular, the results from noise sensitivity and multiple random error analyses will be reviewed. These analyses have shown that the ASDE process has a significant sensitivity to errors in data received from the AFE Inertial Measurement Unit.

Xu, G.; and West, M. (LESC): An Iterative Algorithm for Correlation of Strain Gage Data with Aerodynamic Load. Published in the *AIAA Journal of Aircraft*, Vol. 27, No. 1, pp. 668-670, July 1990.

An iterative algorithm is presented for correlating strain gage data (from flight) with aerodynamic loads using a finite element structural model. The method is illustrated using flight data from the Space Shuttle Orbiter wing. This approach presents a linear combination technique, which assumes the aerodynamic load on the structure can be represented by using a set of polynomial shape functions over the wing surface. A finite element model of the wing structure is used to calibrate the shape functions in terms of unit strain at given gage locations. From measured gage data, weight factors for the shape functions are computed, thus determining the pressure distribution on the structure. It will be shown that iteration of this scheme can improve the accuracy of the computed pressure distribution.

STAR Category 3 - Air Transportation and Safety

Monteleone, F. J. (JSC): Application of Materials Requirements in the Certification of Materials in JSC Flight Hardware Payloads. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

Materials used in all JSC flight hardware payloads must meet the intent of the materials requirements in NASA Handbook (NHB) 1700.7B relative to flight safety. The basic materials flammability and offgassing test verification requirements are identified in NHB 8060.1B. Additional materials usage

requirements must be met for application in liquid oxygen and pressurization gaseous oxygen. These requirements will be included in NHB 8060.1C when it is released later this year; details can be obtained from JSC Materials Technology Branch. The MSFC-SPEC-522B identifies potential stress corrosion sensitive materials. Details of the fracture control requirements for flight materials are presented in NHB 8071.1. The overall materials requirements for JSC controlled payloads should meet the intent of JSC-SE-M-0096A and the overall acceptance ratings identified in MSFC-HDBK-527F/JSC-09604F.

STAR Category 12 - Astronautics (General)

Badhwar, Gautam, D. (JSC); Anz-Meador, Phillip, D. (LESC): Earth Orbital Environments/Launch Vehicles/Orbital Maneuvers/ Payloads. Presented to the British Interplanetary Society, September 1990.

An attempt is made to estimate the mass of the parent satellite from the mass of the debris remaining from its breakup using a technique based on the decay rate and radar cross-section time history. The decay of perigee and apogee with time of an object in orbit provides the area-to-mass ratio and the radar cross-section provides a measure of the effective area of the object, while combining the two gives the mass of the object. The technique has been successfully applied to 12 U.S. breakups and one Arianespace breakup. Calculations exhibiting good agreement with reference mass are also discussed for Soviet intact C-class boosters, intact ASAT target satellites, and intact navigational satellites. It is found that the calculated mass of the ASAT interceptor spacecraft is about one-half of the expected mass, but this may be due to fuel carried on board. For ASAT target breakups the calculated mass is 20-30 times too low; no clear explanation can yet be found for this phenomenon.

Othon, W. L. (LinCom Corporation): Broken Tether and Severed Tether Dynamics: Contingency Procedures for TSS-1. Presented at the 4th International Conference on Tethers in Space, October 1-5, 1990, Florence, Italy.

In preparation for the flight of the Tethered Satellite System (TSS-1), a number of contingency scenarios have been examined involving the structural failure or intentional severing of the tether connecting the Space Shuttle Orbiter and the Italian satellite. These failure scenarios were defined to help develop Orbiter flight techniques to avoid recontact of the tethered satellite or the tether itself with the Orbiter. Tether break involves the material failure of the tether, due to unexpected or extreme mission conditions. The dynamics of broken tethers have been analyzed to define how the tether would move, to determine how a break can be identified by the crew, and to define the techniques to avoid contact between the Orbiter and the severed tether. This tether break analysis was conducted using a finite element tether simulation, which lumped the tether mass into beads connected together in series by spring/dashpot systems. The dynamics of these breaks were compared to mathematical prediction, and procedures for tether break identification were defined.

STAR Category 13 - Astrodynamics

Solcher, W. B.; Robinson, P. E.; Stueber, M. J.; Wiederhoeft, C. J. (LESC): Shuttle Maximum Load Margin Trajectory Design. Presented at the AIAA 15th Annual Technical Symposium, March 24, 1990, Houston, Texas.

This study presents a design method for Space Shuttle ascent flight profiles which optimize launch probability by centering the trajectory within vehicle load

limitations. Earlier flight design studies using simple structures as limiters found that the best results in the critical Mach range were obtained by flying constant dynamic pressure time angle of attach (alpha) and zero angle of sideslip (beta). The detailed load indicators and their parameter sensitivity have changed but not the design parameters. The results of this study shows that flying one set of alpha/beta vs. Mach profiles throughout the year produces wind protection very close to optimum. Flight profiles created using this concept accommodate seasonal environment variations, as well as load driven performance requirements.

Wahbah, M. M. (MDSSC): Rendezvous Trajectory Design. Presented at the International Rendezvous and Docking Conference, July 1990, Houston, Texas.

Cooperative rendezvous and docking between systems that have, or could have, such capabilities can be enhanced by developing standard cooperative rendezvous trajectory design and operations scenarios. This requires the identification of the characteristics of those systems. This paper familiarizes the reader with rendezvous maneuver terminology, common rendezvous trajectory constraints, and rendezvous planning and trajectory design techniques currently employed for the Space Shuttle and the Orbital Maneuvering Vehicle (OMV). The paper also presents typical Shuttle and OMV rendezvous profiles.

Wilson, S. W. (JSC): Fast Round-Trip Mars Trajectories. Presented at the AIAA/AAS Astrodynamics Conference, August 20-22, 1990, Portland, Oregon.

If a flight crew goes to the surface of Mars and stays there for the duration of their stopover, it is much cheaper (in terms of delta-V or spacecraft mass) to minimize their zero-g exposure by limiting the interplanetary transit time of a conjunction-class mission (round-trip = 800-1000 days, Mars stopover -450-700 days) than to impose the same limit on a opposition-class mission (round-trip time <600 days, stopover = 40 days). Using solid-core nuclear thermal propulsion to fly a conjunction-class mission, for a moderate mass penalty the interplanetary transit time (each way) probably could be limited to something in the range of 4 to 6 months, depending on the launch year.

STAR Category 14 - Ground Support Systems and Facilities (Space)

Brown, P. M.; Hajare, A. R.; Stark, G. E. (MITRE): Challenges in the 1990s for Astronaut Training Simulators. Presented at the AIAA Flight Simulation Technologies Conference, September 17-19, 1990, Dayton, Ohio.

In 1978 NASA began using the Shuttle Mission Simulator for training astronauts for the first Space Shuttle flight. Over the last decade, the training facility has evolved with the additions of digital visual systems, a network simulator, and payload simulators. With an ambitious space program planned for the nineties, astronaut training will levy significant new challenges for the simulation community at the Johnson Space Center. This paper describes these challenges both in the near term and the long term. The former includes the challenges of supporting an increasing flight rate, maintaining operations while replacing obsolete subsystems, and incorporating forthcoming changes to the Space Shuttle. Foremost among the long term challenges is training astronauts for complex concurrent missions involving multiple spacecraft and geographically dispersed ground facilities. Other long term challenges include improving the simulator reliability and the operational efficiency of the facilities.

Brown, P. M.; Hajare, A. R. (Mitre): The Shuttle Mission Training Facility at the Johnson Space Center. Presented at the Technology and Innovations In Training and Education Conference, March 12, 1990, Colorado Springs, Colorado.

The Shuttle Mission Training Facility (SMTF) is the primary facility for full mission training for astronauts. In addition to astronaut training, this facility supports the training of ground controllers in the Mission Control Center (MCC). Initially, the SMTF consisted of the fixed base and the motion base Shuttle mission simulators, along with the network simulation system which linked either Space Shuttle simulator to the MCC. As the Shuttle program progressed, the SMTF grew to accommodate new requirements. The enhancements to the facility included additional computers, a separate development facility, a Spacelab simulator, and three payloads simulators. In spite of these enhancements, the facility had limitations which meant that it would not be able to handle the flight rate projected for the 1990s. After an extensive study, a thorough upgrade was started. The upgrade will replace obsolete equipment, improve reliability and maintainability, enhance the fidelity of the simulators, and provide more capacity to support a higher flight rate.

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Doane, K.; McCleary, B.; Pendergrass, P.; Pesek, D. (MDSSC): Day-of-Launch, GNPLOT and ALS Flight Operations Demonstrations. Presented at the Transportable Applications Environment User's Conference, June 5-7, 1990, League City, Texas.

This demonstration presents how the process of doing Day-of-Launch (DOL) wind assessment can be moved off a UNIVAC main frame computer and into a workstation environment, shows how a TAE built interface could be hooked into a commercial graphics package to allow the user to define various types of plot output, and presents how a TAE built user interface could be used to streamline the flight design process for the Advanced Launch System.

Early, L. M. (LESC): An Approach to Scheduling Large Numbers of Interactive Projects - Project Management in the Systems Engineering Simulator (SES). Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The systems engineering simulator (SES), located at the Lyndon B. Johnson Space Center, provides real-time simulation for all on-orbit man-in-the-loop spaceflight activities including astronaut training, mission procedures development,

and space system engineering assessment. Primavera Project Planner project management and control software is used to generate integrated schedules of over 60 SES interrelated projects ranging from 20-400 activities per project. Primavision Plotter graphics software provides presentation-quality management visual aids including Gantt charts and network diagrams. Gantt charts of these SES projects provide the framework for weekly project status meetings conducted with NASA. This presentation discusses the rationale for an integrated project management approach and provides specific examples of SES project schedules reflecting interdependencies and various summary capabilities.

Gleason, W. R. (LESC): Interactive Hierarchical Simulation Development Environment for the Space Systems Automated Integrations and Assembly Facility (SSAIAF). Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The mission of the SSAIAF, located at the Lyndon B. Johnson Space Center, is to support development of assembly and operation procedures, as well as to provide an engineering development tool for the assembly of large space structures. This includes the Space Station Freedom (SSF), modification to SSF for lunar and Mars exploration, and construction of lunar and Mars orbital platforms. The tasks to be performed by SSAIAF have been divided into four categories: simulation, hardware control, simulation and hardware monitoring, and data analysis. Each user of the SSAIAF may select any combination of these tasks and apply them to multiple pieces of hardware simultaneously. This creates a lengthy and complicated development process for each scenario which is to be simulated. This presentation provides an interactive hierarchical environment for simulation model building and manipulation which will provide a cost-effective method for scenario development, modification, and growth.

Hye, A. (LESC): JSC Avionics Engineering Lab (JAEL) Overview. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The JSC Avionics Engineering Lab (JAEL) consists of (1) a simulation element that supports closed-loop capability with flight system element; (2) integrate simulation, interface, and flight system elements; (3) an auto mode capability from entry interface to main gear touchdown; and (4) a data management system for validation. Existing entry Shuttle engineering simulation (SES) simulation software is being modeled to enhance execution speed. The JAEL provides quick access to hardware and software for engineering work, is user friendly, and can stop and continue an entire simulation for dumps or debug. It also is equipped with a main general-purpose computer (GPC) console where new GPCs are being tested for production purposes and the console can be used in the Shuttle Avionics Integration Laboratory (SAIL)/JAEL interconnect mode. The burn-in console is being used for open-loop testing with new and old GPCs and for closed-loop testing with new GPCs.

Lueke, W. J. (JSC): Modernization of a NASA/JSC Arc-Heated Wind Tunnel Reentry Environment Test Facility. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The construction phase is under way for a fiscal year (FY) 1989 construction of facility project at JSC to modernize the 10Mw Atmospheric Reentry Materials and Structures Evaluation Facility; Protection System Engineering at JSC, and future programs testing thermal protection systems for manned spacecraft. The project will refurbish the Arc-Heated Wind

Tunnel Reentry Environment Test Facility with construction of a new 12 foot diameter vacuum test chamber. The project will replace two aging boilers with one large boiler to drive the steam ejector vacuum pumping system serving both test positions. A "Laser Light" enclosure will be constructed next to the new test chamber for plasma diagnostics work. A new metal building will also be constructed on the west side of bldg. 222 for a shop area.

McDonald, W. P. (LESC): Validation of the Systems Engineering Simulator (SES). Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The SES is a large-scale man-in-the-loop simulator, which is currently being used to support Space Shuttle and Space Station Freedom engineering design studies. Validation of such a simulator is an ongoing process which takes place at several levels of complexity and involves a variety of validation criteria. This presentation provides an overview of the current SES validation activities in support of the SES On-orbit Elements Simulator (OES). These activities include development of validation plans, running validation tests, analyzing test data, presentation of validation reports, and maintenance of the OES validation status data base. The baseline validation data for the OES ranges from offline calculations and data from other simulators, to flight data and comments from astronauts. The future plans include the development of expert systems to automate the validation process.

McKay, T. D. (LESC): Lockheed's Support of the Human-Computer Interaction Laboratory at Johnson Space Center. Presented at Lockheed's 10th Corporate Supportability Symposium, May 22-23, 1990, Burbank, California.

The paper provides the reader an understanding of the role of the Human-Computer Interaction Laboratory (HCIL) in the NASA Agency. The role the NASA technical monitor plays in the laboratory and the role of the Lockheed personnel are reviewed. A description of the computer hardware and software used in the HCIL is provided, as is a review of the work currently being conducted in the HCIL. The work is categorized into the areas of applied research, human computer interface program support, and lunar and Mars mission activities. Finally, a brief discussion of future work for the HCIL is covered.

Nguyen, L. A. (LESC): Space Station Mobile Servicing Center Real Time Simulator. Presented at the 1990 SCS Western Multiconference, January 17-19, 1990, San Diego, California.

The Mobile Servicing Center (MSC) of the Space Station Freedom consists of two seven-joint manipulator arms mounted on a transporter which can move along the space station truss structure. An effort has been made to construct a real time, man-in-the-loop dynamic simulator of this system in the Systems Engineering Simulator (SES), located at JSC. This presentation describes the development of mathematical models involved in the simulation, as well as their implementation on dual processor minicomputers together with all software designs needed to make this a pioneer MSC simulator.

Rudisill, M. (JSC): NASA Johnson Space Center Human-Computer Interaction Laboratory. Presented at the Space Operations, Applications, and Research Symposium, June 28, 1990, Albuquerque, New Mexico.

The Human-Computer Interaction Laboratory (HCIL) was established in 1984 at the NASA Johnson Space Center to (1) perform applied research in human interaction with advanced computer-based technologies, and (2) provide a resource of personnel, a facility, and a research data base to support the design of human-

computer interfaces within spacecraft. The HCIL has an active applied research program and is involved in several spacecraft research projects. Work is organized into (1) Base Research and Technology (e.g., Interfaces to Intelligent Systems, Onscreen Graphics, HCI in Multitasking Environments) (2) Program HCI Support (e.g., Space Station Freedom, Spacelab) and (3) the Human Exploration Initiative (e.g., Operator Modeling, Information Technologies Data Base). A description of personnel, the facility, and organization is given in addition to an overview of laboratory projects.

Sims, J. T. (JSC); Sterling, M. R. (RSOC): Ascent/Abort Training in the Shuttle Mission Simulator. Presented at the AIAA Flight Simulation Technologies Conference and to be published in the proceedings, September 17-19, 1990, Dayton, Ohio.

Space Shuttle ascents and ascent aborts present a unique training problem. Shuttle abort profiles include scenarios that range from flights to orbit to landings at various international landing fields. Orbiter flight crews are trained in ascent and abort flight techniques at the Johnson Space Center. The Shuttle Mission Simulator is the primary tool used in this training. It employs a motion system, visual systems, and a high-fidelity cockpit to enhance training accuracy. A team concept is used to train flight crews and flight controllers for each mission to ensure a thorough understanding in both orbiter systems and mission specific flight profiles.

Stark, G. E. (MITRE): Software Reliability for Flight Crew Training Simulators. Presented at the AIAA Flight Simulation Technologies Conference, September 17, 1990, Dayton, Ohio.

Flight crew simulator failures are costly and may affect the timing or efficiency of a mission; thus, reliability is one of the most important issues facing simulator developers today. The reliability of a simulator is the probability that a training session of length t can be completed without a failure. Simulator failure is defined and three sources of failure are compared. Also discussed are the cost of software failure, a model for software reliability measurement, and a method for establishing a software reliability object. Data from the NASA Shuttle Mission Training Facility are presented to illustrate the technique, and the implications of using the method on the software testing process are examined.

STAR Category 15 - Launch Vehicles and Space Vehicles

Brady, T. K. (JSC): Summary of Results from the Testing of Three Prototype Thermal Bus Systems for Space Station Freedom. Presented at the AIAA/ASME 6th Thermophysics and Heat Transfer Conference, June 18-20, 1990, Seattle, Washington.

Three Space Station Freedom (SSF) prototype two-phase thermal bus systems, utilizing an ammonia working fluid, underwent extensive evaluation at the Johnson Space Center (JSC) thermal testbed during 1988 and 1989. The thermal buses delivered to and tested at JSC were manufactured by Boeing Aerospace Corporation (BAC), Grumman, and Lockheed Engineering and Sciences Company (LESC), respectively. All three test articles were exercised in a similar ambient test program to characterize performance under simulated SSF operating conditions. Additionally, the BAC and LESC thermal buses were integrated with heat pipe radiators and tested in a thermal vacuum environment. Testing at JSC has shown that two-phase thermal bus performance can generally be bounded in an ambient test program; however, integrated thermal vacuum testing with SSF prototype heat pipe

radiators is required to fully characterize system performance.

Buck, C. A. (MDSSC): Space Station Freedom Airlock/Extravehicular Activities Operations. Presented at the 20th Intersociety Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

The Space Station Freedom airlock is a pressurized flight element slated for launch in mid-1997. The airlock has an integral part in space station procedures and is responsible for providing resources and equipment for a variety of unique operations. These operations include nominal extravehicular activity (EVA) egress and ingress, pre-breathe procedures, suit servicing, large orbital replacement unit (ORU) pass-through operations, hyperbaric treatments, and routine airlock maintenance. Some of these scenarios are quite complex, and require the airlock to operate at a wide range of internal pressures and temperatures. This paper discusses the general configuration and, in more detail, the various operational scenarios and their impact on the airlock design. The airlock is composed of two chambers, the equipment lock (EL), and the crewlock (CL). Both chambers have a significant role in efficiently accommodating the airlock outfitting hardware and distributed system interfaces, as well as accomplishing the required operational procedures.

Cerna, P. J. (JSC); Williams, D. E. (MDSSC): Expanded Capabilities of the Extended Duration Orbiter (EDO). Presented at the 20th Annual Intersociety Conference on Environmental Systems (ICES), July 9-12, 1990, Williamsburg, Virginia.

In its current configuration, the orbiter is limited to a maximum of 10 days by Environmental Control and Life Support System (ECLSS) consumables, stowage constraints, and the fuel cell reactants. The capabilities of the EDO will permit longer duration Spacelab, Spacelab, and commercially developed space facility (CDSF) missions. Additionally, the EDO may be required for Space Station Freedom assembly operations in the late 1990s. Of NASA's fleet, both Columbia and Endeavor will be modified to accomplish extended missions of up to 16 days. As compared to the current orbiter, the EDO will consist of an improved carbon dioxide removal system for the cabin to reduce the amount of stowed lithium hydroxide, a redesigned waste collection system to replace the existing unit, extra gaseous nitrogen for the crew cabin atmosphere, increased stowage volume in the middeck for food and personal effects, a new trash compactor to minimize water volume, and additional cryogenic oxygen and hydrogen to maintain necessary power levels.

Faget, N.; Cerna, P. J.; Saucier, D. R. (JSC): Engineering and Operational Aspects of the Extended Duration Orbiter. Presented at the Intersociety Energy Conversion Engineering Conference, August 12, 1990, Reno, Nevada.

NASA is currently pursuing a program to lengthen the mission duration of the Space Shuttle from 10 days to 16 days, with future plans to increase the on-orbit stay time to 28 days. Presently, the length of the mission is limited by fuel cell reactants, stowage constraints, and life support systems consumables. NASA received approval in December 1988 to modify the Columbia to extend its mission duration to 16 days. Additionally, the Endeavor is being manufactured so as to facilitate its transformation to a 28-day vehicle. The first extended-duration orbiter (EDO) launch of Columbia is slated for March 1992 with the United States Microgravity Laboratory as its payload. Scientific payloads which require longer periods of zero-gravity in the vacuum of space will benefit keenly from the EDO program.

Grooms, H. R.; DeBarro, C.F.; Paydarfar, S. (Rockwell International): What Is an Optimal Spacecraft Structure. Presented at the 31st AIAA/ASME/ ASCE/AHS/ACS Structures, Structural Dynamics, and Materials Conference, March 2-4, 1990, Long Beach, California.

A method for performing a comprehensive evaluation of a spacecraft structural design is presented. The paper gives a brief history of structural optimization followed by a description of a typical current spacecraft structural design procedure. The proposed method for the evaluation of structural designs allows for many facets of the design to be considered simultaneously. Additionally, weighting factors are used to allow the relative importance of the various criteria to be incorporated. The results obtained from applying the method to a spacecraft design problem are included.

James, J. T. (JSC); Limero, T. (KRUG); Taylor, R. (KRUG); Pierson, D. (JSC): Space Station Freedom Viewed as a "Tight Building." Presented at the 1990 SAE International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

Space Station Freedom (SSF) - with its 30-year projected lifetime and a completely closed-loop environmental control and life support system - is perhaps the ultimate "tight building." Recognizing the potential to develop tight building syndrome (TBS) and initiating actions to minimize possible TBS occurrences on SSF requires a multi-disciplinary approach that begins with appropriate design concerns and ends with detection and control measures on board SSF. While many of the circumstances and methodologies garnered from investigating tight buildings on Earth are similar to those that might be encountered on board SSF, SSF also presents a unique environment and a special set of constraints which will require the adaptation of previous protocols. Air contamination, including volatile organic compounds and microorganisms, is the focus of the discussion. Preventive steps to avoid TBS, controlling environmental factors that may lead to TBS, and on-board, real-time instrumentation for the detection of potential causes of TBS are also outlined.

Jensen, D. G.; Rudisill, M. (JSC): Evolving Technologies for Space Station Freedom Computer-Based Workstations. Published in the Proceedings of Technology for Space Evolution, a Workshop, 1990.

Space Station Freedom computer-based workstations are comprised of the human-computer interface (HCI) software that presents the displays and hardware that make up the workstations. The HCI software includes the window manager, user interface management system, control and monitor display manager, user-interface language manager, caution and warning annunciation manager, video display manager, and user-support environment session manager. The workstation hardware consists of command and control, cupola, and laboratory workstations that provide station system, manipulator, and free-flyer control capability. Evolving technologies for HCI include voice recognition and production, direct manipulation, enhanced information displays, software automation, intelligent systems, user modeling methods and tools, and HCI prototyping. Evolving technologies that support robotics activities include virtual workstations, machine vision systems, animation, and force reflection.

Lamkin, S. L. (JSC); McCandless, W. (LESC): Pathfinder Autonomous Rendezvous and Docking Project FY 1989 Annual Report, NASA TM-102163, August 1990.

The AR&D Project will develop and demonstrate the support of manned and unmanned vehicle operations in lunar and planetary orbits. In this initial phase of the project, primary emphasis has been placed on definition of the system

requirements for candidate Pathfinder mission applications and correlation of these system-level requirements with specific requirements. The FY 1989 activities detailed in this document are best characterized as foundation building. Most of the effort was dedicated to assessing the current state of the art, identifying desired elaborations and expansions to this level of development, and charting a course that will realize the desired objectives in the future. This document details efforts across all work packages in developing those requirements and tools needed to test, refine, and validate basic AR&D elements.

STAR Category 16 - Space Transportation

Brown, M. F.; Schentrup, S. M. (JSC): Requirements for Extravehicular Activities on the Lunar and Martian Surfaces. Presented at the SAE 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

Since extravehicular activity (EVA) will be an integral part of the establishment of both a lunar base and the exploration of the martian surface, specific requirements for the EVA systems need to be determined. The unique conditions in which an extravehicular mobility unit must operate include environmental factors such as partial gravity, dust, thermal gradients, atmospheric conditions, lighting, and radiation. The suit and portable life support system must be designed to accommodate these environmental factors, but must also support exploration and the establishment of a permanent human presence on these surfaces. This paper presents the requirements for EVA on the lunar and martian surfaces.

Cioni, J. L. (JSC): Crew Emergency Return Vehicle (CERV). Presented at the International Docking Conference, July 1990, Houston, Texas.

NASA, as part of its commitment to safety, has enunciated the concept of Assured Crew Return Capability for manned space missions. The Crew Emergency Return Vehicle is the manifestation of this concept for Space Station Freedom. The CERV concept began at the Johnson Space Center following the Challenger accident and was recommended to be part of the Freedom architecture. Phase A studies concentrated on concepts and requirements, providing a good foundation for carrying the program into the definition phase. Studies have shown that a wide range of vehicle/system concepts exist that can meet the fundamental requirements of CERV. Studies have also shown the concepts to be sound and that a Freedom-based vehicle is required to provide the emergency support needed. The continuing program will provide NASA a detailed understanding of the CERV system, costs, and schedules prior to starting hardware development in FY 1992.

Fraser, G. F. (RSOC): Space Station Assured Crew Return (ACRV) System and Operational Considerations. Presented at the 27th Annual Space Congress, April 24-27, 1990, Cocoa Beach, Florida.

The Space Station currently is being designed to maximize crew safety through fault tolerance, safe-haven provisions, and crew delivery and return along the Space Transportation System (STS). Studies have identified the need for assured crew return capability through a space-based "lifeboat" that is always available for use in medical emergencies, Space Station failures, and interruption of STS services. This paper reviews major mission, operational, and system requirements and the process for evaluating a range of practical options. It describes flight and ground system design concepts and studies

being performed to select the best system. Flight vehicles include capsules with ballistic and low lift/drag characteristics and lifting body aerodynamic-shaped designs. Ground systems emphasize the use of existing resources.

Kennedy, K. J. (JSC): Space Transportation Node: The Atrium Facility. Published in the *Proceedings for Engineering, Construction, Operations in Space II*, April 22-26, 1990, Albuquerque, New Mexico.

During the next 30 years, with the expansion of the infrastructure of space transportation, a transportation node will be an important link between Earth and other planets. This paper presents a conceptual design of a Space Transportation Node used primarily as an assembly platform supporting the lunar transportation system. Although transportation nodes are traditionally an extension of Space Station Freedom, this concept was initiated to study node architecture, not as a growth of Space Station, but rather as an uninhibited concept synthesizing form and function. This concept, the Atrium Facility, is designed to support lunar base activities before, during, and after the lunar base build-up phase. This paper will discuss a few of the key element designs and rational for those concepts.

Mohler, R. R.; Singhal, A. K.; Deardorff, G. W. (LESC); Beckham, W. S. (JSC): Accommodating Scientific Payloads Onboard the Space Shuttle. Presented at the 86th Annual Meeting on the AAG, April 19-22, 1990, Ontario, Canada.

Very few members of the scientific or engineering communities are aware of the procedures and specifications required to integrate a payload on board the Space Shuttle or the timelines involved. As a start in alleviating this information gap, we present the "Mission Management" necessary to accommodate scientific experiments for a Shuttle flight. Many microgravity experiments, such as growing protein products, cell processes, and composite testing, take place in the Shuttle middeck area in specified lockers. These lockers are self-contained and may be supplied with electrical power. Many of these middeck experiments are the precursors to the commercialization of space through space stations and space-based laboratories. Understanding the Mission Management processes will expedite the design of the experiments by the principal investigators and, therefore, experimental results.

Morrison, D. R. (JSC); Holemans, J.; Cassanto, J. (ITA); Rose, A. (MDSSC); Luttges, M. (Univ. of Colorado); Todd, P: Bioserve-ITA Materials Dispersion Apparatus Payload: A Low Cost MPS Payload. Presented at the 41st Annual Meeting of the International Astronautics Federation, December 1990. Dresden, Germany.

This paper presents the design, operation, and experiment protocol of the Bioserve-ITA Materials Dispersion Apparatus (BIMDA) payload to be flown on the Space Shuttle on STS-37. Instrumentation Technology Associates, Inc. and the Bioserve Space Technologies, a NASA Center for the Commercial Development of Space, will investigate the methods and commercial potential of biomedical and fluid science applications in the microgravity environment of space. The BIMDA payload, to be flown in the Refrigerator/ Incubator Module (R/IM) in the Orbiter middeck, consists of three different devices designed to mix fluids in space: materials dispersion apparatus (MDA) minilabs, cell syringes, and bioprocessing modules.

Petro, A. J. (JSC): A Safe and Efficient Personnel Launch System. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

During the last few years of this century and the first decades of the twenty-first century, the Space Shuttle fleet will be reaching retirement age. Systems using advanced technology such as airbreathing hypersonic propulsion may not be mature enough for application to operational launch systems. The goal of safe, reliable, low-cost transportation to orbit in this transition period might best be accomplished by using mature vehicle technology and innovative operations. A simple, rugged personnel launch system (PLS) would transport people to and from low Earth orbit, beginning in the late 1990s. The vehicle is primarily designed to carry personnel to an orbiting space station or to deliver crews embarking on lunar or planetary missions. Such a vehicle could also be used for short, Earth-orbit sortie missions, space rescue missions, and some satellite servicing missions. The PLS would serve as one element in a transportation architecture that might include heavy-life cargo vehicles and multiple-role spacecraft such as the current Space Shuttle.

Sepahban, S. (Barrios): ACRV Operations Concept. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

An important feature of the Assured Crew Return Vehicle (ACRV) operations philosophy is that the system must make maximum use of existing resources so as to minimize the unique ACRV resources required. A preliminary operations concept based on this philosophy and covering the ground, flight, mission support, and landing and recovery operations has been produced in-house. The major features of the current ACRV operations concept, including the facility options, training, search and rescue, and medical operations, will be discussed.

Taylor, P. A. ; Zipay, J. (JSC): Crew Escape Module for the Space Shuttle Orbiter. Are Astronauts Worth That Much Money? Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The Space Shuttle Orbiter was originally designed with no provision for crew escape. It was thought that system redundancy, system reliability, and quality control would prevent a catastrophic failure. After the 1986 Challenger accident, this design philosophy was reassessed. A feasibility study was done on incorporating an escape module into the existing Orbiter hardware. One crew escape module concept involves replacing the current crew compartment with an aerodynamically and aerothermodynamically designed blunt-body module that can be separated from the Orbiter providing crew escape capability during any phase of the flight regime. The blunt-body module design, impacts to the Orbiter, and costs of implementing such an escape system are presented. Some thoughts on the philosophy of crew escape are discussed. Arguments will be presented to show that although crew escape from a manned spacecraft is a requirement, the costs to implement such a system will be significant.

STAR Category 17 - Spacecraft Communications, Command, and Tracking

Karasack, V. G. (LESC): High Temperature Superconductor Antenna Investigations. Presented at SPIE's 1990 Technical Symposium on Optical Engineering and Photonics in Aerospace Sensing, Superconductivity Applications for Infrared and Microwave Devices, April 19-20, 1990, Orlando, Florida.

The use of superconductors to increase antenna radiation efficiency and gain is examined. Although the gain of all normal-metal antennas can be increased through the use of superconductors, some

structures have greater potential for practical improvement than others. Some structures suffer a great degradation in bandwidth when replaced with superconductors, but for others the improvement in efficiency is trivial due to the minimal contribution of the high efficiency of the structure. The following antennas and related structures are discussed: electrically small antennas, impedance matching of antennas, microstrip antennas, microwave and millimeter-wave antenna arrays, and super directive arrays. The greatest potential practical improvements occur for large microwave and millimeter-wave arrays and the impedance matching of antennas.

Kwon, H. M. (LESC): Capacity and Cutoff Rate of Coded FH/MFSK Communications with Imperfect Side Information Generators. Published in the IEEE *Journal on Selected Areas in Communications*, Vol. 8, No. 5, pp. 750-761, June 1990.

In a coded frequency-hopped M-ary frequency shift keying (FH/MFSK) communication system, it is known that if perfect side information about the jamming state is available to the decoder, substantial improvement in performance is possible. However, thermal noise, which is present in practical communication systems, can corrupt the jamming state information (JSI). In this paper, when JSI is imperfect due to thermal noise, we calculate the capacities and cutoff rates of the channels as a function of the signal-to-jamming-noise ratio, for memoryless, noncoherent FH/MFSK systems under partial-band noise jamming (PBNJ). We consider both soft and hard decision metrics with perfect, imperfect, and no JSI. Also, we introduce three imperfect JSI generators.

Powell, M. R. (JSC): Analysis of Doppler Ultrasound Bubble Detection Data by Means of the Time/Intensity Integral. Presented at the 1990 SOAR Conference, June 26-28, 1990, Albuquerque, New Mexico.

In order to introduce a more precise interpretation of decompression studies, the "Grade Probabilistic" concept was introduced in 1974 (Powell, *Aerospace Medicine* 45, 505-508); this method considered the Spencer grades as well. Currently, in many laboratories Doppler bubble grades are determined at various time intervals post decompression. It then becomes possible to relate the integral of "Doppler signal intensity" and time to decompression stress. In the method presented here, the Spencer grades are converted to relative gas volumes; this is based upon calibration using "in vivo" gas injection studies (Powell, et al., The Physiology and Medicine of Diving, Chapter 17, 1982). The deficiencies of the method are those of Doppler bubble detection in general; that is, the gas phase detected is most likely not spawned in tissues responsible for Type I decompression sickness. Examples of use in both hyper- and hypobaric conditions will be given.

Stephens, E. (JSC): Free-Space Optical Communications in Support of Future Manned Spaceflight. Presented at OE/LASE '90, January 14-19, 1990, Los Angeles, California.

Recent advances in technology make optical communications a viable alternative to radio-frequency (RF) in space applications. The Tracking and Communications Division of the NASA Johnson Space Center is looking at possible applications of optical systems for Space Station Freedom, lunar missions, and Mars missions. The effort for the Space Station Freedom program is in three areas: (1) proximity operations-communications and tracking; (2) direct low Earth orbit (LEO) -to-ground high-data-rate communications link; and (3) internal

(module) wireless communications. The effort for a Mars mission is in two areas, laser docking and deep space communications link. There are two types of activities being performed in-house, current technology evaluations and future system requirements. The paper describes the effort to determine where optical communications and tracking could be applied in future manned missions, what the basic requirements are for those missions, and what conceptual designs exist for the C&T systems.

Tritsch, C. L.; Talent, D. L. (LESC): Design of a Shuttle Based Space Debris Telescope. Published in the *SPIE Proceedings*, February 13, 1990, Tucson, Arizona.

A 1.6-meter diameter f/0.95 all-reflecting telescope was designed to observe orbital debris particles as small as 1 mm from the shuttle payload bay. The telescope was specified to have a flag focal surface without the imposition of refractive elements. Two design configurations involving three mirrors were evaluated -- a reflective Schmidt-Cassegrain and a modified Paul corrector. The Paul system was found to be more compact and appropriate for this application.

STAR Category 18 - Spacecraft Design, Testing, and Performance

Christiansen, E. L. (JSC): Advanced Meteoroid/Debris Shielding Concepts. Presented at the AIAA/NASA/ DOD Orbital Debris Conference, April 16-19, 1990, Baltimore, Maryland.

An ongoing program at the NASA Johnson Space Center Hypervelocity Impact Research Laboratory (HIRL) is to develop alternatives for spacecraft meteoroid and orbital debris shielding that provide a weight improvement over conventional two-sheet aluminum "Whipple" shields. Theoretical analyses of expected shielding performance of a variety of metallic, ceramic, and composite bumper materials were used to select candidates for subsequent hypervelocity impact tests. Of the shielding materials and concepts tested, a multishock concept (Cour-Palais and Crews, 1989) and a double-bumper system, consisting of an aluminum mesh followed by an aluminum sheet, performed better than either single or double aluminum mesh double-bumper shields compared to aluminum Whipple shields.

Christiansen, E. L. (JSC); Crews, J. L. ; Horn, J. R. (MSFC). Augmentation of Orbital Debris Shielding for Space Station Freedom. Presented at AIAA Space Programs and Technologies, September 25-28, 1990. Huntsville, Alabama.

Augmentation of orbital debris shielding is becoming the only practical method for protecting Space Station Freedom (SSF) from the threat of orbital debris. The purpose of shield augmentation is to reduce risks of critical element failure over the 30-year SSF life, thereby insuring crew and station survivability. If the original shielding is designed to provide adequate lifetime meteoroid protection, augmentation shields are needed only in selected areas of SSF, such as forward and side surfaces of pallets and habitable modules, because of the directional nature of debris. This paper describes augmentation concepts in more detail, and points out that early augmentation of SSF debris shielding (6-9 years after First Element Launch) will provide the greatest weight, cost, and safety benefits to the program.

Christiansen, E. L. (JSC): Investigation of Hypervelocity Impact Damage to Space Station Truss Tubes. Presented at the 1989 Hypervelocity Impact Symposium, December 12-14, 1989, San Antonio, Texas.

A series of 58 hypervelocity impact data shots was used to determine the effect graphite-epoxy tube properties, such as ply orientation, elastic modulus, wall thickness, and surface coatings, have on the extent of impact damage. Both visible and internal damage was measured. Correlations were developed relating impactor and target parameters to damage extent. These experimental results were then applied in a preliminary assessment of the failure rate of Space Station truss tubes from meteoroid and orbital debris impacts. A failure criterion for the truss tubes was developed from an analytical study using a finite element model and on-orbit structural loading condition.

Crews, J. L. (JSC); Cour-Palais, B. G. (MDSSC): A "Shocking" New Shield Concept or How to Make a 7 km/sec Aluminum on Aluminum Impact Look Like a 10. Presented at the 1989 Hypervelocity Impact Symposium, December 11-14, 1989, San Antonio, Texas.

The results of an advanced spacecraft shielding program conducted at the NASA Johnson Space Center Hypervelocity Impact Research Laboratory are presented. The results include two new aspects of shielding design: the geometrical configuration and the type of material used for the shield. The geometrical configuration of the shield will be the prime focus of this paper due to its application over a large range of materials. The uniqueness of this concept is in the utilization of a multishock (MS) shielding technique where ultra-thin (t_s) spaced, shield elements are used to repeatedly shock the impacting projectile (diameter d_p) to a high enough energy state to cause melting and vaporization at velocities which normally would not produce these results. The new concept provides a shield which can be tailored to meet many design requirements, produce minimal secondary debris particles, provide a means for designing an augmentable shielding system, and, most important, reduce the weight of debris shielding.

Curry, D. M. (JSC); Bohlman, F.; Johnson, D. (LTV): Thermal Structural Analysis of the Orbiter Reinforced Carbon-Carbon Chinpanel. Presented at the First Thermal Structures Conference, November 13-15, 1990, Charlottesville, Virginia.

Understanding the capabilities and limitations of analytical tools allows an opportunity to identify better techniques for utilization on specific problems and provides a direction for the continual development of new methods. This paper deals directly with the analytical methodology used for design and evaluation of a reinforced carbon-carbon (RCC) thermal protection system component on the forward fuselage of the Space Shuttle Orbiter. Design constraints, flight environments, conceptual design iterations, and analytical methods will be presented. This methodology provided the basis for the flight design and certification. A discussion of the thermal/structural response of teas-built configuration will be presented, along with what additional effort might be conducted to complement the design analysis.

Deffenbaugh, D. M.; Svedeman, S. J.; Schroeder, E. C.; Gerlach C. R. (Southwest Research Institute): On-Orbit Compressor Technology Program Final Report; NASA CR-185645, October 1990.

This report is a synopsis of the On-Orbit Compressor Technology Program performed under Contract No. NAS9-18051 and concerns compressor technology applicable for use by the Space Station Fluid Management System, Space Station Propulsion System, and related on-orbit fluid transfer systems.

The approach is to extend the current state-of-the-art in natural gas compressor technology to the unique requirements of high-pressure, low-flow, small, light, and low-power devices for on-orbit applications. This technology is adapted to seven on-orbit conceptual designs and one prototype is developed and tested. The conclusion is that compressor technology has been developed for on-orbit applications that balances all of the complex design requirements, and is provided within a time frame consistent with the Space Station Freedom schedule. The test program has documented that the performance of the prototype compressor meets the EIS requirements.

Dierlam, T.A. (The Charles Stark Draper Lab): Entry Vehicle Performance Analysis and Atmospheric Guidance Algorithm for Precision Landing on Mars, NASA CR-185614, May, 1990.

Future missions to Mars may require pinpoint landing precision, possibly on the order of tens of meters. A parametric study of the various factors related to entry vehicle performance in the Mars environment is undertaken to develop general vehicle aerodynamic design requirements. The combination of low lift-to-drag ratio and low atmospheric density at Mars results in a large phugoid motion involving the dynamic pressure, which complicates trajectory control. Vehicle ballistic coefficient is demonstrated to be the predominant characteristic affecting final dynamic pressure. An adaptive precision entry atmospheric guidance scheme is presented, using a numeric predictor-corrector algorithm to control downrange, an azimuth controller to govern cross-range, and an analytic control law to reduce the final dynamic pressure. Performance is tested against a variety of dispersions, and results from selected test cases are presented. Precision entry using bank angle control only is demonstrated to be feasible at Mars.

Difalco, C. J. (LESC): A Generic Simulation of the Orbital Maneuvering Vehicle (OMV) in the SES. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The Systems Engineering Simulator (SES), located at the Lyndon B. Johnson Space Center, is a real-time, man-in-the-loop engineering and crew training simulator for the Space Shuttle and Space Station Freedom Programs. The Orbital Maneuvering Vehicle (OMV) is one element of the On-orbit Elements Simulator (OES) in the SES. Since its inception in 1986, the OMV simulation has evolved into a medium fidelity test-bed for analysis of flight procedures and vehicle system engineering assessment. Current flight test objectives call for docking the OMV to the Hubble Space Telescope. Despite this apparent single program objective, the OMV simulation in the SES has been adapted for other engineering studies including the Crew and Equipment Retrieval System (CERS) and Space Station Freedom traffic management studies. This demonstrates the versatility of what on the surface appears to be a single purpose element in the SES. The SES expects the OMV simulation to take on new and innovative roles, perhaps far beyond its original charter, in the design and development of Space Station Freedom. This presentation provides an overview of the OMV in the SES and its use as a generic remotely piloted vehicle.

Ewert, M. (JSC); Chambliss, J. (LESC): Modular, Thermal Bus-to-Radiator Integral Heat Exchanger Design for SSF. Presented at the Intersociety Conference on Environmental Systems and at the AIAA 15th Annual Technical Symposium, May 24, 1990, Williamsburg, Virginia.

A conceptual design for the interface of the SSF two-phase thermal bus with the heat-rejecting radiator panels has been developed. The concept uses baseline technology for the radiator panels and thermal bus condenser, and replaces the

current baseline interface hardware with a direct bus-to-radiator heat pipe integral connection. The concept integrates the radiator panel and condenser units into a single unit and is referred to as the "integral heat exchanger (IHX)" concept. It addresses the substantial weight and assembly complexities and the inefficiency of the current contact heat exchanger mechanism. The paper describes the concept and testing, addresses savings to be had, presents data on such savings, and addresses the logistical implications of this concept versus the currently accepted model.

Grayson, K. ; Swearingen, T. (JSC): ORION: A Low-Thrust Mission for Exploration of Io, Titan, and Triton. Presented at the AIAA 15th Annual Technical Symposium, March 24, 1990, Houston, Texas.

This paper discusses the conceptual design of an interplanetary spacecraft to Io, Titan, and Triton. These are the respective moons of Jupiter and Neptune. Io, Titan, and Triton were chosen because they have atmospheres and are the most interesting to scientists on Earth.

Hill, W. (JSC); Mitchell, S. M. (RIC): Certification of Rewaterproofing Agent for Shuttle Thermal Protection System. Presented at the National American Chemical Society Meeting, April 23-27, 1990, Boston, Massachusetts.

A test program was initiated to procure a rewaterproofing agent that would satisfactorily waterproof the Shuttle Orbiter TPS after each flight while not affecting the substrate materials. The initial agent, hexamethyldisilizane, while rewaterproofing very satisfactorily, caused serious deterioration of the substrate silicone materials. This was primarily due to the fact that during the waterproofing reaction with the HRSI tile and AFRSI blankets, ammonia was created which caused reversion/end capping of the substrate silicone materials. This paper describes the chemical and mechanical properties testing performed in screening new waterproofing agents and selecting the best one for complete development tests in rewaterproofing RSI tiles and AFRSI blankets, culminating in a 100-mission certification test program.

Kantara, J. (LESC): ATCS Radiator Assessment of MB1 through MB6 in Gravity Gradient Attitude. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The study considered three different Space Station Freedom (SSF) attitudes and two central thermal bus (CTB) radiator panel orientations resulting in four major cases. The SSF attitude was assessed (1) in its normal orbiting mode, (2) with the CTB radiator panel achieving instant minimum environment, (3) in the gravity gradient mode with the CTB panels edge to Earth, and (4) in the arrow mode with CTB panels feathered and edge to Earth. These radiator panel sizes were assessed for each of these cases: (1) 50-foot long, (2) 43-foot long, and (3) 22-foot long panels. In order to calculate the number of panels needed for each case, the environmental absorbed fluxes were determined for each case to evaluate the net heat rejection capabilities per unit area. The study was limited to the case where the SSF was orbiting at an altitude of 230 n. mi. and at beta angles of 0 degrees and 52 degrees with end-of-life optical properties. The results from the study showed that the maximum heat rejection capability per unit area was accomplished whenever the radiator was edge to Earth for beta = 0 degrees.

Kantara, J. (LESC): Space Station Freedom Central Thermal Bus Graded Groove Radiator Panel Performance. Presented to the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

This report investigates the Space Station Freedom central thermal bus

radiator assembly with graded groove radiator panels. The purpose of the study was to identify individual radiator panel weight and heat-rejection capabilities, corresponding bus condenser weight, number of radiator panels, total radiator width span, and total radiator assembly weight in order to dissipate 82.2 kW of heat to outer space. Modeling and performance analyses were done using a FORTRAN program developed by LESC. The parameters that were varied in the course of the study were the facesheet thickness, heat pipe fin length, panel width, panel length, and fin efficiency. For all cases considered, and for a 45% safety margin on the heat pipe transport capability, the optimum performance and radiator system weight were produced by the 22' long panels with 48" width.

Maraia, R. J.; Kowal, T. J.; Curry, D. M.; Madden, C. B.; Ortiz, C. R.; Pham, V. T. (JSC): AFE Aerobrake Ceramic Thermal Protection System Design. Presented at the American Ceramics Society Symposium, October 25-27, 1990, Seattle, Washington.

One of the most challenging phases of all future interbody space travel is the arrival encounter, with its inherent deceleration requirements. The Aeroassist Flight Experiment (AFE), scheduled for 1994, will provide the critical data applicable to aeroassist vehicle design required for future programs including the lunar/Mars initiative. This paper discusses the design of the thermal protection system of the AFE aerobrake. Ceramic reusable surface insulation will be used to demonstrate the thermal protection capability at geosychronous return velocity (33,000 ft/s). Detailed math models were developed to select and size the TPS for the more severe environment associated with a geosynchronous return. It is shown that current orbiter materials can be successfully used for this application.

McBarron, J. W. (JSC); Balinskas, R. (Hamilton Standard); Spampinato, P. (ILC-Dover): Shuttle Extravehicular Mobility Unit (EMU) Operational Enhancement. Presented at the 20th Annual ICES Conference, July 9-12, 1990, Williamsburg, Virginia.

The NASA/Industry Shuttle extravehicular mobility unit (EMU) team initiated an EMU program activity in 1988 to reduce EMU criticality 1 failure causes, reduce ground operations costs, and enhance on-orbit operational extravehicular activity (EVA) capability. Replacement/ refurbishment hardware is being developed, certified, and delivered. System-level life extension testing is expected to extend the life limited components replacement schedule. Goals of this program are to achieve a 25% reduction in ground turnaround man-hours and processing time between missions and to extend EVA on-orbit capabilities expected to be necessary to support Space Station Freedom assembly and contingency EVA operations. This paper identifies and describes tasks being implemented with expected benefits to NASA-manned spaceflight programs.

Merlina, P.; Bogo, W.; Briccarello, M.; Cesare, S.; Lucchetti, F. (Aeritalia Societa Aerospaziale Italiana): Tethered Gravity Laboratories Study. NASA CR -185628, May 1990.

This document is submitted in compliance with contract NAS 9-17877. This study investigated ways of controlling the microgravity environment of the International Space Station by means of a tethered system. Four main study tasks were performed.

Meyerson, R. E. (JSC): An Experimental Study to Improve Space Shuttle Approach and Landing Performance. Presented at the AIAA 8th Applied Aerodynamics Conference, August 20-22, 1990, Portland, Oregon.

Engineers at JSC have conducted experiments to study the effects of modifications to the base area of the Space Shuttle Orbiter on approach and landing performance. A candidate configuration, the "OMS plate," has been chosen for further study based on wind tunnel test results. This modification consists of a curved plate which extends the length of the upper portion of the Orbiter base. The addition of this plate reduces Orbiter base drag by up to 16% and has positive effects on performance. An aerodynamic model including the effects of these modifications has been produced for use in Space Shuttle landing simulations.

Parma, G. F. (JSC): Design and Testing of Robot-Compatible Fasteners for the Space Station Truss. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The backbone of Space Station Freedom consists of a 145 m (476 ft) long truss to which all Space Station elements are attached. Most efforts to assemble this truss have focused on the 5-m-long members being assembled by EVA (extravehicular activity) astronauts. The Robotics and Mechanical Systems Laboratory in the Structures & Mechanics Division is looking at a different approach. We intend to demonstrate the assembly of 2 bays of full-scale truss in a totally automated robotic work cell. This demonstration will utilize two 7-degree-of-freedom Robotics Research K-1607 manipulators integrated with a large assembly platform, which will allow them to translate 4.8 m (15.6 ft) vertically and 6.8 m (22.4 ft) horizontally on either side of the truss. This presentation will concentrate on four prototype robot-friendly structural joints which have been designed, built, and are being evaluated for use in this demonstration. These joints have been designed to be simpler, lighter, and less expensive than their EVA counterparts because much of the complication can be moved from the joint to the robotic end effector. The joints have been tested for ease of robotic assembly as well as for structural properties.

Poast, K. I. (JSC): Thermal Response of a Space Shuttle Fuel Cell to a Loss of Cooling. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

Proper operation of the Space Shuttle Fuel Cell Powerplant (FCP) thermal, electrical, and reactant control subsystems is critical to its operational and functional integrity during all Space Shuttle mission phases. These subsystems interactively maintain the health of the FCP by providing reactant conditioning, product water removal, and thermal control to meet vehicle and payload power requirements. In order to understand the system dynamics of the loss of thermal control to a Space Shuttle FCP, tests were performed to simulate various onboard system failures. This paper presents the results of these tests conducted at the Thermochemical Test Area by the impact on the failure management assessments of Space Shuttle FCPs for the potential on-orbit loss of FCP thermal control.

Price, C. R.; Burns, S. H. (JSC): Multiple Manipulator Control from Orbiter for Space Station Assembly. Presented at the 13th Annual AAS Guidance and Control Conference, February 2-7, 1990, Keystone, Colorado.

The baseline Space Station Freedom assembly sequence requires the serial and interlaced use of multiple manipulators based on and operated from the Space Shuttle Orbiter. Evaluations of the usage and control of these manipulators from the Orbiter are being conducted at

the Johnson Space Center using computer graphics animation and real-time human-in-the-loop kinematic simulations. The computer graphics animation efforts have been directed towards determining first cut component distribution in the Orbiter payload bay and reach and clearance geometries for a subset of the twenty Shuttle missions required for assembly. The real-time kinematic simulations are being used to refine reach and clearance as well as to evaluate closed-circuit television viewing and displays and controls configurations. Of particular interest is the potential of a common set of hand controllers for commanding all of the different manipulations.

Rexrode, S. G. (MDSSC): Servicing Vehicle Performance Analysis and Satellite Capture Model Development. Presented at the AIAA 15th Annual Technical Symposium, May 1990, Houston, Texas.

The servicing of free-flyer satellites will require the use of a servicing vehicle, such as the Orbital Maneuvering Vehicle (OMV), to perform satellite retrieval and redeployment and/or in-situ maintenance. OMV performance capabilities must be well understood prior to development of candidate strategies for orbit transfer studies appropriate for a servicing vehicle based at an orbital node facility. A preliminary comparison of trajectory profiles is also included. This performance assessment is used as a foundation for developing candidate satellite capture models by superimposing mission requirements for proposed free-flyer satellites.

Scheffer, T. (MDSSC); Barry, T. (JSC): Integration by Parts. Presented at the 12th Aerospace Testing Seminar, March 13-15, 1990, Los Angeles, California.

Unique integration and, verification challenges associated with Space Station Freedom (SSF) require a solution - data management system (DMS) kits. Particular emphasis was placed on utilizing the capabilities and services of the on-board DMS to provide integration and verification tools, not only for the DMS but for other on-board distributed systems as well. DMS kits provided to system/software developers supplied a common set of integration and verification tools and hardware that were then used by individual system developers to simulate the complete data processing environment that will be available on board SSF. This paper describes the evolution of the integration process from the system level to final integration of multiple launch packages, addressing both ground and on-orbit aspects of the problem.

Sun, W. J. (LESC): Prediction of Maximum Vibroacoustic and Transient Combined Loads. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

This paper discusses the development of a set of design load factors for preliminary design purposes conservative enough to ensure no negative margins are obtained in the coupled loads analysis and no design impacts are expected in the STS verification loads cycle. In the method proposed, the limit design loads of a shuttle payload for lift-off are predicted. The payload standard deviation used is computed from an acceleration response variation formula. The peak factor used is predicted based upon the first passage theory and the mean extreme-value. These design load factors are compared with other payload community approaches. The studies indicate that the other, standard methods produce lower or higher predictions than the proposed mean extreme-value method, which the author recommends.

Sunkel, J. W. (JSC); Shieh, L. S. (UH): Multistage Design of an Optimal Momentum Management Controller for the Space Station. Presented at the AIAA Guidance, Navigation, and Control Conference, August 8-22, 1990, Portland, Oregon.

This paper presents a multistage design scheme for determining an optimal control moment gyro momentum and attitude control system for the Space Station. First, the Space Station equations of motion are linearized and then block-decomposed into two block decoupled subsystems using the matrix sign algorithm. Next, a sequential design procedure is utilized for designing a linear quadratic regulator for each subsystem, which optimally places the elgenvalues of the closed-loop subsystem in the region of an open sector, bounded by lines inclined at $\pm$ pi/2k (for k = 2 or 3) from the negative real axis, and the left-hand side of a line parallel to the imaginary axis in the s-plane. Simulation results are presented to compare the resultant designs.

Switzer, K. L. (MDSSC): Space Station Freedom Airlock Outfitting to Support Extravehicular Activity. Presented at the 20th Intersociety Conference on Environmental Systems (ICES), July 9-12, 1990, Williamsburg, Virginia.

This paper discusses the design and outfitting of the Space Station Freedom airlock. It summarizes the evolution of the two chamber inline configuration airlock. A description of the structure and hatches and the major requirements driving their design are included. The primary focus of the paper is a description of the internal and external outfitting of the airlock with equipment and associated distributed systems necessary to support extra-vehicular activity (EVA) requirements. Equipment used to reservice the Extra-vehicular Mobility Unit (EMU), provide internal and external umbilical support for the EMU, control the depressurization of the airlock, and provide hyperbaric treatment of crewmembers, and external support equipment utilized during real-time EVA operations is described.

Teixeira, C. (JSC): Earth to Orbit Launch System Alternatives. Presented at the Space Programs and Technologies Conference '90, September 25-28, 1990, Huntsville, Alabama.

Launch vehicle concepts for Earth-to-orbit transportation in support of Lunar and Mars Missions are highly interrelated with mission logistics, transfer vehicle design, extent of reusability, and required on-orbit operations. Some fundamental parameters such as size of aerobraked transfer systems, magnitude and frequency of propellant deliveries, in addition to transportation of human crews, all drive vehicle concepts and flight rate strategies. Several Earth-to-orbit concepts are defined with the objective of minimizing required on-orbit operations, specifically assembly and refueling. The result is a modular transportation system which in general is compatible with the Space Shuttle. This compatibility offers benefits in terms of resiliency and reduced development costs. Utilization of complementary elements such as a personnel launch system is also proposed as a means of enhancing the modularity and commonality concept.

Williams, S. D. (LESC); Pavolsky, J. E.; Curry, D. M. (JSC): A Preliminary TPS Design for MRSR-Aerobraking at Mars and at Earth. Presented at the AIAA 28th Aerospace Sciences Meeting, January 8-11, 1990, Reno, Nevada.

An investigation was conducted to determine the feasibility of using an aerobrake system for an unmanned mission to Mars and for a return vehicle to Earth. A preliminary thermal protection system (TPS) is examined for two small nose radius, straight biconic vehicles aerocapturing at Mars. The TPS for these vehicles - entering at 6 km/s and 8 km/s - has an advantage over a propulsive burn

velocity reduction for orbit insertion. The TPS for each vehicle consisted of an ablator in the region of high heating and reusable insulation over the rest of the structure. It was determined that a reusable TPS could be used over 98% of the aeroshell structure. Also presented is the preliminary TPS design for an Apollo-shaped vehicle aerocapturing at Earth. As with biconics, this vehicle had an ablator in the region of high heating and reusable insulation on the aft conic section. In contrast to vehicles aerocapturing at Mars, the ablator is used on 63% of the vehicle's aeroshell structure.

STAR Category 20 - Spacecraft Propulsion and Power

Boyd, W. C. (JSC); Bertolino, J. (Aerojet Propulsion Division): Updated OMS Engine Status-Sea Level Test Results. Presented at the 1990 JANNAF Propulsion Meeting, October 2-4, 1990, Anaheim, California.

The current Space Shuttle Orbital Maneuvering Engine (OME) is pressure fed. Performance uprating of this engine is being pursued by JSC. Component level design, fabrication, and test activities on this engine system have been ongoing since 1984. More recently, a complete engine, designated the Integrated Component Test Bed (ICTB), has been tested at sea level conditions by Aerojet Tech Systems. A description of the test hardware, and results of the sea level test program are presented. These results, which include the test condition operating envelope and projected performance at altitude conditions, confirm the capability of the selected Uprated OME (UOME) configuration to meet or exceed performance and operational requirements. Engine flexibility, demonstrated through testing at two different operational mixture ratios, along with a summary of projected Space Shuttle performance enhancements using the UOME, are discussed. Planned future activities, including ICTB tests at simulated altitude conditions, and recommendations for further engine development, are also discussed.

Hooper, J. C.; Riccio, J. R. (JSC): Space Shuttle Aft Propulsion System Enhancements. Presented at the 26th AIAA/SAE/ASME/ASEE Joint Propulsion Conference, July 16-18, 1990, Orlando, Florida.

The goal of the NASA Assured Shuttle Availability (ASA) Program is to improve the inherent safety, reliability, economy, and performance of selected Space Shuttle systems. In this interest, NASA has commissioned a study to determine the characteristics of an aft propulsion system for the Space Shuttle Orbiter that would combine the propellant storage and pressurization systems of the Orbital Maneuvering System (OMS) and Reaction Control System (RCS). This paper presents a review of the current OMS and RCS design, development, operations, and flight experience, and a status of the integrated aft propulsion system study as part of the ASA program.

Krohn, D. D. (JSC): Space Shuttle Vernier Thruster Long-Life Chamber Development. Presented at the 26th AIAA/SAE/ASME Joint Propulsion Conference, July 16-18, 1990, Orlando, Florida.

The Space Shuttle reaction control system (RCS) vernier thruster is a pressure-fed engine that utilizes storable propellants to provide precise attitude control for the Orbiter. The current vernier thruster is life limited due to its chamber material. By developing an iridum-coated rhenium chamber for the vernier, substantial gains could be achieved in the operational life of the chamber. The present RCS vernier, its requirements, its operating characteristics, and its life limitations are described. The history and current technology status of iridium-coated rhenium are presented along with a description of the operational life capabilities to be gained from

implementing this material into the design of a long-life vernier chamber. Discussion of the proposed demonstration program to be performed by the NASA Lyndon B. Johnson Space Center to attain additional insight into the application of this technology to the RCS vernier includes the technical objectives, approach, and program schedule. Plans for further development and integration with the Orbiter and the Shuttle system are also presented.

STAR Category 26 - Metallic Materials

Henkener, J. A. (LESC); Forman, R. G. (JSC): An Experimental Evaluation of the Fracture Mechanics Properties of Be-Cu CDA172. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas. NASA TM-102166.

A series of fracture mechanics tests, using the Be-Cu alloy CDA172 in the round rod product form, was conducted in a laboratory air environment at room temperature. This report includes tensile data in both the L and C directions and Kick data in both the C-R and CL orientations. Fracture toughness values were also derived from M(T) (center-craked), PS(T) (surface-cracked), and CC01 (corner cracked) specimens of varying thickness. Fatigue crack growth data were obtained for the C-R orientation at stress ratios of 0.1, 0.4, and 0.7 and for the C-L orientation at stress ratios of 0.1, 0.3, 0.4, and 0.7.

Lauer, H. V. (LESC); Morris, R. V. (JSC); Vempati, R. K. (JSC). Physical Properties of Mn-Substituted Geothites and Hematites. Presented at the Clay Minerals Society 27th Annual Meeting, October 6-11, 1990, Columbia, Michigan.

Recent studies have suggested that Mn-substituted goethite and hematite occur in terrestrial environments. The objectives of this study are to determine physical properties (including XRD, TGA, Mossbauer, magnetic, and optical) of synthetically-prepared Mn-substituted Fe oxides.

STAR Category 28 - Propellants and Fuels

Hurlbert, E. A. (JSC); Abe, J. T. (Rockwell): Methods Used to Investigate and Resolve Shuttle Helium Pressure Regulator Instability. Presented at the 26th AIAA/SAE/ASME/ASEE Joint Propulsion Conference, July 16-18, 1990, Orlando, Florida.

The Space Shuttle main propulsion system 750-psia regulator failure investigation and redesign effort began with the full-open failure of the regulator in the test stand in late 1986 at the Eaton Valve and Actuator Division Facility in California. Failure analysis and subsequent testing revealed outlet pressure instability in the regulator and the test system, which could cause structural failure of the regulator internal bellows and result in a failed-open main poppet. Outlet pressure instabilities were found in the regulators on each Space Shuttle vehicle. The program, facilities, and analysis tools used to solve the problem are described.

Linley, L. J. (JSC); Mansfield, J. A. (JM Technical): A Statistical Analysis of Temperature Measurements in Large Fuel Spill Fires. Presented at the 1990 JANNAF Propulsion Systems Hazards Subcommittee Meeting, April 3-6, 1990, Laurel, Maryland.

Temperature measurements were obtained throughout the fire plume region with space and time resolutions that permit extensive statistical analysis. Statistical models were developed that characterize the temperature behavior, and the data was processed to provide information that is directly applicable to various engineering problems. For example, the dependence of the probability that the time-average

temperature will exceed a given value on location within the fire and on exposure duration was established. This was incorporated with a statistical model of the spatial distribution of ordnance on the flight deck (corresponding to a high density arrangement of aircraft on the flight deck) to establish the probability that the temperature of ordnance exposure would exceed a given value. Contours of time-average temperature were also developed; contours in the horizontal plane at several heights are presented for spill fires at different wind speeds.

Pedley, M.; Baker, D.; Beeson, H.; Wedlich, R.; Benz, F.; Bunker, R.; Martin, N. (White Sands Test Facility): Fire, Explosion, Compatibility, and Safety Hazards of Hydrazine. Published as RD-WSTF-0002, February 20, 1990. (Release as NASA Reference Publication pending.)

Hydrazine (N_2H_4) is used as an aerospace fuel, an antioxidant in industrial processes, and in the production of pesticides and pharmaceuticals, to name just a few applications. The hazards associated with the use of vapor and liquid hydrazine in aerospace systems are the focus of this manual. This manual presents information that designers, builders, and users of hydrazine systems can use to avoid or resolve hydrazine hazards. Pertinent research is summarized, and presented in a concise quick-reference volume. Additional information can be found in the sources cited throughout the manual. New information obtained on the hazards of hydrazine will be incorporated into this manual as it becomes available.

STAR Category 31 - Engineering (General)

Bannerot, R. B. (UH): NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1990. NASA CR-185637, December 1990.

The 1990 NASA/ASEE Summer Faculty Fellowship Program was conducted by the University of Houston and Johnson Space Center and operated under the auspices of the American Society for Engineering Education. The 10-week program was funded by the Office of University Affairs, NASA Headquarters, Washington, D. C. The objectives of the program are to further the professional knowledge of qualified engineering and science faculty members, to stimulate an exchange of ideas between participants and NASA, to enrich and refresh the research and teaching activities of participants' institutions, and to contribute to the research objectives of NASA. This document compiles final reports of research projects by faculty fellows in collaboration with JSC colleagues.

Jenks, K. (Rockwell): Using Air Flow for Microgravity Equipment Restraint. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

This presentation discusses and demonstrates a working model of a restraint system which allows astronauts to use air flowing through a fan to restrain small objects in microgravity. Astronauts throughout the history of the space program have complained about the difficulties involved in holding and manipulating small objects in microgravity, since objects tend to drift without restraining forces. Various mechanisms have been devised to restrain these objects, including hook-and-loop fasteners, gray tape, bungee cords (springs), clips, and custom-designed parts trays, each of which has advantages

and disadvantages. The portable aerodynamic work surface (PAWS), or Detailed Test Objective (DTO) 0643, is a new, portable hardware restraint which has advantages over each of the previous methods of restraining objects in microgravity. PAWS is planned for flight on the Space Shuttle.

STAR Category 33 - Electronics and Electrical Engineering

Entine, G.; Nagargar, V.; Sharif, D. (Radiation Monitoring Devices, Inc.): Solid State Neutron Dosimeter For Space Applications, NASA CR-185633, August 17, 1990.

Those in spaceflight are exposed to significant flux of high energy neutrons from both primary and secondary sources of ionizing radiation. We propose to construct a compact neutron sensor that can be incorporated in a flight instrument to provide real time measurement of this flux, using a special PIN silicon diode that is insensitive to other forms of ionizing radiation. Research was conducted in several areas to determine the design and construction of a better reading system with high precision and to investigate the physics of the device, especially with regard to the sensitivity and reproducibility of the neutron response. This information was used to achieve high sensitivity at low neutron doses. Measurements were then made to confirm that PIN diodes with enhanced sensitivity were sufficiently insensitive to other forms of radiation so reliable readings could be obtained under all foreseeable flight conditions. Research shows we can enhance the PIN diode sensitivity to measure low doses of neutrons encountered in spaceflights. Instrumentation necessary for reading these devices has been developed and can be integrated into a small package.

Meyer, S.; Takeuchi, E. (Wilson Greatbach, Limited): Manufacture and Evaluation of Li/BCX DD Cells, NASA CR-185610, June, 1990.

This project focused on cell manufacture, acceptance and lot certification of cells, performance testing of cells, and abuse testing of cells. Acceptance testing included open circuit and load voltage check, visual examination, size and weight measurements, and high temperature exposure. Lot certification tests were performed for capacity performance and for performance under conditions of thermal and electrical abuse. These tests included 300°F exposure, capacity discharge, fuse check, high temperature exposure, high rate discharge, short circuit, vibration, and overdischarge testing. Johnson Space Center conducted life test evaluations on 200 cells. A parametric evaluation of the capacity discharge of Li/BCX DD cells was performed over a variety of temperatures and discharge rates to discern the performance capability of the cell. Tests were also performed over a variety of electrical and thermal abuse conditions. Abuse tests included short circuit, charging, overdischarge, high temperature exposure, shock, and vibration.

Munford, R. E. (LESC): Kapton Wire Arc Track Testing, NASA CR-185642, October 1990.

Kapton wire arc tracking tests were performed at JSC in 1990 using test procedure KWATT BB01 for use in assessing the safety of the Space Shuttle Orbiter wiring, which is predominantly Kapton insulated. The main objectives were to investigate, with respect to arc tracking, the effectiveness of circuit protection devices and the influence of wire size, voltage levels, bundling, electrical loading, and installation hardware. Arc tracking was initiated by dipping the insulation-bared, powered wires into a mixture of graphite powder and copper fillings. Pure graphite powder

was found to be too slow, since it provided too much resistance to the shorting circuit. Pure copper granules, on the other hand, did not provide enough resistance, resulting in dead shorts and causing circuit protection devices to remove the power. Methods using abrasive techniques were judged too time-consuming and unreliable.

STAR Category 34 - Fluid Mechanics and Heat Transfer

Blackwell, H. E. (BSA Services): BSA Services Final Report. NASA CR-185664, October 24, 1990.

Three tasks were defined in the SOW: (1) Spectral Fitting of Current Data, (2) Shock Layer Modeling Using DSMC Code, and (3) Production of Nitrogen Oxides and Excited Nitrogen in Flow Fields. All three tasks were carried forward satisfactorily over the given time period with some alteration from the initial set of subtasks. Some changes, due to the nature of the research, provided results beyond the scope of the original proposal. An abstract, resulting from efforts on task 3 and the full paper, was completed and scheduled for presentation at an AIAA meeting in January, and is near its final form.

Dresser, H. S.; Newberry, C. F.; Surber, T. E.; Szema, K. Y.; Chakravarthy, S. R. (Rockwell International): A Comparison of CFD, Wind Tunnel and Flight Pressures on the Space Shuttle Orbiter Payload Bay Doors. Presented at the AIAA/ ASEE Aircraft Conference, January 8-11, 1990, Reno, Nevada.

Computational Fluid Dynamics (CFD) has reached a level of maturity where it can now be successfully used to verify wind tunnel test data and correlate flight data. This paper illustrates this point with applications of CFD to the Space Shuttle launch system. Transonic wind tunnel results produced pressure loadings on the Orbiter payload bay doors which differed from those experienced in flight. The CFD was used to reconcile this difference and showed excellent correlation with flight measurements. Results of the CFD study indicated that wind tunnel data in the region of Mach 1.05 were greatly influenced by tunnel wall reflection and model flow blockage effects. A Euler flow code developed by S. R. Chakravarthy and K. Y. Szema at the Rockwell International Science Center was used to perform the CFD computations. The Euler flow code models the continuous flowfield as a series of finite volume elements described by total variation diminishing (TVD) finite difference formations.

Scott, C. D. (JSC): A Survey of Intrusive and Nonintrusive Measurements of Properties in Arc Jets. Presented at the AIAA/ASME 5th Thermophysics and Heat Transfer Conference, June 18-20, 1990, Seattle, Washington.

Techniques are reviewed for determining flow properties in low density arc jets used for materials and structures testing. Included are flow total enthalphy, heat fluxes, static temperatures (translational, rotational, and electron), electron density, species concentrations, and flow velocity that have actually been applied to arc jet flow diagnostics. Intrusive techniques covered are pressure, heat flux, electrostatic, and mass sampling. Nonintrusive techniques include emission spectroscopy, laser induced fluorescence, laser Thomson scattering, and Raman scattering. Several techniques must be used to obtain all of the flow field properties necessary for determining catalytic atom recombination rates and for other applications where gas/surface chemistry is important.

Scott, C. D. (JSC): Wall Catalytic Recombination and Boundary Conditions in Nonequlibrium Hypersonic Flows - With Applications. Presented at the Third Joint Europe/U.S. Short Course in Hypersonics, October 1-5, 1990, Aachen, West Germany.

Catalysts and their relation to aerodynamic heating in nonequilibrium hypersonic flows are presented. The species equations and their boundary conditions are given for binary and multicomponent gases. Slip effects are included for application of continuum methods to low density flows. Measurement techniques for determining catalytic wall recombination rates are discussed, including arc jets and flow reactors. Results are given for a number of materials of interest to the aerospace community, including glassy coatings such as the RCG coating of the Space Shuttle and for high temperature refractory metals such as coated niobium. Examples of calculations of the heat flux in nonequilibrium flows, as applied to the Space Shuttle, the planned Aeroassist Flight Experiment, and a hypersonic slender vehicle, are given.

STAR Category 35 - Instrumentation and Photography

Pitts, D. E. (JSC): High Speed Photographic Techniques at the Johnson Space Center. Presented at the 9th Cordin Meeting on High Speed Cameras and High Speed Photographic Techniques, June 11-15, 1990, Salt Lake City, Utah.

High-speed photography is required to image rapid events such as simulations of orbital debris impacting spacecraft structures. In the gun laboratories in the Solar System Exploration Division, a laser system which provides a 10 nsec pulse at .86-.89 um is used to illuminate a projectile as it exits the light gas gun and impacts the simulated spacecraft structure. An infrared film (2481) is used to capture images of this impact. Since the laser only produces 350 W peak power, and the images are collected by way of transmission, the large amounts of debris produced during the impact significantly reduce the contrast of the scene. Because of this, it is sometimes desirable to push the infrared film during development to increase the contrast of the scene. Digital image analysis can sometimes be used to increase the contrast to a desirable level without the risk involved in pushing or pulling the film. Digital techniques for contrast enhancement such as histogram equalization are discussed.

Talent, D. L. (LESC): A Space-based Concept for a Collision Warning Sensor. Presented at Space Programs and Tech Conference or Debris Assessment and Hazard Analysis, September 25, 1990, Huntsville, Alabama.

A concept for a space-based collision warning sensor has been developed and proposed as a captive payload on a space shuttle flight for the mid-1990's. Relying on passive sensing of debris objects in optical and/or IR passbands, it will use state-of-the-art solid state technologies such as CCDs. A variety of observing modes will be examined under various conditions of solar phase angle and pass geometry. Particle sizes of interest will be from 1 mm to several centimeters in diameter, the range of greatest concern to spacecraft survivability. To maximize useful observation time, choice mission characteristics would be inclination in the range of 57 degrees to 66.5 degrees and an altitude of about 500 km. The ramification of this effort to the survivability of Space Station Freedom against damage by orbital debris will be discussed.

Tapphorn, R. (LESC/WSTF); Porter, A. (JSC/WSTF): Infrared Fiber Optic Fire Sensors: Concepts and Designs for Space Station Applications. NASA TM-102167, 1990. (Originally published as WSTF-TR-427-001.)

This paper discusses using infrared fiber-optic (IFO) sensors as distributed fire sensors for the Space Station. Testing shows that IFO fire sensors will be able to detect fires in complex spacecraft with a network of lightweight fibers interfaced to a central detector. Optimum configurations for prototype development were selected; fiber-multiple configurations are preferred for large areas, while small spacecraft modules can be monitored with fiber configurations that are not location sensitive with respect to individual fibers. Responsivity measurements were conducted and signal processing techniques were investigated. Single-fiber background-limited-ranges (BLR) for early sensing of hydrocarbon and hydrogen flames could be extended from 2-3 m to 8 m by optically chopping the radiation signals either at the fiber input or within the fiber, using electro-optic modulators.

Victor, J. M. (LESC): Target Recognition Using the APA 512. Presented at the JAIPCC Symposium, March 22, 1990, Houston, Texas.

The APA-512 machine vision-processing system is being used at JSC to identify targets for the EVA retriever robot. The APA-512 thresholds a video scene and generates blobs of connected pixels. A number of characteristics of these blobs are determined by the hardware with additional characteristics software "cooked" from these values. These blob characteristics can be determined in "real time" and are determined each frame. These characteristics can then be used to identify specific targets. A preknowledge of target shape factors is required for motion detection. A number of problems complicate target identification. These include illumination direction and intensity, object orientation and movement, and also occlusions.

STAR Category 36 - Lasers and Masers

Loral Defense Systems: 3-D Laser Radar Vision Processor System Final Report. NASA CR-185640, October 1990.

LDS-Akron has developed a 3-D Laser Radar Vision Processor system capable of detecting, classifying, and identifying small mobile targets as well as larger fixed targets using 3-dimensional laser radar imagery in conjunction with a robotic type system. This processor system is designed to interface with the NASA Johnson Space Center in-house EVA Retriever Robot Program and provide it with the necessary information to fetch and grasp targets in space.

University of Alabama: Laser Welding in Space Final Report. NASA CR-185638, October 26, 1990.

Because our time in space has been so short, we have had very little experience with extended durations in orbit. For example, the Space Station is to be designed for a 30-year life, yet there are many questions that must be considered if we are to select the appropriate materials and construction techniques for extended stays in space. In keeping with the goal of planning for the construction, repair, and maintenance of facilities on other planetary bodies, this report examines the use of laser welding in space.

STAR Category 38 - Quality Assurance and Reliability

Carvalho, T. L. (Rockwell): Manned Space Systems Utilization of Product Assurance and Supportability Technology. Presented at the AIAA Third Space Logistics Symposium, April 30 - May 2, 1990, Colorado Springs, Colorado.

This paper analyzes how product assurance and supportability technologies are considered and applied to the design and development of manned space systems. Applications of these technologies continue to be reduced in scope due to budget constraints. This paper questions the advisability of this reduction. The small amount of funds directed towards this process leaves little room for analysis; therefore, it is unrealistic to expect to benefit from the collection of data and coalescence for viable "lessons learned." High initial costs of implementing some of the improvements gleaned from these technologies, in addition to scheduling pressures, keep most improvements from occurring. The author purports that new tools and breakthroughs derived from space exploration are not providing the maximum return on their investment.

Peters, H. L.; Fussell, L. R.; Goodwin, M. A. (RSOC): Capturing and Using Quality Assurance Knowledge for Shuttle Post MECO Flight System. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

Ascent initialization (I-load) values used by the Shuttle's on-board computers for nominal and abort mission scenarios are verified by a six degree-of-freedom computer simulation. The procedure that the Ascent Post Main Engine Cutoff (Post-MECO) group uses to perform quality assurance (QA) of the simulation is time consuming. Also, the QA information is not sufficiently documented, hindering transfer of knowledge and problem resolution. A new QA procedure which retains the current high level of integrity while reducing the time required to perform QA is needed to support the increasing Shuttle flight rate. A knowledge capture process, "embedded" into the group activities, has been initiated to verify the existing QA checks, define new ones, and document all rationale. A prototype electronic knowledge base has been developed with Macintosh's Hypercard to serve as a knowledge capture tool and a knowledge repository. It has also been designed to support a future capability to automatically generate code. This paper will describe the knowledge capture process, the design and use of the Hypercard knowledge base, and the expected extensions.

Petro, A. J. (JSC): Techniques for Debris Control. Presented at the AIAA/NASA/DOD Conference on Orbital Debris, April 16-19, 1990, Baltimore, Maryland.

This paper will summarize a wide range of approaches which have been proposed for controlling the growth of man-made debris in Earth orbit. Several approaches developed in studies at the Johnson Space Center will be described in detail. These approaches include the retrieval of inoperative satellites with an orbital maneuvering vehicle, and the provisioning of satellites and upper stages with devices for self-disposal. Self-disposal devices include propulsive de-orbit motors and passive drag-augmentation devices. Concepts for sweeping small debris from the orbital environment will also be described. An evaluation of the technical feasibility and economic practicality of the various control methods will be provided. In general, methods which prevent the accumulation of large debris objects were found to provide greater promise for control of the debris problem than methods of removing small debris particles.

Veach, W. (MDSSC): Space Station Freedom Assembly Interruptability Concept. Presented at the AIAA 15th Annual Technical Conference, May 24, 1990, Houston, Texas.

This paper provides philosophies and guidelines for use in assessing the interruptability of the evolving Space Station assembly sequence, centering on anticipating the effects of potential interruptions on interim configurations to identify potential high-risk situations. Potential interruptions include component delivery problems, Orbiter-related interruptions during an assembly flight, and SSF systems problems. Phased approaches are proposed to assist operations analysts in developing specific recommendations to eliminate/minimize the time spent in high-risk configurations. These approaches typically involve adjustments to Orbiter manifests, sequences of events, mission/flight rules, and SSF systems design, with the intent of maximizing the probability of SSF survival and minimizing the adverse operational effects after an interruption.

STAR Category 39 - Structural Mechanics

Larsen, C. E. (JSC); Lutes, L. D. (TAMU): Predicting the Fatigue Life of Offshore Structures by the Single-Moment Spectral Method. Presented at the 2nd International Conference on Stochastic Structural Dynamics, May 9-11, 1990, Boca Raton, Florida.

The dependence of fatigue damage accumulation on power spectral density (psd) is investigated for Gaussian random processes representing stresses in offshore structures. This involves extensive computer simulation of representative stress time histories and related analyses to predict the time of fatigue failure. The single-moment (SM) spectral method recently introduced predicts the damage accumulation rate based only on a simple calculation from the psd curve (a moment integral). The accuracy of the SM method and of other spectral methods is studied by comparing results with ones calculated from the more expensive alternative of using simulated stress time histories, rainflow analysis, and Palmgren-Miner calculations. The SM method may provide a valuable tool for predicting offshore structures' fatigue life subject to complex time histories of loading, as required in new structures design and in reassessment of aging structures. To allow proper balance between fatigue life and initial cost, a fatigue prediction method is needed that is accurate and easy to apply, both of which criteria the SM method appears to meet.

Parma, G. F. (JSC): Selection of a Truss Joint for Robotic Assembly of Space Structures. Presented at the NASA Center for Intelligent Robotic Systems for Space Exploration Conference, November 29-30, 1990, Troy, New York.

The backbone of Space Station Freedom consists of a 145-m (476-ft) long truss to which all space station elements are attached. Most efforts to assemble this truss have focused on the 5-m long members being assembled by extravehicular activity (EVA) astronauts. The Robotics and Mechanical Systems Laboratory in the Structure & Mechanics Division intends to demonstrate the assembly of two days of full-scale truss in a totally automated robotic work cell. This presentation will concentrate on four prototype robot-friendly structural joints which have been designed, built, and evaluated for use in this demonstration. The truss joint design is simpler, lighter, and less expensive than EVA counterparts because much of the complication can be moved from the joint to the robotic end effector. The presentation will include these test results as well as the evaluation process leading to the selection of the joint to be used in the full scale truss assembly.

Shein, S. , Marquette, B. (MDSSC); Larsen, C. E. (JSC): Generation of the Space Station Freedom On-Orbit Dynamic Loads Analysis Model Using MSC/NASTRAN V66A Superelements. Presented at the 2nd Annual MSC Taiwan Users Conference, October 15-16, 1990, Taipei, Taiwan.

The complex nature of the Space Station Freedom (SSF) structure and the contractual constraint of the project made the component mode synthesis approach ideal for developing the integrated on-orbit dynamic loads analysis model for SSF. Classic Craig-Bamptom constrained boundary component mode reduction technique was used to generate the dynamically reduced models for all major SSF component. Components were supplied to MSC/NASTRAN either in terms of modal properties in OUTPUT4 matrix format or were generated internally via MSC/NASTRAN super element option. Model effective weight was used to select component modes to be included in each super element. Collector super elements were used to better describe local mounting mechanisms as defined at their boundary. Each external super element component model was thoroughly checked for unconstrained rigid body behavior before the model was merged to the residual structure for system eigen solution. This technique was used to develop analytical models for all assembly configurations. The development of the Assembly Complete model illustrates the process here.

Shivakumar, V. (LESC): The Boundary Force Method Applied to Fracture Mechanics - A Solution to the Problem of Ill-Conditioning. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

This paper discusses the application of fracture mechanics concepts to space-craft hardware. For all payloads carried aboard the Shuttle and all Space Station hardware, NASA requires that design be based on fracture control procedures. Fracture critical components must meet normally imposed aerospace standards of design, analysis, and testing, and also have their safe life verified. The fatigue crack growth program, NASA/FLAGRO, was created to perform safe life and other types of fracture mechanics analysis; NASA/FLAGRO can also compute critical crack sizes, fits to crack growth rate data, and life of glass-like materials subject to time dependent stresses.

Spanos, P. D.; Mushung, J. J. (LESC): Representation of High Frequency Space Shuttle Data by ARMA Algorithms and Random Response Spectra. Presented at the 31st Structures, Structural Dynamics and Materials Conference, April 2-4, 1990, Long Beach, California.

High frequency Space Shuttle lift-off data are treated by auto regressive (AR) and autoregressive-moving-average (ARMA) digital algorithms. These algorithms provide useful information on the spectral densities of the data. Further, they yield spectral models which lend themselves to incorporation to the concept of the random response spectrum. This concept yields a reasonably smooth power spectrum for the design of structural and mechanical systems when the available data bank is limited. Owing to the nonstationary aspect of the lift-off event, the pertinent data are divided into three parts. Each part is associated with a rather distinguishable phase of the lift-off event in which a stationary environment can be expected. While the results presented are rather preliminary in nature, attention is called to the availability of the subject algorithms and the need to augment the Space Shuttle data bank as more flights are completed.

Weiss, S. P. (JSC); Hunt, D. L. (SDRC); West, W. M. (LESC); Dunlap, T. A.; Freesmeyer, S. (Zonic Corp): Development and Implementation of a Shuttle Modal Inspection System. Published in *Sound and Vibration Magazine*, September 1990.

A major task occurring between Space Shuttle flights is to inspect Orbiter subsystems such as control surfaces, the vertical tail, wings, and body flap. Inspection techniques to date have consisted primarily of visual and X-ray methods, which are not only time consuming but are less comprehensive than is desired. Previous Shuttle component and Orbiter ground modal testing revealed that Orbiter component damage can be identified using standard modal test methods. Therefore, NASA has procured a dedicated Shuttle modal inspection system (SMIS) to be used for structural subsystem inspection. This paper presents a background on the use of modal testing to detect Shuttle component damage, and details this new implementation and an early use of the SMIS capability to investigate a potential Orbiter vibration problem.

Wensley, D. C.; Bickers, B. C. (MDSSC); Gutkowski, G. A. (JSC): Integrated Truss Structure and Assembly Techniques. Presented at the 41st International Astronautical Congress, October 10, 1990, Dresden, Germany.

This paper examines the current design and on-orbit assembly techniques for several principal elements and distributed systems of the Space Station Freedom (SSF) integrated truss structure. Discussed are the main structure and the design considerations used to determine the materials, geometry, and erectable joints of the truss strut assembly. Also discussed are pallet structures for mounting external components of distributed systems; rotary joints for pointing solar arrays and radiators while transferring power, data, and fluids across the joint interfaces; extravehicular activity (EVA) equipment and translation aids for SSF assembly and maintenance; fluid and electrical utility distribution systems for external plumbing and wiring; and the propulsion system for SSF reboost and attitude control. On-orbit assembly techniques - inclusive of manned EVA, Shuttle, and SSF robotic capabilities and specially designed flight support equipment - are described with respect to these elements and distributed systems. The challenge for the SSF program is to simultaneously satisfy the many requirements for hardware design, SSF operations, and on-orbit assembly.

STAR Category 42 - Geosciences (General)

England, A. W. (University of Michigan): The Fractal Dimension as Diverse Topographies and the Effect of Spatial Windowing. Published as *Geological Survey of Canada Paper 9-4,* 1990.

Scattering theory for random, natural surfaces, e.g., those of soil, rock, snow, and ice, is based upon the variance spectrum and the correlation length of the rough surface. These parameters permit a solution to the forward problem-deriving the scattered field from roughness. There is seldom enough information about the scattered field to solve the more interesting inverse problem-deriving roughness from the scattered field. The inverse problem might become tractable if there were systematic relationships among the statistical parameters that characterize rough surfaces. The fractal dimension (Df) may be such a systematic relationship. For example, the topographies of three diverse geologic terrains - near Richmond, Virginia, near Brainerd, Minnesota, and west of Greeley, Colorado - demonstrate remarkable constancy among DFs for spatial wavelengths between 200 meters and 90 kilometers.

Evans, C. A.; Kimball, K. L. (LESC). Strontium Isotopes of Calcite Veins in Periodotite, Iberian Margin: Constraints. Presented at the Geological Society of America, November 1, 1990, Dallas, Texas.

A 130 km ridge of mantle-derived peridotite was emplaced at the continent-ocean boundary off Iberia during crustal thinning prior to sea floor spreading in the North Atlantic, roughly 115 MYA. Peridotite recovered from the ridge is variably altered, deformed, and cut by calcite veins. The calcite was apparently precipitated from seawater at sea floor temperatures. Results suggest that the peridotite was exposed on the sea floor 70-75 MYA. Spatial variation in peridotite alteration assemblages suggest that seawater circulation was largely restricted to established channels/fractures in the rock until the fractures were filled by calcite precipitation. Calcite from the bottom of the drilled sequence has Milocene seawater 87Sr/86Sr values, and we suggest that more recent (Miocene) tectonic activity created new fractures for seawater circulation.

Gooding, J. L. (JSC); Velbel, M. A; Long, D. T. (Michigan State University): Terrestrial Weathering of Antarctic Stone Meteorites: Formation of Mg-Carbonates on Ordinary Chondrites. Published in *Geochimica Et Cosmochimica Acta*, Vol. 55, pp. 67-76, 1991.

White efflorescences from weathering occur superposed on fusion crusts or along fractures in the interiors of ~5% of meteorites in the U.S. Antartic collection. Efflorescences from equilbrated ordinary chondrites consist of hydrous Mg-carbonates nesquehonite. X-ray diffraction and scanning electron microscope studies of efflorescences from LEW 85320 (H5) show abundant elongate prismatic crystals of nesquehonite with minor local encrustations of hydromagnestie. Abundant Na, K, Ca, and Rb suggest that the observed contents of these elements require only modest fractionation of chondritic composition, whereas extensive fractionation is required to derive the observed cation ratios from terrestrial seasalts. Therefore, cations in evaporate minerals on Antarctic meteorites are, most likely, not products of contamination by terrestrial (marine) salts. The Mg in efflorescences probably originated from weathering of meteoritic olivine; other cations in the efflorescences are also of meteoritic provenance. Thermodynamic analysis of the reaction forsterite + H_2O + CO_2 nesquehonite + silica at Antarctic temperatures and pCO_2 indicate spontaneity for all water activities greater than 0.6, compatible with the presence of liquid water as brines and/or thin films.

Gruener, J. E. (LESC): El Malpais Lava Tubes of Grants, New Mexico: An Early Analog to Lunar Lava Tubes. Presented at the Engineering, Construction, & Operations in Space: Proceedings of Space 90, April 23-26, 1990, Albuquerque, New Mexico.

This paper describes a field trip to the lava tubes in the El Malpais lava flow near Grants, New Mexico. The purposes of the field trip was to explore the lava tubes and evaluate their potential usefulness as terrestrial analogs to lunar lava tubes and get an understanding of the problems that astronauts might encounter when they explore lava tubes on the Moon.

Jones, J. H.; Janney, P. E. (JSC): Partitioning of Ni, P, Ir, Au, and Ge Between Taenite and P-Rich Kamacite. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

Jones, J. H. (JSC); Paslick, C. R. (University of Michigan); McKay, G. A. (JSC): Constraints on the Partial Melt Model of Eucrite Genesis Through Investigation of Sc Partition Coefficients for Olivine. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

Eucrite meteorites fall under the general classification of basaltic achondrites and are composed mainly of calcic plagioclase and Ca-poor pyroxene. Eucrites are believed to have formed either (1) by extensive fractional crystallization of more magnesian liquids or (2) as primary melts. Ultimately, phase relations controlling these two crystallization paths depend on pressure and Fe/Mg ratio, making it difficult to distinguish between the two genetic models on the basis of major element chemistry alone. Although rare Earth element plots of the eucrites are relatively flat, other trace elements - e.g., Sc - are markedly depleted. Earlier work using Sc partition coefficients (ScD) for olivine indicated that olivine alone as a residual phase could account for the Sc depletion seen in eucrites. ScD was not measured specifically for eucrites, however, and the results were claimed accurate only to within 20%. We have experimentally determined Sc partition coefficients for olivine and pyroxene in eucritic melts and used these in modeling equations to place further constraints on the melting history of eucrites.

Jones, J. H. (JSC); Paslick, C. R. (University of Michigan); McKay, G. A. (JSC): Experimental Constraints on the Composition of the Eucrite Parent Body. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

Two differing hypothesis have been invoked to explain the origin of the main group eucrites: (1) low-pressure peritectic partial melting of a peridotitic source and (2) partial melting followed by fractional crystallization of low-Ca pyroxene. The first model produces eucrites in a single step. The second model assumes that even the most primitive main group eucrites are fractionated liquids and that eucrite + diogenite = the original parental liquid. Using new experimental partitioning data for Sc, we have attempted to evaluate these two models.Unfortunately, the Sc data alone cannot be used to unequivocally rule out one model or the other. The results of our experiment indicate that either model is viable as long as large amounts of pyroxene are not involved in the second model.

Jones, J. H. (JSC); Walker, D. (Lamont-Doherty Geological Observatory): Thermal Diffusion in Fe-Ni-S-P Metallic Liquids. Presented at the 21st Lunar and Planetary Science Conference, March 13-16, 1990, Houston, Texas.

If a homogeneous solution is placed in a temperature gradient, composition gradients within the solution may be established. In general, this process is referred to as thermal diffusion; in liquids, it is called the Soret effect. The Soret effects that have been reported for metallic liquids have not been regarded as extremely important in the solidification and segregation of liquid alloys. For example, in the Sn-Pb system, compositional variations attributed to the Soret effects are ~10-15%. Consequently, many metallurgical solidification processes are investigated by Czochralski growth ("crystal pulling"), with the solid-liquid interface in a steep thermal gradient.

Jones, J. H. (JSC); Walker, D. (Lamont-Doherty Geological Observatory): The Influence of Pressure on Trace Element Partitioning in the Fe-Ni-S System. Presented at the AGU Conference, December 2, 1990, San Francisco, California.

Siderophile elements in the upper mantle of the Earth record a complex history of metal-silicate fractionations. It is still not clear that any one model of core

formation and accretion quantitatively accounts for the mantle abundances of these elements. One possible reason for this situation is that most of the experiments relevant to core formation have been performed at one bar pressure. To explore the effect of pressure on solid metal-liquid metal partitioning, we have measured partition coefficients for Ni, Au, Ge, and P at elevated pressures. Thus, many partition coefficients determined at one bar in the Fe-Ni-S system may have general applicability to nearly the entire upper mantle. For other elements, such as Ge, one-bar experiments may still be valid to ~50 kbar.

Nelson, D. O. (NRC); Phinney, W. C. (JSC): Production of Evolved Planetary Crust Through Partial Melting of Basalt. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

The interaction of basaltic magma with granitoid crust is a common mechanism of magma evolution of Earth and an evolved crustal signature has been recognized in the Apollo 14 VHK basalts and in the shergottites of the SNC suite. The origin of this evolved crustal signature is controversial, as are the implications of its suspected presence in the process of planetary crustal evolution. In particular, does the requirement of an evolved crustal component necessarily imply the existence of a significant silicic crustal reservoir similar to that on the Earth, or could its presence simply reflect processes that occur during the under-and interpreting of large-scale basaltic magmas in a precursor mafic crust?

Phinney, W. C. (JSC); Nelson, D. O. (NRC): Geochemical Arguments Against Lateral Intrusion of Matachewan Dikes. Presented at the 2nd International Dike Conference, September 12-16, 1990, Adelaide, Australia.

If dikes intrude laterally, there should be geochemical signatures that can be related along the length of the dike. Kalsbeek and Taylor found identical geochemical and isotopic signatures throughout the entire length of a single dike that could be traced for 400 km in Greenland. They were unable to convince themselves of exactly what mechanism provided the homogeneity, but lateral intrusion was one of the options that was seriously considered. In the case of the Matachewan dike-swarm, no individual dikes can be traced either in outcrops or by magnetic anomalies for more than a few kilometers along strike. However, the overall pattern of the dike swarm allows broad segments of the dikes to be roughly correlated along the strike direction. Thus, samples of many dikes taken along several parallel traverses perpendicular to the strike direction, each separated by tens of kilometers along the strike direction, should allow a test of the geochemical relations of groups of dikes along the general direction of strike.

STAR Category 43 - Earth Resources

Helfert, M. R. (JSC): Documentation of 25 Years of Global Environmental Changes: Analysis of Critical Trends. Presented at the Miami Museum of Science, March 29, 1990, Miami, Florida.

Study of astronaut observations and photographic documentation taken during NASA manned spaceflights (1965-1990) demonstrates that misuse of global resources during the past 25 years is resulting in significant losses of global forested areas, reduction of high quality water resources, increased atmospheric pollution, increased decertification and soil salinization, and evidence of authropogenically-induced climatic variations on regional, if not synoptic, scales. The primary geographic focus of this presentation is upon environmental changes documented by astronauts in the global tropics, but will also highlight significant environmental trends in the middle latitudes of the Northern

Hemisphere. Environmental changes in Africa show a marked reduction of surface hydrologic resources since 1965, a concomittant increase in the use of fossil water of irrigated agriculture, large-scale deforestation in all major regions of the continent, and increased frequency and areal extent of continental-sized, transoceanic Saharan dust events to both Europe and the New World.

Helfert, M. R. (JSC): Geological and Meteorological Observations of the Earth from Space. Presented at the Clinical Chemistry in Space Symposium, March 22-24, 1990, Nassau Bay, Texas.

During the past 28 years, NASA astronauts have acquired over 100,000 photographs of the Earth. This data base is used by Earth and environmental scientists to provide scientific information concerning various global environmental changes, to study terrestrial geological features using multiple-look angles and stereoscopic enhancements, and to document fleeting, little known meteorological and oceanic phenomena not seen from any over space-based sensor. This presentation reviews the current state of major global environmental changes and trends under way in the Amazon, Africa and Madagascar, South/Southeast Asia, and the Soviet Union. Also reviewed are major geological, meteorological, and oceanographic discoveries and insights that have been made using astronaut photography.

Helfert, M. R.; Lulla, K.P.; Whitehead, V. S.; Amsbury, D.; Runco, S.; Cleave, M.; Walter, D.; Grabe, R.; and Lee, M. (JSC); Evans, C.; Wilkinson, M. J.; Johnson, W. (LESC): Earth Observations During Space Shuttle Mission STS-34, Published in *Geocarto International*, Vol. 5, No. 3, October/November 1990.

Earth observations made during Space Shuttle flight STS-30 are discussed.

Helfert, M. R.; Lulla, K. P. (JSC): Measurement of Aral' Sea Water Decreases Documented During 1985-1990 Space Shuttle Missions. Presented at the Symposium on the Aral' Sea Crisis - Environmental Issues in Central Asia, July 14-19, 1990, Bloomington, Indiana.

Increased water diversion from the Amu Dar'ya and Syr'Dar'ya Rivers watersheds for intensive irrigated agriculture has significantly changed regional hydrologic budgets and degraded water quality. The most significant impact has been the reduction of primary water inputs to the Aral' Sea. The reduction of water input to the Aral' Sea has resulted in the accelerated reduction in the water area and level, increased salinity, changed micro- and mesoclimatic regimes, decreased biological productivity, severe economic impacts, and human societal disruptions in the Aral' Sea region. Observations acquired during Space Shuttle missions are just one of many possible data inputs for understanding the Aral' Sea situation. The limited objective of this paper is to demonstrate one possible way to use Space Shuttle analog photographic data to produce digital measurements of the variance of the Aral' Sea over time.

Helfert, M. R.; Lulla, K. P. (JSC): Mapping Continental Scale Biomass Burning and Smoke Palls from the Space Shuttle: Part I Amazonian Smoke Palls. Published in *Photogrammetric Engineering and Remote Sensing*, September-October 1990.

Space Shuttle and Skylab-3 photography has been used to map the areal extent of Amazonian smoke palls associated with biomass burning. Areas covered with smoke have increased from ~300,000 km^2 in 1973 to continental-size smoke palls measuring ~3,000,000 km^2 in 1985 and 1988. Mapping these smoke palls has been accomplished using space photography mainly from the Space Shuttle era. Astronaut observations of such dynamic and vital phenomenon indicate the need to integrate unique human capabilities while in orbit and human-directed sensor technologies in future global change research. The 100,000+ Space Shuttle photographs of the Earth have the potential to provide vital information on regional smoke pall patterns and other global environmental phenomena.

Helfert, M. R.; Lulla, K. P.; Whitehead, V. S.; Amsbury, D. (JSC); Evans, C.; Wilkinson, M. J.; Johnson, W. (LESC); Runco, S.; Cleave, M.; Walker, D.; Grabe, R.; Lee, M. (JSC): Earth Observations During Space Shuttle Mission STS-30 - May 4-8, 1989. Published in *Geocarto International*, Vol. 5, No. 3, October/ November 1990.

Helfert, M. R. (JSC). Global Tropical Environmental Change, 1962-1990. Presented at the Colloquium, Departments of Information Science and Geography, Wayne State University, October 12, 1990, Detroit, Michigan.

The global tropics comprise roughly 50% of the Earth's surface between 30 degrees N and S latitude. This zone includes ~77% of the world's population of ~5.4 B souls living in ~122 national units. This area is arguably the most overpopulated, least resource rich, least developed economically, and most politically unstable area of the world. The increasing human population has put great pressure upon the renewable natural and biotic resources of the region. The results of this, especially since the early- to mid-1970s, are decreasing biotic diversity, large-scale replacement of "natural" tropical biomass with biomass of direct human derivation and control, degradation of soil and water resources, and bio geochemical effects of probably major, but still unquantified, impacts. This presentation highlights the major areas of environmental degradation in the global tropics that have been documented during NASA manned spaceflights since the early 1960s. The documented changes are approached regionally, following a typical west-to-east revolution of the Space Shuttle in a 28.5 degree latitude orbital inclination.

Helfert, M. R. (JSC): Status and Trends of Forest Conversion in the Amazonian Biome of Brazil, 1973-1990. Presented at Michigan State University, October 9, 1990, Lansing, Michigan.

Conversion of forested areas in the 5.7M km2 of the true Amazonian biome of Brazil has occurred since the early 16th century. Until the late 1890s, however, this conversion was piecemeal and nonsystematic along the southern periphery of the "Amazon" and along the southern international borders with Uruguay, Argentina, Paraguay, and Bolivia. International borders were defined and recognized by treaty in 1978. Following this, the Brazilian government began to undertake agricultural colonization programs along its national borders in the Amazonian biome to (1) settle the newly defined border area (the Polonoroeste Project); (2) claim largely unsettled areas not yet in dispute (the Calha Norte Project); (3) transfer peasant populations to the Amazon Basin; (4) provide a settlement outlet for peasants impacted by severe environmental

degradation and droughts; (5) provide an alternative to the increasing population of landless peasants and unemployed laborers settling in the urban corridor of the southeast; and (6) provide a population, labor, and skill base to be used to develop natural resources in the Amazon Basin.

Lulla, K.P. (JSC): Astronaut Earth Observations Photography - An International Database for Global Change Studies. Presented at the Earth Technology Institute Meeting on Remote Sensing Technologies and Global Changes, March 28 - April 1, 1990, Brussels, Belgium.

NASA's bold plans to launch an ambitious program to study global Earth processes using space platforms is bound to usher in an era of unprecedented new thinking about our home planet. Astronauts orbiting the Earth on board the Space Shuttle have repeatedly indicated that "the awareness of mankind as a global community becomes powerfully evident." Astronauts, operating in a discovery mode, make scientifically useful Earth observations and document Earth processes using photography and videography. To date, about 100,000 Earth-viewing photographs have been acquired, making this a large and ever-expanding data base for the tropical region between 28.5 degrees N and S. These image data have the potential to provide an in-depth insight into the nature of global change on our planet. It is hoped that this resource generated by intelligent observers in space will be tapped by the scientific community.

Lulla, K. P. (JSC); Everitt, J.; Escobar, D.; Richardson, A. (ARS): Aerospace Video Imaging Systems for Rangeland Management. Presented at the Photogrammetric Engineering and Remote Sensing Conference, March 1990.

This paper presents an overview on the application of airborne video imagery for assessment of rangeland resources. Multispectral black-and-white video with visible/near-infrared (0.4 - 1.1 um) sensitivity, color-infrared, normal color, and black-and-white midinfrared (1.45 - 2.0 um) and thermal infrared (1.0 - 5.5 um) video have been used to detect or distinguish among many rangeland and other natural resource variables such as heavy grazing, drought stressed grass, phytomass levels, burned areas, soil salinity, plant communities and species, and gopher and ant mounds. The digitization and computer processing of video imagery has also been demonstrated. Video imagery does not have the detailed resolution of film, but these results have shown it has considerable potential as an applied remote sensing tool for rangeland management. In the future, spaceborne video systems may provide additional data for monitoring and management of rangelands.

Lulla, K. P. (JSC); Nellis, M. D.; Briggs, J.; Bussing, C. (Kansas State University): Interfacing Geographics Information Systems and Space Shuttle Photography for Monitoring Elephant Impact in Botswana. Presented at the 13th Applied Geography Conference, October 24-27, 1990, Charlotte, North Carolina.

Successful implementation of the Botswana National Conservation Strategy and other natural resource related programs in Botswana could profit from the development of an effective monitoring approach combining geographic information systems and remote sensing. Chobe National Park is one of the most important wildlife parks in Africa. Numerous interrelated factors have impacted the deciduous forest in this area. Human use of the forest has made it more susceptible to fire. Additionally, elephants' numbers have increased dramatically, and now number more than 50,000 in this portion of Botswana. Elephants destroy vegetation, thus impacting on the deciduous forests of this region. Botswana officials, however are limited in

making decisions about animal populations and forest resource management of the Chobe National Park, due to a lack of spatial information on elephant impact. The objective of this paper is to determine the use of Space Shuttle Photography, in combination with other spatial information sources, for assessing the variations in elephant impact on the forest reserves within the area of northern Botswana.

Lulla, K.P.; Helfert, M. (JSC): Camcorders in Space Shuttle Earth Observations. *Geocarto International* Vol. 5, No. 1, pp. 50-53, March 1990.

Videographic sensors and cameras are becoming increasingly useful tools for remote sensing science investigations and applications. There has been tremendous growth in the use of aerial video systems for resource assessment, environmental monitoring, and site specific mapping. Videographics sensing has also been attempted from space platforms such as the Space Shuttle with encouraging results. Beginning in 1989, the Astronaut Office at Johnson Space Center has sponsored a detailed project to evaluate commercially available Camcorder systems during Shuttle flights with three objectives: (1) to document their mission activities, (2) to record the results of their middeck flight experiments, (3) to capture views of the Earth. The objective of this column is to discuss the uses of camcorders in Earth observation activities during STS-30.

Lulla, K.P.; Helfert, M. (JSC): Mapping Recent Continental Scale Biomass Burning and Smoke Palls from the Space Shuttle: Part I Amazonian Smoke Palls. Published in *Photogrammetric Engineering and Remote Sensing*, September/October 1990.

Space Shuttle and Skylab-3 photography has been used to map the areal extent of Amazonian smoke palls associated with biomass burning (1973-1988). Areas covered with smoke have increased from ~300,000 sq km in 1973 to continental-size smoke palls measuring ~3,000,000 sq km in 1985 and 1988. Mapping of these smoke palls has been accomplished using space photography mainly from the Space Shuttle era. Astronaut observations of such dynamic and vital phenomenon indicate the need to integrate unique human capabilities while on orbit and human-directed sensor technologies in future Global Change research. The 100,000+ Space Shuttle photographs of the Earth have the potential to provide vital information on regional smoke pall patterns and other global environmental phenomena.

Lulla, K.P.; Helfert, M. (JSC): Space Observations of Large Scale Biomass Burning and Tropospheric Smokepalls in the Amazon Basin. Presented at the ISPRS Symposium on Global Environment Monitoring, September 17-21, 1990, Victoria, B. C., Canada.

Photographs taken by the astronauts aboard Space Shuttle and Skylab missions have documented the presence, increasing frequency, areal shift, and areal growth of large-scale smoke palls in the lower troposphere of the Amazon Basin from 1973 through 1988. Over this 16-year period 520 photographs have been taken and used to map changes in the geographic location and size of these Amazon smoke palls. In the early period (Skylab-3, 1973), these smoke palls appear to be primarily associated with agricultural field preparations in Southern Brazil, Paraguay, and Northern Argentina. By the middle and late 1980s the geographic focus of these smoke palls had migrated north and northwest ~15 degrees of latitude, and was more typically associated with large-scale forest clearing. The forest clearing of the middle-late 1980s is primarily associated with the establishment of road grids and agricultural colonies in the western Brazilian States of Acre, Amazonas, and Rondonia. Smoke palls areas in the

annual Amazon dry-seasons (July-October) have increased from ~300,000 sq. km in 1973 to ~3,000,000 sq km in 1985 and 1988.

Lulla, K.P.; Helfert, M. (JSC): Catalogs of Space Shuttle Earth Observations Photography. Published in *Geocarto International*, 1990.

In our previous columns in *Geocarto International*, we discussed basic tools and important aspects of the Space Shuttle Earth Observations Office operational activities. For example, Amsbury and Bremer (1989) discussed the still evolving mission camera systems, Lulla and Helfert (1990) described the testing of video camcorder systems used aboard several Space Shuttle missions, and Helms et al., (1990) discussed real-time mission support for Earth observations using imagery from both polar-orbiting and geostationary meteorological satellites. This data is provided by the Environment Remote Sensing Analysis Facility (ERSAF). Lulla and Helfert (1989) discussed the educational uses of the thirty year data base of NASA space photography. In this issue of Geocarto International, we discuss a major postflight activity of the Space Shuttle Earth Observations Office–cataloguing and indexing of mission data into standard formats, and the availability of the Space Shuttle mission catalogs published by the Johnson Space Center for scientific use of this ever expanding data base.

Lulla, K. P. (JSC); Jakubauskas, M. E. (Univ. of Kansas); Mausel, P. W. (Indiana State Univ.): Assessment of Vegetation Change in a Fire-Altered Landscape. Published in *Photogrammetric Engineering and Remote Sensing*, Vol. 56, pp. 371-378, March 3, 1990.

Classification comparisons of pine and deciduous forest classes (1973-1982) revealed that the most change in vegetation occurred in areas subjected to the most intense burn. Two classes of regenerating forest comprised the majority of the change, while the remaining change was associated with shrub vegetation or another forest class. Results from this research indicate that vegetation change detection can be accomplished using post classification comparison within the context of geographic information system analysis.

Ming, D. W. (JSC); Galindo, C. (LESC); Allen, E. R. (TAMU); Henninger, D. L. (JSC); Hossner, L. R. (TAMU): Characterization of Zeolite/Phosphate Rock Substrate after Zeoponic Plant Growth Experiments: Exchangeable Potassium, Ammonium, and Calcium. Presented at the American Society of Agronomy Annual Meetings, October 21-26, 1990, San Antonio, Texas.

The objective of this study was to determine exchangeable K^+, NH_4^+, and Ca^{2+} remaining on zeolitic exchange sites after wheat was grown for 255 d (vegetative stage) in a synthetic soil composed of quartz sand and a zeoponic substrate (zeolite clinoptilolite, CP, and phosphate rock, PR). Ca and P were made available to wheat by dissolution of PR. K and N were made available by ion exchange reactions involving Ca^{2+} from PR dissolution and K^+ and NH_4^+ on zeolitic exchange sites. Two sources of Cp, Texas (TX) and Wyoming (WY), and two sources of PR, North Carolina (NC) and Tennessee (TN), were used to form four zeoponic substrates (TX/NC, TX/TN, WY/NC, and WY/TN). After plant growth experiments, exchangeable K^+, NH_4^+, and Ca^{2+} were removed from zeolitic exchange sites by Cs^+. The equivalent fraction of Ca^{2+} on zeolitic exchange sites increased with decreasing amounts of zeoponic substrate in the synthetic soil. As the percentage of zeoponic substrate increased (>25%) only small equivalent fractions of K^+ and NH_4^+ were removed from zeolitic exchange sites; however, plant tissue tests indicated adequate levels of N and K were released into solution for plant growth.

STAR Category 45 - Environmental Pollution

Stansbery, E. G. (JSC); Schaepev, H. (LESC): Orbital Debris Radar Design Verification Test Using ALCOR. Presented at the Space Surveillance Workshop, April 3-5, 1990, Lexington, Massachusetts.

NASA has agreed to use the Haystack radar in a "beam park" operation mode to characterize the orbital debris population at Space Station altitudes to sizes down to 1 cm diameter. Open-loop monopulse signals and Doppler range rates will be used to determine approximate orbital elements. An experiment was performed in July 1989 using ALCOR radar and known satellites to simulate these types of data to (1) verify calculations that predict the accuracy of orbit elements from an open-loop monopulse receiver network during "beam park" operation, (2) investigate the scintillation characteristics from known orbital debris objects as they pass through the radar beam during "beam park," and (3) investigate whether objects passing through the side-lobes of the radar can be discriminated from objects passing through the main beam. A special calibration of the off-boresight monopulse signals was performed. Results of the calibration and the experiment are presented.

Talent, D. L. (LESC): A Model for the Evolution of the Low Earth Orbit Debris Environment. Presented at the ESA Space Environment Analysis Workshop, October 9-12, 1990, Noordwijk, the Netherlands.

A set of coupled differential equations expressing the time rate of change of the number of objects on orbit has been developed and solved numerically for several cases of interest. In this model the low earth orbit (LEO) environment is partitioned into N tiers, where N may take on any value from one to as large an integer value as expedient, and the particle types are divided into M discrete particle size bins. This model, many-particles-many-boxes (MPMB), allows for an examination of orbital debris sources and sinks within each tier of the LEO environment, including crossfeed terms between tiers. It allows a detailed examination of the projected behavior of the orbital debris environment under various assumptions of environmental utilization, break-up rates, explosion frequency, solar cycle phenomena, and debris mitigation protocols. It shows that, under certain conditions, the environment will become unstable against runaway growth. It will also suggest strategies to reduce the rate of debris hazard growth to future space operations.

Talent, D. L. (LESC): Analytical Model for Orbital Debris Environmental Management. Presented at the NASA/DOD/AIAA Workshop on Orbital Debris, April 1990, Baltimore, Maryland.

The development of a simple differential equation expressing the time rate of change of the number of macroscopic objects on orbit as a function of the time-dependent balance of sources and sinks is presented. This approach, the particle-in-the-box (PIB) model, treats source terms (launches per years, objects deployed per launch, and explosion-generated debris, fragmentation, and collision) together with sink terms (atmospheric drag and debris removal) to determine the growth/decay rate of the orbital population and the number of objects on orbit at a particular time. Functions of the PIB model are (1) to test the stability of the orbital environment against runaway growth and (2) to serve as an illustrative model of the future growth of the orbital environment and how it will be affected by projected international use. The advantage of the simple PIB model compared to stochastic methods - low calculational overhead - is also illustrated.

Talent, D. L. (LESC); Livingston, W. (National Solar Observatory): Stalking Geosats with a Camera. Published in *Sky and Telescope*, September 1990.

STAR Category 47 - Meteorology and Climatology

Findlay, J. T.; Jasinski, R. A. (JSC): Final Shuttle-derived Atmospheric Database: Development and Results from Thirty-Two Flights. NASA CR-185636. July 1990.

The final Shuttle-derived atmospheric data base developed under NASA Contract NAS9-17394 is presented herein. The relational data base comprises data from 32 Space Transportation System descent flights to include the available meteorology data taken in support of each flight as well as model data based on the United States Standard 1976 and 1962 atmospheres, the NASA Marshall Space Flight Center Global Reference Atmospheric Model, and the United States Air Force 1978 Reference Atmospheres. Though somewhat limited, the ensemble of flights permit a reasonable sampling of monthly, seasonal, and latitudinal variations that can be utilized for atmospheric science investigations, model evaluations, and upgrades, as appropriate. More significantly, the unparalleled vertical resolution in the Shuttle-derived results indicate density shears normally associated with internal gravity waves or local atmospheric instabilities. Consequently, these atmospheres can also be used as stress atmospheres for Guidance, Navigation and Control system development and analysis as part of any advanced space vehicle design activities.

STAR Category 48 - Oceanography

Jones, J. H. (JSC); Sharpton, V. L.; Schuaytz, B. C. (Lunar Planetary Institute): Arguments Favoring a Continental Impact Site at the K/T Boundary, September 1990, Perth, Australia.

Although excess siderophiles and shocked quartz grains demonstrate that the Cretaceous/Tertiary boundary layer worldwide contains ejecta from a major impact event, the source crater has not been identified. A submarine impact site seemed reasonable to early workers because of the great surface area of the ocean and its ability to hide such a large structure. Although geochemical data provided some intriguing hints of oceanic impact, they appear to be superceded by more robust clastic evidence of a continental K/T impact site. Unusually thick K/T deposits in Haiti suggest the K/T impact site may be located in the Caribbean region and recently two candidate structures (one continental, one oceanic) have been proposed. Our analysis seems to preclude the oceanic candidate because a mafic affinity would be expected but is not observed. If further work supports a Caribbean locale, we suggest that the impact site could lie on the extensive continental shelves in this region, including the Bahama, Campeche, and Yucatan platforms.

STAR Category 52 - Aerospace Medicine

Beck, B. G. (JSC): Preventive Medicine Program - Risk Analysis and Risk Reduction. Presented at the 1990 *SOAR* Conference, June 26-28,1990. Albuquerque, New Mexico.

Health risk analysis is routinely determined on the active and retired astronaut population utilizing laboratory analysis and questionnaires. This health risk appraisal (HRA) is used to identify risks associated with premature death or serious illness, and attempts to quantify

the impact of the risks. Risk reduction can involve dietary counseling, lifestyle counseling, or medications. Stone Risk Profiles (SRPs) graph the laboratory analysis of 24-hour urine samples and indicate the risk of nephrolithiasis. Intervention in the form of dietary counseling or medications can alter the SRP and, theoretically, reduce the risk of stone formation. Routine annual testing for total, LDL, and HDL cholesterol and triglycerides is performed. The National Cholesterol Education Program (NCEP) of the National Institute of Health has recently suggested overall guidelines for determining and managing hypercholesterolemia. The Medical Operations Branch Cholesterol Policy has been adapted from these NCEP guidelines. Intervention will include general cholesterol education, dietary counseling and, if indicated, medication therapy. Followup of the active and retired astronaut corps will reveal the results of such a preventive medicine program.

Beck, B. G. (JSC); Tripp, L. D.; Frazier, J. W. (Wright State University): Use of Echocardiography to Evaluate the Effects of Lower Body Negative Pressure as a Countermeasure to Negative Gz Acceleration. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

Negative Gz maneuvers in high performance aircraft are avoided because of unpleasant sensations and adverse physiological effects. This study used echocardiography to measure the effect of lower body negative pressure (LBNP) during negative Gz exposures to evaluate its use as a countermeasure. The results exhibited persistent unloading of cardiovascular volumes with LBNP used during these levels of -Gz. Subjective symptoms at -2.0 Bz acceleration improved with LBNP.

Chandlee, G. O.; Minchew, M.; Torres, C. (LESC): Operational Experience Databases: Applicability to the Development of an Aerospace Medical Database. Presented at the 1990 Aerospace Medical Assoc. Meeting, May 13-17, 1990. New Orleans, Louisiana.

Successful medical procedures during planned orbital space flights will require establishing an interface so that crewmembers can access medical data bases containing experiences and knowledge acquired from previous space flights. Our work provides a possible model for such a data base based on an operational experience data base currently being developed.

Chen, Y. M. (KRUG); Whitson, P. A.; Cintron, N. M. (JSC): Immunoreactive Prohormone Atrial Natriuretic Peptides 1-30 and 31-67: A Single Circulating Amino-Terminal Peptide Exists. Published in *Biochemical and Biophysical Research Communications*, Vol. 166, No. 2, 1990, pp. 794-800.

Sep-Pak C18 extraction of human plasma radioimmunoassay using antibodies which recognize atrial natriuretic peptide (99-128) and the prohormone sequences 1-30 and 31-67 resulted in mean values from 20 normal subjects of 26.2 ($\pm$ 173), and 368 ($\pm$ 160) pg/ml, respectively. A high correlation coefficient between values obtained using antibodies recognizing prohormone sequences 1-30 and 31-67 was observed ($R = 0.84$). Chromatographic elution of synthetic peptides 1-30 and 31-67 was observed at 48 and 39% acetonitrile, respectively. However, extracted plasma immunoreactivity of 1-30 and 31-67 both eluted at 46% acetonitrile. Data suggest that the radioimmunoassay using antibodies recognizing prohormone sequences 1-30 and 31-67 may represent the measurement of a unique larger amino-terminal peptide fragment containing antigenic sites recognized by both antisera.

Fortney, S. M. (JSC); Jones, M.; Dussack, L.; Rehbein, T. (KRUG); Charles, J.; Bungo, M. (JSC): Evaluation of Prolonged Lower Body Negative Pressure Exposure and Saline Ingestion on Restoring Orthostatic Responses During Bedrest. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

This study was designed to determine if lower body negative pressure (LBNP) exposure time could be reduced to 2 hours and still effectively restore orthostatic responses. Ten subjects (24-42 years) underwent 4-hour and 2-hour soaks, separated by at least 4 days, during a 13-day 6 degree head-down bedrest (BR). Orthostatic responses were evaluated during a graded LBNP response test at 2 and 24 hours after each soak. Plasma volume (PV) decreased 10 ± 2% during BR and was restored to within 4% of the pre-BR level for 24 hours after both soaks. Mean heart rate at -50 mmHg was 102 ± 5 bpm before BR, 109 ± 2 bpm 2 hours after the 4-hour soak, and 116 ± 4 bpm 2 hours after the soak. Mean blood pressure was maintained through the response test after the 4-hour soak but fell precipitously after the 2-hour soak. The soak interval cannot be reduced to 2 hours and preserve the beneficial effects on orthostasis. The mechanism by which the soak procedure improves orthostatic responses may be independent of its effects on PV.

Fortney, S. M. (JSC); Rehbein, T.; Dussack, L.; Jones, M.; Lanehart, D. (KRUG); Charles, J.; Bungo, M. (JSC): Cardiovascular Response to Prolonged Lower Body Negative Pressure and Isotonic Saline Ingestion. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

Prolonged lower body negative pressure (LBNP) with ingestion of isotonic saline ("soak") is proposed as a countermeasure for orthostatic intolerance following space flight. The purpose of this study was to define the cardiovascular responses during such a soak procedure.

Fortney, S. M. (JSC); Rehbein, T.; Dussack, L.; Steinmann, L. (KRUG); Charles, J.; Bungo, M. (JSC): Effect of 13 days of Bedrest on Cardiac Responses During Presyncopal Lower Body Negative Pressure. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

Cardiac function changes during space flight. Understanding the cardiovascular response to simulated microgravity may provide insight into orthostatic tolerance mechanisms.

Goochee, C. F. (University of Houston): Research to Determine Stress Level and Coping Mechanisms of Cells.

This task represented research effort in the development of methodology for measuring the "stress level" of cells in culture, and in the development of a deeper understanding of how cells cope with environmental stress. The first 2 years of this project (1985-1987) were devoted to establishment of laboratory facilities and development of experimental techniques to be used in this project. During the final year (1988), several projects were completed; talks were given at national meetings, and two journal papers were published. Brief summaries of the results for this project are presented.

Gosbee, J.; Willis, C. (KRUG): Physical Examination in Microgravity. Presented at the Aerospace Medical Association Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

A variety of medical procedures, including physical examination (PE) are planned for the Space Station Freedom Health Maintenance Facility. The objectives of this experiment were to assess problems inherent in performing a PE in microgravity, and to evaluate methods of patient and examiner restraint. Given effective examiner and subject restraint, no inherent limitations were identified in performing PE tasks in

microgravity. Some form of lower torso restraint for the examiner is required for PE tasks using the patient restraint/medical workstation. Specific patient and examiner restraint configurations are required to accomplish PE tasks on a flat surface; however, minimal special equipment is necessary.

Greenisen, M. C.; Newton, F. K.; Squires, W. G. (JSC): Force Transmission Capabilities and Efficiency of Advanced Space Suit Assemblies. Presented at the Federation of American Societies for Experimental Biology Conference, April 1-5, 1990, Washington, D. C.

The purpose of this study was to investigate force transmission capabilities and the metabolic cost of various extravehicular activity (EVA) tasks during simulated microgravity (whole-body water immersion) using three space suits. Two new prototype Space Station suits, the AX-5 and MKIII, were pressurized at 57.2 kN m-2 and compared against the currently used 29.6 kN m-2 shuttle suit. Four male astronauts were asked to perform at random, 10 static and dynamic arm exercises. A fatigue trial was also performed on four exercises during which metabolic rate was measured and efficiency was calculated in each of the suits. The activities were selected to simulate actual EVA tasks. The test article was an underwater dynamometry system to which the astronauts were secured by foot restraints. Force transmission capabilities were evaluated during two series of tests, static and dynamic. Evaluation of percent changes indicated change in force transmission capabilities across the spacesuits. During the efficiency testing, a steady-state metabolic rate could be compared across suits and within astronauts. Analysis revealed significant differences in metabolic rate within astronauts ($p < 0.05$) and nonsignificant differences between the suits.

Harm, D. L. (JSC); Paloski, W. H. (KRUG); Resche, M. F. (JSC); Doxey, D. D. Skinner, N. C.; Michaud, L. K. (KRUG); Parker, D. E. (Miami University): Postural Changes Following Sensory Reinterpretation as an Analog to Space Flight. Presented at the European Space Agency Conference Proceedings, May 28 - June 1, 1990, Trieste, Italy.

Postural control changes noted in astronauts immediately following space flight are thought to be caused by in-flight adaptive changes in central nervous system (CNS) processing of sensory information from the visual, vestibular, and proprioceptive systems. In order to elicit these adaptive changes in ground-based studies, we developed a Tilt-Translation Device (TTD) which causes the sensory inputs from the otolith organs as linear translations of the subject. This device is designed to simulate partially the stimulus rearrangement experienced by astronauts during microgravity. In the present study, postural stability was assessed in ten subjects before and after 30 minutes of exposure to TTD. The resulting data suggests that exposure to TTD causes a decrease in postural stability and a shift in postural control strategy similar to those reported in postflight studies of astronauts. We conclude that the TTD may be an effective weightlessness simulator, and that the postural changes following TTD exposure may provide a useful dependent measure for evaluation of this apparatus.

Harm, D. L.; Reschke, M. (JSC); Paloski, W. H. (KRUG); Parker, D. E. (Miami University): Effects of OTTR on Postural Stability. Presented at the 10th International Symposium on Disorders of Posture and Gait, September 2-6, 1990, Munich, Germany.

During space flight, adaptive neural recalibration of sensory inputs from the visual, vestibular, and proprioceptive systems is initiated to match the prevailing gravitoinertial environment. One such adaptive response is described by the otolith tilt-translation reinterpretation

(OTTR) hypothesis which states that, because of the absence of gravity, interpretation of otolith signals as tilt is meaningless. Thus, the CNS adapts by reinterpreting all otolith signals as linear motion. We hypothesized that such adaptive modification of vestibular signals would lead to postural instabilities in a one-g environment. Ten subjects were exposed to a tilt-translation device (TTD) designed to produce the OTTR response. Before and after TTD exposure, postural stability was assessed using a modified version of the Neurocom Equitest System. Data inspection indicates that exposure to the TTD results in (1) decreased stability on tests which eliminate visual and ankle proprioceptive inputs, and (2) a trend to shift from an ankle torque to a hip sway strategy following OTTR. We conclude that previously reported postflight postural instabilities result, at least in part, from in-flight OTTR.

Harm, D. L.; Reschke, M. F. (JSC); Skinner, N.; Michaud, L. (KRUG); Parker, D. E. (Miami University): Effects of Different Visual-Vestibular-Proprioceptive Phase Relations on Compensatory Vertical Eye Movements, Presented at the *ASMA* Annual Meeting May 13-17, 1990, New Orleans, Louisiana.

Following prolonged exposure to microgravity, graviceptor signals are interpreted principally as translation. Preflight adaptation training protocols are under development to reproduce immediate postflight responses. In a device that allows different phase relations between visual surround and subject tilt from vertical, two phase relations were compared to determine which would facilitate similar responses on the ground. METHODS: Ten subjects were exposed to two stimulus rearrangement (SR) conditions and to a No-SR condition in a tilt-translation device. During exposure to the stimulus conditions, oscillation of the visual surround position with respect to the subject lagged the subject's pitch oscillation position by either 270 degrees (SR-270) or 90 degrees (SR-90). In the No-SR condition, subjects were exposed to pitch oscillation in darkness. Compensatory vertical eye movements (CVEMs) were recorded before and after 30-minute exposures to the experimental conditions. RESULTS: The largest decrease in the amplitude of CVEMs was observed for the SR-270 condition (44%), followed by the SR-90 condition (28%), whereas no change in CVEMs was observed for the No-SR condition. CONCLUSIONS: The results suggest that adaptation occurs when translational self-motion cues associated with visual surround velocity are congruent in direction and time with graviceptor force and pressure cues associated with pitch position.

Huntoon, C. L. (JSC): Medical "Spinoffs" from the U.S. Space Program. Presented at the Annual Australian Biomedical Engineering, October 10-12, 1990, Adelaide, South Australia.

The U.S. space program promotes scientific advances because new information and tools are needed to achieve its goals. NASA provides funds for a diverse group of scientists and engineers to solve interdisciplinary problems. Space biomedical researchers are now investigating sensory disorientation and space motion sickness; cardiovascular deconditioning; and losses of fluid, red blood cells, muscle tissue, and bone mineral, which occur during weightlessness. Their research will help solve health problems on Earth such as osteoporosis, orthostatic hypertension (fainting), and disequilibrium. Preventing or ameliorating some of the conditions caused by weightlessness will require that medical research be performed in space. This will necessitate smaller instruments and noninvasive methods of measuring physiologic and pharmacologic variables, which will also benefit medical practice on Earth.

Huntoon, C. L. (JSC): Physiological Effects of Space Flight. Presented at the Annual Australian Biomedical Engineering, October 10-12, 1990, Adelaide, South Australia.

The primary effects of space flight that influence human physiology are the reduction of hydrostatic gradients, reduction in use and gravitational loading of bone and muscle, and stress. Each of these sets into motion a series of responses that culminates in alteration of homeostatic set points as a means of adaptation to the space environment. Set point alterations are believed to include decreases in venous pressure; red blood cell mass; total body water; plasma volume; and serum sodium, chloride, potassium, and osmolality. Serum calcium and phosphate increase. Hormones such as erythropoietin, atrial natriuretic peptide, aldosterone, cortisol, antiduretic hormone, and growth hormone are involved in the dynamic processes that bring about the new set points. Investigation of metabolic alterations that occur during space flight can provide insight into the mechanisms by which body fluid volume, serum electrolyte levels, muscle and bone mass, and other aspects of human physiology are regulated.

Huntoon, C. L.; Schneider, V. S. (JSC); Krauhs, J. M. (KRUG): Space Flight Induced Osteoporosis. Published in *Osteoporosis*, (1990?).

Disease and aging are not the only causes of bone loss from the human skeleton. Bone loss may occur when there is a decline in the forces applied to the skeleton. These forces include the force of gravity as well as the mechanical stimulation resulting from normal ambulatory activity. When these forces are reduced, a normal adaptive process secondary to disuse is thought to result in bone loss. Bone loss has been confirmed in both the U.S. and U.S.S.R. experiments and is now considered one of the most important issues for long-duration space flight. This response to weightlessness might prove hazardous to astronauts and cosmonauts, not only because hypercalciuria might lead to the formation of rental calculi during flight, but because axial skeletal fractures may occur upon entering Earth's gravity. For these reasons, efforts are being made to prevent or minimize loss of bone in space.

James, J. T. (JSC); Lawrence-Beckett, E. (CRD&E): Initial Experience with the EYTEX in vitro Eye Irritation Test System. Presented to the Society of Toxicology, February 12-19, 1990, Miami Beach, Florida.

The EYETEX in vitro eye irritation test was evaluated as a screening method for two groups of compounds. The first consisted of 10 typical commercial products provided by the manufacturer of the test system. Identical compounds were provided to a number of other labs participating in external validation. Comparison of our in vitro data with data from other labs gave a 93% correlation, whereas comparison of our in vitro scores with in vivo Draize scores gave an 89% equivalence. A second group of 14 compounds, many with military applications, were tested to compare in vivo scores. Both the standard assay and the membrane partition assay were used to score compounds. Of the 14, 1 compound could not be tested due to intense color production (2,4-dinitrophenyl hydrazine) and 2 were scored one classification above their in vivo irritation scores. This gave an equivalence value of 92% for the second group of compounds. Our initial conclusion, based on limited data, is that EYETEX offers considerable promise as a screen for eye irritants.

Jennings, R. T.; Santy, P. A. (JSC): Reproduction in the Space Environment. Published in *Obstetrics and Gynecology*. Vol. 45, pp. 1-17, January 1990.

Long-duration space flight and eventual colonization of our solar system

will require successful control of reproductive function and a thorough understanding of factors unique to space flight and their impact on gynecologic and obstetric parameters. Part II of this paper examines the specific environmental factors associated with space flight and the implications of human reproduction. Space environmental hazards discussed include radiation, alteration in atmospheric pressure and breathing gas partial pressures, prolonged toxicological exposure, and microgravity. The effects of countermeasures necessary to reduce cardiovascular deconditioning, calcium loss, muscle wasting, and neurovestibular problems are also considered. In addition, the impact of microgravity on male fertility and gamete quality is explored. Due to current constraints, human pregnancy is now contra-indicated for space flight.

Krebs, J. M; LeBlanc, A.; Evans, H.; Kuo, M. (KRUG); Schneider, V. S. (JSC): Energy Absorption, Lean Body Mass, and Total Body Fat Changes During Five Weeks of Continuous Bedrest. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D.C. *Aviation, Space, and Environmental Medicine*, Vol. 61, pp. 314-318, 1990.

Continuous bedrest is used as an analog for the weightlessness state. The purpose of this study was to examine lean body mass changes that occur during bedrest when subjects are fed a constant 7-day rotation diet. Six male volunteers (age 24-61 y, 177.7 ± 50 cm, weight 75.0 ± 5.5 kg) lived on a metabolic research ward for 11 weeks. Subjects were ambulatory during weeks 1-6 and remained in continuous bedrest during weeks 6-11. Daily caloric intake was 2547; weekly weights were measured. Potassium-40 (K-40) counting and nitrogen (N) balance were used to determine lean body mass changes.

Kumar, K. V.; Waligora, J. M.; Calkins, D.S. (JSC): Threshold Altitude Resulting in Decompression Sickness. Published in the *Aviation, Space, and Environmental Medicine*, August 1990.

A review of case reports, hypobaric chamber training data, and experimental evidence indicated that the threshold for incidence of altitude Decompression Sickness (DCS) was influenced by various factors such as prior denitrogenation, exercise or rest, and period of exposure, in addition to individual susceptibility. This was illustrated by logistic regression analysis on the incidence of DCS below 9,144 m (30,000 ft) using the above variables. The examples showed that definition of threshold altitude should be qualified by the particular combination of experimental variables under which it was observed.

Kumar, K.V. (NRC); Waligora, J. M.; Horrigan, D. J. (JSC); Calkins, D. S. (KRUG): Estimation of Survival Functions in Altitude Decompression Sickness. Presented at the Aerospace Medical Association Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

The onset of symptoms due to decompression sickness (DCS) are time dependent. Further, data on DCS are usually right-censored due to incomplete recording of failure times on some subjects (e.g., with no DCS). We present that survival analysis is more appropriate under such circumstances. A total of 100 exposures to 9,144 m involving direct ascent with (1) 3.5 hours (n = 34), (2) 4.0 hour (n = 28), and (3) 6.0 hour (n = 38) ground-level prebreathe were examined by survival analysis. The observed incidence of disease-free survival times showed significant ($p < 0.05$) improvement only under 6.0 hour, compared to 3.5, hour prebreathe profile. Further stratification of data using age and sex did not change this difference. It is concluded that survival analysis is a useful method to examine time-dependent characteristics of DCS.

Lam, C. W. (KRUG); Galen, T. J. (LESC); Boyd, J. F.; Pierson, D. L. (JSC): Mechanism of Transport and Distribution of Organic Solvents in Blood. February 21, 1990.

Little is known about the mechanism of transport and distribution of volatile organic compounds in blood. Studies were conducted on five typical organic solvents to investigate this. Groups of four to five rats were exposed for 2 hours to 500 ppm of n-hexane, toluene, chloroform, methyl isobutyl ketone or diethyl either vapor; 94,66,90,31, or 49% respectively, of these solvents in the blood were found in the red blood cells (RBCs). Similar results were obtained in vitro when aqueous solutions of these solvents were added to rat blood. In vitro studies were also conducted on human blood with these solvents; 66, 43, 65, 49, or 46% respectively, of the added solvent was taken up by the RBCs. Results indicate that RBCs from humans and rats exhibited substantial differences in affinity for three more hydrophobic solvents studied.

Lathers, C. M.; Diamandis, P. H.; Riddle, J. M.; Mukai, C.; Elton, K. F.; Bungo, M. W.; Charles, J. B. (JSC): Acute and Intermediate Cardiovascular Responses to Zero Gravity and to Fractional Gravity Levels Induced by Head-down and Head-up Tilt. Published in *Journal of Chemical Pharmacology*, Vol. 30, pp. 494-523, June 1990.

Determination of early cardiovascular responses to simulated gravity levels between zero-g and one-g will add knowledge of cardiovascular responses to space flight. Cardiovascular responses to 6 hours in a -5° head-down bedrest model of weightlessness (zero-g) were compared to those in head-up tilts of +10°, +20°, and +42° (1/6, 1/3, and 2/3G, respectively). Six healthy young adult males experienced the four angles on separate days. Cardiac output and peak aortic flow reflected the angle at start of tilt; values at all angles converged by the second hour, decreased through the third hour, and increased thereafter. Cardiovascular values were related to tilt angle for the first 2 hours of tilt, but after hour 3 values at all 4 angles began to converge, suggesting that cardiovascular homeostatic mechanisms seek a common adapted state regardless of effective gravity level (tilt angle) up to 2/3G.

Leach, C. S. (JSC): Space Life Sciences: A Historical Perspective. Presented at the *AAAS*, February 15-20, 1990, New Orleans, Louisiana.

Life sciences research in space originated from aviation medicine. There was doubt that any higher organisms could survive in space. The early flights of monkeys, mice, dogs, and chimpanzees provided space medicine researchers with information that improved the safety of human astronauts. Although it has been difficult to obtain data during flight, an extensive amount of medical data from astronauts has been accumulated over the years. To study biochemical changes in the body, samples of body fluids must be obtained. This was first done on Gemini 7, when urine samples were collected to prepare for the series of Apollo missions. The results of the Skylab experiments have been invaluable for space medicine. Blood was drawn in space for the first time on the three Skylab missions. We still rely on Skylab data for information about the effects of remaining in space for a month or longer. The Space Shuttle and especially Skylab, provided opportunities for additional integrated experiments. This year the first Spacelab mission dedicated to research in the life sciences is scheduled for launch.

Leach, C. S.; Pool, S. L.; Sawin, C. F. (JSC); Nicogossian, A. E. (NASA HQS): Extended Duration Orbiter Medical Project. Presented at the 41st International Astronautical Congress, October 6-12, 1990, Dresden, Germany.

The Extended Duration Orbiter Medical Project (EDOMP) has been instituted to obtain information about physiologic effects of extending mission duration and the effectiveness of countermeasures against factors that might compromise crew health, safety, or performance on extended-duration missions. Only those investigations that address operational problems or flight-associated Detailed Supplementary Objectives, as well as ground-based studies. Investigator teams have been formed in the following areas: biomedical physiology, cardiovascular and fluid/electrolyte physiology, environmental health, muscle and exercise physiology, and neurophysiology. The program is under way and will continue on each shuttle flight as the manifest builds toward a 16-day orbital flight.

Morrison, D. R. (JSC); Cohly, H. (KRUG): Molecular Enhancement of Free-Fluid Electrophoretic Separation of Lymphyocytes. Presented at the *AIAA* 28th Aerospace Sciences Meeting, January 8-11, 1990, Reno, Nevada.

Purified subpopulation of lymphocytes have many applications in research of autoimmune diseases, cancer mechanisms, immune surveillance, and transplant rejection. Isolation of immune competent subsets of B and T cells can be a key step in the production of commercial hybridomas which produce interferon, interleukins, and valuable monoclonal antibodies. Space experiments have demonstrated that Continuous Flow Electrophoresis (CFE) resolution and throughput capacity can be greatly enhanced by operations in microgravity; however, experiment opportunities are scarce. Preincubation with antibodies specific for certain antigen receptors can reduce the electrophoretic mobility (EPM) of B cells by 10% and the use of double or triple antibody tagging can reduce the EPM by as much as 65%. CFE separation of certain lymphocyte subpopulations from bone marrow or other purified cell preparations needed for transplantation still require the high resolution and large throughput capacity only available during separations in microgravity. Model lymphocyte culture systems have been developed to demonstrate how new molecular methods can be used to enhance ground control and space flight separations of target lymphocytes by CFE.

Powell, M. R. (JSC): Doppler Monitoring of Repetitive and Repetitive, Multiday Diving in Human Subjects. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

Decompression algorithms have traditionally been calculated on the basis of single dives; the possibility of interaction of dives has been considered only in the aspect of so-called long half-time compartments. Tissue gas phase formation and resolution has not generally been considered even though two decades of ultrasound studies have indicated the presence of a "silent" gas phase. Recreational scuba divers were exposed in a dry hyperbaric chamber for: (i) two to three dives a day [Phase I], (ii) for six dives/day for 6 consecutive days [Phase IIa], or (iii) four dives/day for 6 consecutive days [Phase IIb]. Dives were from 35 to 130 fsw and were both single and multilevel. All dives were calculated from the Recreational Dive Planner (PADI, Santa Anna, CA). Precordial Doppler monitoring was performed after each dive. From the Doppler results of Phase IIb, no evidence could be found for "accommodation' (= decreased tendency towards gas phase formation) as the dives progressed from the first to the sixth day. Doppler bubbles were as follows: Phase I < Phase IIb << Phase IIa; multilevel dives < single level dives. The type of dive and the interdive interval plays a role

in the resolution of the tissue gas phase. This is not always determinable from gas loading analysis.

Powell, M. R. (JSC). Silent Bubbles - Their Detection and Effects. Presented at the Workshop on Hypobaric Decompression, October 16-18, 1990, San Antonio, Texas.

Resche, M. (JSC); Kohl, R. L.; Spector, S. (KRUG). Effect of Nonsedating Antihistamines in Motion Sickness. Presented at the American College of Allergy and Immunology, November 10-14, 1990, San Francisco, California.

Turfenadine, astemizole, and doxepin were tested in male subjects in a randomized, double-blinded, and crossed-over design study to assess the efficacy of new oral antihistamines as anti-motion sickness drugs. The studies revealed a statistically significant therapeutic effect from terfenadine ($p < 0.5$) and doxepin ($p < 0.01$), but not astemizole, as measured by the subject's increased tolerance to Coriolis stimulation. This suggests a selective peripheral antihistamine action may be sufficient to control motion sickness. The research raises questions regarding current theories on the etiology of motion sickness, its associated autonomic system dysfunction, and the validity of assumptions that effective pharmacological agents must act centrally.

Reschke, M. F. (JSC): Wood, S. J.; Verrett, C. M. (KRUG); Clement, G. R. (CRNS, Paris): The Effect of Graviception on Cross-Coupled Eye Movements Elicited as a Function of Optokinetic Stimulation and Parabolic Flight. Presented at the 1990 SOAR Conference, June 26-28, 1990, Albuquerque, New Mexico.

When the visual scene is ambiguous, how does the brain use graviception to resolve conflict and establish the perception of upright? This question was addressed by recording eye movements in response to a full-field optokinetic stimulus (OKS) oriented in different planes during parabolic flight. Four subjects were tested during parabolic flight and were exposed to full-field horizontal, vertical, or oblique OKS while restrained in a seated position. In the case of oblique OKS, analyzing the slow phase eye velocity (SPV) indicated acceleration specific modulation of horizontal and vertical eye movements while transitioning from one to zero g. When the oblique OKS was down and left, horizontal SPV increased and vertical SPV decreased; the opposite occurred when OKS was up and right. Some cross-coupling was associated with the other planes of OKS, but the same rule applied. SPV was specific to direction of acceleration. Changes in gravitoinertial force can induce cross-coupling of eye movements that assist in the resolution of ambiguous visual movement, indicating an influence on vestibular brainstem velocity storage.

Reschke, M. F.; Harm, D. L. (JSC); Paloski, W. H.; Wood, S. J. (KRUG); Oas, J. G. (UTMB): Adaptation of Gaze During Target Acquisition with Added Head Inertia. Presented at the 1990 *SOAR* Conference, June 26-28, 1990. Albuquerque, New Mexico.

This study investigated gaze stability using a simple adaptation protocol as an analog for space flight. Ten subjects were exposed to a simple adaptation protocol consisting of target acquisition (TA) with head unloaded; TA with head loaded; a 20-min adaptation period during which the subjects made ±60-degree head movements at 0.33 Hz with the head loaded, followed by TA; and were TA immediately after the load was removed from the head. Head movements were recorded with a gonoimeter. Horizontal eye movements were obtained with standard EOG procedures. All testing was done in the dark. Subjects could be classified as those who achieved final gaze position at the point of maximum

head velocity and obtained final gaze position long after reaching maximum head velocity. Subjects tended to adopt individual strategies during adaptation; most showed a rebound response upon removal of the load. The adaptation method used in this study was shown to be a good analog for protocol development of future space flight experiments.

Reschke, M. F. (JSC); Kolafa, J. J.; Brumley, E. A.; Vanderploeg, J. M.; Wood, S. J. (KRUG): Development of Standardized Test Procedures Using Reversing Prisms for the Study of Motion Sickness. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

The purpose of this study was to establish standard procedures using prisms for provocation and to compare the results between right/left reversing prisms (R/L-RP) and up/down reversing prisms (U/D-RP). Seventeen subjects were tested with four provocative methods: (1) R/L-RP, (2) U/D-RP, (3) static chair during parabolic flight, and (4) a modified version of the Pensacola coriolis sickness testing using a step velocity profile (SVMT). The R/L-RP were significantly more provocative than the U/D-RP, and the R/L-RP elicited symptoms in subjects relatively refactory to motion sickness symptoms induced by the static chair and SVMT. The prism tests proved to be a valuable training technique in longer duration motion environments. R/L-RP are quantitatively more provocative than are U/D-RP and add the capability of longer duration motion sickness testing to currently available methods.

Reschke, M. F. (JSC); Paloski, W. H. (KRUG); Oas, J. G. (UTMB): Dynamic Contributions of Head and Eye Movement to Gaze During Acquisition of Targets of Varying Eccentricity. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

Reports that perceptual illusions often accompany head movements immediately following space flight suggest that neurosensory adaptation to zero g may result in alternations in the relative dynamic contributions of head and eye movements to gaze. To provide a platform from which this hypothesis could be investigated following space flight, this study was performed to establish the dynamic characteristics of gaze in normal human subjects. Six subjects were studied using a 1 m radius display containing LED targets embedded at 0 degrees and at $\pm$ 20 degrees and $\pm$ 80 degrees of right/left eccentricity. Eye movements were recorded using a goniometer. At the conclusion of the experiment, it was determined that the relative temporal contributions of eye and head motions to gaze are complex; they appear to depend on the eccentricity of the target and the adopted strategy of the subject.

Reschke, M. F. (JSC); Robinson, S. H.; Zografos, J. L.; Wood, S. J. (KRUG): The Effects of Eccentric Rotation on the Vertical Vestibulo-Ocular Reflex. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana and at the SOAR Conference, June 26-28, 1990, Albuquerque, New Mexico.

This study was designed to investigate changes in the vertical vestibulo-ocular reflex (VOR) during y-axis rotation with the head on-axis (no change in linear acceleration) and with the head positioned off-center, with a linear acceleration vector that changes in magnitude and direction during sinusoidal stimulation. Ten subjects were rotated about their y axes while lying on their left sides. The subjects' heads were

centered over the axis in one test session and positioned 18 inches off-axis in another. Using differing frequencies, the subjects were given alerting tasks and eye movements were recorded with both electro-oculographic and camera video techniques. For both on- and off-axis conditions, the VOR gain was directly proportional to the stimulus frequency, not concentric and eccentric rotation conditions.

Reschke, M. F. (JSC); Zografos, J.; Zerkus, M. (KRUG): Electronically Controlled Light Occluding Goggles. Presented at the Eighth Annual Conference on Biomedical Engineering Research, February 16, 1990, Houston, Texas.

A new device is being developed to assist vestibular researchers in controlling input to the visual system of subjects participating in studies of Optokinetic After Nystagmus (OKAN). The Electronically Controlled Light Occluding Goggles (ELOG) are being developed as part of the Microgravity Vestibular Investigation (MVI) which will fly aboard the STS-42 Space Shuttle flight. The ELOG allows a researcher to control the viewing field of a subject either manually or by computer control. The 140° horizontal by 140° vertical viewing field of the subject can be switched between transparent red or total darkness. Transparent red is used to maintain dark adaptation which stabilizes corneo-retinal potential in Electro-Oculogram (EOG) studies. The ELOG has the capability to occlude the visual scene of either the left eye, right eye or both. The ELOG consists of a light weight ski goggle frame housing a set of electrically activated liquid crystal light shutters. The shutters become clear when subjected to an alternating current (100v @ 300Hz) and are opaque when no electric current is applied. A plastic fliter is used to provide red tent. A battery-powered DC to AC converter provides power to the shutters. It is expected the ELOG will add fine control to experiments studying OKAN, and they may be useful in other types of vestibular and/or visual research.

Richard, E. E. (KRUG); Russo, D. (JSC): Development of the Space Station Freedom Environment Health System. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

The Environmental Health System (EHS), a subsystem of the Space Station Freedom (SSF) ensures that crewmembers will have a safe and healthful environment in which to live and work. EHS comprises six subsystems: Microbiology, Toxicology, Water Quality, Radiological Health, Vibroacoustics, and Barothermal Physiology. Each subsystem contributes to the overall functions of the EHS including environmental planning, monitoring, health assessments, and operations support. The EHS will provide hardware for monitoring the air, water, and internal surfaces of SSF, including capabilities for in-flight sample collection, processing, and analysis. The closed environment of SSF and its dependence on recycled air and water will necessitate a reliable monitoring system to alert crewmembers if contamination levels exceed the maximum allowable limits established to ensure health and safety. This paper describes the functions and hardware design status of the EHS.

Santy, P. A. (JSC); Mathes, K. L.; Karakulko, K. (KRUG): The Health Stabilization Program for the Space Transportation System. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D.C.

The purpose of the Health Stabilization Program (HSP) for the Space Transportation System (STS) is to safeguard crew health through the development of an awareness among NASA employees, contractors, and STS crew families of the need to protect Shuttle flight crews from being exposed to infectious diseases. The first 24 STS flight

medical debriefs were reviewed to identify instances where HSP procedures either were not followed or were ineffective. Of the last seven STS flights (to STS 61-C), fire demonstrated significant problems with infectious diseases in either flight crew, backup personnel, or crew families. The results of the review clearly showed that the HSP was not effective in its preventive measures and that a sense of complacency developed because of initial successes in the Apollo Program and early STS flights.

Sauer, R.L. (JSC); Schultz, J. R.; Taylor, R. D.; Flanagan, D. T.; Gibbons, R. E. (KRUG); Pierson, D. L. (JSC): Biofilm Formation in Iodinated Spacecraft Water Systems; 2nd Interim Report. Presented at the 1990 *SOAR* Symposium, June 26-28, 1990, Albuquerque, New Mexico.

Legionella pneumophila grown in water cultures in association with other microorganisms were less sensitive to disinfection by chlorine and iodine than were agar-passaged cultures. Differences in sensitivity to these disinfection procedures were determined by comparing CxT99 values and molar CxT99 values. The CxT99 value for water-grown legionellae was 1500X that of agar-grown cultures when iodine was used. A 68-fold difference was experienced when chlorine was the disinfecting agent. Iodine was 50X more effective than chlorine when used with agar-grown cultures but only twice as effective when tested against water-grown legionella cultures. CxTxS values were used to compare sensitivities in very resistant populations such as those found in biofilms. These values showed water cultures of legionellae associated with stainless steel surfaces were 135X more resistant than were unattached legionellae and were 210,000X less sensitive than were agar-grown cultures. Such results indicate that the conditions under which legionellae are grown can dramatically affect their susceptibility to some disinfectants and must be considered when evaluating the efficacy of a disinfecting agent.

Schulz, J. M. (JSC): Pain Management in Space. Published in Chapter for Textbook, *Practical Management of Pain.*

Space habitation will demand the development of appropriate medical facilities. Medical problems must be appropriately and definitively addressed for the patient's interest, and to assure mission, project, and program success. A medical problem handled poorly could affect a mission significantly and cost millions for a rescue attempt. Several options exist for acute pain management on board U.S. spacecraft. These options are limited by size and weight considerations, microgravity-related concerns, and the fact that present spacecraft can deorbit rapidly in an emergency to receive ground-based medical care. In addition, as mission durations increase, the rapid return option decreases, then the requirement for addressing chronic pain syndrome arises. A space based medical facility will be comparable to a hospital, although it will require some unique considerations. Common pathogens will be the same during space flight as in the terrestrial environment. Although etiologies may differ, trauma in space will present with the same type of injuries as on Earth. Therefore, to a large degree, medical facility design and development should parallel those of modern hospitals.

Waligora, J. M. (JSC); Kumar, K. V. (NRC): Intensity of Exercise and Likelihood of Decompression Sickness. Presented at the Aerospace Medical Association Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

This study was conducted to assess if a higher transient level of exercise - a level which has occurred in 5% of operational extravehicular activities in space - is a driver in terms of risk assessment in decompression sickness (DCS). In a crossover design, 10 males

were exposed to 6.5 psi pressure in the hypobaric chamber without oxygen prebreathe. During one exposure, the average metabolic rate was 200 KCal/hr throughout, while the other exposure included 1 hour of 400-500 KCal/hr during the 3 hours of exposure. Low exercise resulted in 18% symptoms of DCS, while high exercise resulted in 36% symptoms (including two cases of Type II DCS). These results indicated that high exercise peaks may be particularly productive of Type II DCS symptoms.

Waligora, J. M.; Horrigan, D. J. (JSC); Kumar, K. V. (NRC): Intensity of Exercise and Likelihood of Decompression Sickness. Presented at the Aerospace Medical Association Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

This study was conducted to assess if a higher transient level of exercise - a level which has occurred in 5% of operational extravehicular activities in space - is a driver in terms of risk assessment in decompression sickness (DCS). In a crossover design, 10 males were exposed to 6.5 psi pressure in the hypobaric chamber without oxygen prebreathe. During one exposure, the average metabolic rate was 200 KCal/hr throughout, while the other exposure included 1 hour of 400-500 KCal/hr during the 3 hours of exposure. Low exercise resulted in 18% symptoms of DCS, while high exercise resulted in 36% symptoms (including two cases of Type II DCS). These results indicated that high exercise peaks may be particularly productive of Type II DCS symptoms.

Whitson, P. A. (JSC); Huls, H.; Chen, Y. M. (KRUG); Cintron, N. M.; Sams, C. F. (JSC): Endothelin-Like Immunoreactivity in Bovine Brain Microvessel Endothelial Cell (BMEC) Conditioned Medium. Presented at the American Society for Cell Biology Annual Meeting, December 9-13, 1990, San Diego, California, and published in the *Journal of Cell Biology*, Vol. III, p. 105a, 1990.

To better understand how endothelin (ET) synthesis is regulated in brain microvessels, we examined primary cultures of bovine brain microvessel endothelial cells (BMECs). The average ET level 4 days after monolayer formation was 468 ($\pm$ 151) fmole/million cells/24 hours (n = 2). Radioimmunoassay of HPLC-fractionated medium in a 20-60% acetonitrile gradient produced a major peak which comigrated with the synthetic ET-1 standard. No immuno reactivity occurred in fractions corresponding to the 39 amino acid precursor molecule–big ET, suggesting that the immuno reactivity detected in BMEC medium corresponds to ET-1. Accumulation of immuno reactivity increased over 24 hours; however, the rate of ET production/million cells declined 3-8 days after monolayer formation. Although this suggests greater degradation of the ET by the cells, the ET production/well was unaltered. Medium preconditioned on C6 glial cells for 48 hours and placed on BMECs for 24 hours decreased the ET immuno reactivity, suggesting that glial cells modulate the production of ET in BMECs. This in vitro culture system may be a valuable tool for examining the expression and synthesis of endothelin in blood-brain barrier endothelial cells.

Womack, W. D. (JSC); Gilder, C. W. (GEGS): Spacelab Life Sciences 1 Dedicated Life Sciences Mission. Presented at AIAA Space Program and Technologies Conference, September 25-28, 1990, Huntsville, Alabama.

The Spacelab Life Sciences 1 (SLS-1) mission is the first in a series of missions dedicated to life sciences research. The 20 interdisciplinary experiments conducted during this mission, both human and animal studies, explored the early stages of physiological adaptation responses in spaceflight. Specifically, these experiments studied biomedical and gravitational biology

issues relating to three general areas: (1) cardiovascular and cardiopulmonary deconditioning, (2) altered vestibular function, and (3) altered metabolic function including altered fluid electrolyte regulation, muscle atrophy and bone demineralization, and decreased red blood cell mass and altered immunologic responses. Secondary experiments provided additional scientific information and test hardware, and monitored the quality of the Spacelab environment.

STAR Category 53 - Behavioral Sciences

Kennedy, R. S.; Wilkes, R. L.; Baltzley, D. R.; Fowlkes, J. E. (Essex Corporation): Development of Microcomputer-Based Mental Acuity Tests for Repeated Measures Studies. NASA CR-185607, January 1990.

The purpose of this report is to detail the development of the Automated Performance Test System (APTS), a computer battery of mental acuity tests that can be used to assess human performance in the presence of toxic elements and environmental stressors. There were four objectives in the development of APTS. First, the technical requirements for developing APTS followed the tenets of the classical theory of mental tests, which requires that tests meet set criteria like stability and reliability (the lack of which constitutes insensitivity).

Schafer, L. E.; Probe, J. D.; Greenisen, M. C.; Bagian, J. P. (JSC); Krutz, R. W. (Brooks AFB School of Aerospace Medicine): Variation of Crewmember Reach Envelopes During Exposure to a 1-6 Gx Gravitational Field. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

The purpose of this study was to determine the variation in crewmember upper limb reach as a function of sequentially increasing G loads. All testing was performed at the centrifuge facility of the Brooks AFB School of Aerospace Medicine (SAM). Seven astronauts and three naive U.S. Air Force test subjects were exposed to a ramping acceleration profile from 1 to 6 Gx in a stepwise fashion. Each subject performed a standardized reach sweep during a one-minute interval at each integer G plateau. The reach parameters were determined from these sweeps using video motion tracking techniques. Changes in reach envelopes as a function of Gx field magnitude occurred.

STAR Category 54 - Man/System Technology and Life Support

Beck, B. G.; Davis, J. R. (JSC): Update on the Incidence of Space Motion Sickness Since STS-26. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

Space motion sickness (SMS) has been an operational medical concern, especially for short-duration space flight. The incidence of SMS prior to the Challenger accident was 67% for first-time crewmembers of the Space Shuttle. Since STS-26 (return-to-flight), in September 1988, the launch and entry suit (LES) has been used, and there has been concern that use of the suit may increase the incidence of SMS. A standardized questionnaire and oral debriefings have been used to collect postflight medical information. This information was used to determine the LES's influence on SMS. This study found no evidence for an increase in severity or incidence of SMS as a result of the LES.

Bourland, C. T. (JSC); Smith, M. (ILC): Selection of Human Consumables for Future Space Missions. Presented at the NASA Symposium: Waste Processing in Space for Advanced Life Support, September 11-13, 1990, Ames Research Center, Moffett Field, California.

There are many unsolved technological problems in the area of human consumables for long-duration missions. Current food preservation technologies are not designed for the shelf life required for long-duration missions. Recycling and processing of foodstuff in a closed environment has not been demonstrated. There are unsolved problems with laundry of clothing and flame retardation. Recycling of water with monitoring capabilities to insure safety has not yet been accomplished in U.S. spacecraft. Many state-of-the-art advancements in biotechnology and engineered foods offer promise for solving the complex problems involved in providing human consumables for long-duration space flights.

Bourland, C. T. (JSC): Evolution of the Space Station Food System. Presented at the Nutrition in Space Symposium, April 1, 1990, Washington, D.C.

The proposed food system for Freedom Station evolved from experiences and developments of past U.S. manned missions. The longer planned missions for Freedom Station required that food acceptability be given a high priority in the type of food preservation selected. To meet the acceptability criteria, approximately one-half of the food will be frozen or refrigerated. Fresh fruit and vegetables will be preserved by controlled atmosphere packaging, and ultra high temperature pasteurization with aseptic packaging will be used to provide fresh milk. Most foods will be packaged in single-service containers which can be heated in the convection/microwave oven. Special consideration will be given to food-generated trash. Food containers will be compacted and returned to Earth for disposal. Planned food service equipment, menu selection and design, and emergency food supplies will also be presented.

Brown, M. F. (JSC); Lee, M. G.; Powell, F. T. (Life Systems, Inc.): Hybrid Air Revitalization System for a Closed Ecosystem. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

For future extended-duration, manned missions, development of life support systems that require minimum expendables, power, weight, and volume is essential. The ability to produce useful materials with minimum processing by using metabolic and life support byproducts is also of great importance. This paper describes a closed ecosystem concept that includes a Hybrid Air Revitalization System (HARS) which houses edible plants in a plant habitat for removing metabolic CO2 and moisture for plant photosynthesis while producing O2 for crew consumption. The system also includes electrochemical CO2 and O2 separators and a moisture condenser/separator for CO2, O2, and humidity levels in the crew and plant habitats at their respective optimal conditions.

Cioletti, L. A.; Mishra, S. K.; Richard, E. E.; (KRUG); Pierson, D. L. (JSC): Microbiology Facilities Aboard Space Station Freedom. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

The environment of Space Station Freedom cannot be maintained germ-free. To protect the astronauts' health from microbial diseases and the spacecraft from microbial colonization and system-fouling, a comprehensive microbiological facility has been planned. The Microbiology Subsystem is designed so that isolation and identification of a wide range

of microbes from clinical specimens and environmental samples and antibiotic sensitivities can be performed.

Cullingford, H. S. (JSC); Bennett, W. P.; Holley, W. A.; Carnes, J. G.; Jones, P. S. (LESC): CELSS Simulations for a Lunar Outpost. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

The Controlled Ecological Life Support System (CELSS) Emulator is operational for computer simulations of integrated CELSS operations involving humans, plants, process machinery, and reservoirs while the development of new capabilities continues. This paper describes a 5-year simulation of two mission scenarios consisting of 14 different "events" that could take place at a lunar outpost. The time-dependent status of the life support consumables was calculated in response to the two selected mission scenarios. This application demonstrates that complex sequences of events are reproducible for understanding of integrated mission operations.

Cullingford, H. S. (JSC); Bennett, W. P.; Holley, W. A.; Carnes, J. G.; Jones, S. (LESC): The Controlled Ecological Life Support System (CELSS) Simulations for a Lunar Outpost. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

The Controlled Ecological Life Support System (CELSS) Emulator has been under development at JSC to analyze computer simulations of integrated CELSS operations involving humans, plants, and process machinery. This paper describes a lunar base simulation, supporting a variable crew size over a 5-year period. High productivity wheat is the sole driver for biogeneration functions, including the crew diet. The time-dependent status of the life support reservoirs is related to a lunar base strategy. The CELSS Emulator allows one to generate model data sets, store libraries of results for further analysis, and display plots of model variables as a function of time.

Cullingford, H. S. (JSC); Microwave Irradiation of Cellulose and Enzymatic Hydrolysis of Waste Paper. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

Potential waste materials like waste paper and crop growth byproducts associated with a Controlled Ecological Life Support System (CELSS) must be efficiently used in long-term missions. This study investigates the possibility of using microwave pretreatment to enhance enzymatic hydrolysis of waste paper and other cellulosic wastes. Experimental data indicate that pretreatment with microwave irradiation at 110 C for 5 minutes increased the rate of enzymatic hydrolysis from 37% cellulose converted in 48 hours for the untreated sample to 92% converted for the treated sample. The microwave irradiation appears to collapse some of the highly crystalline structure of the cellulose matrix. Addition of acetic acid during the same process significantly reduced the rate of enzymatic action.

Cullingford, H. S. (JSC); Schwartzhoph, S. H. (LESC): Conceptual Design for a Lunar-Base Controlled Ecological Life Support System (LCELSS). Presented at the Space 90: The 2nd International Conference on Engineering, Etc. in Space, April 23-26, 1990, Albuquerque, New Mexico; at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia; and at the Joint Soviet-American Symposium on Controlled Ecological Systems, April 22-27, 1990, Krasnoyarsk, USSR.

Regenerative life support technology is needed for long-duration missions and

the establishment of lunar or planetary bases. This paper describes a conceptual design of a Lunar-Base Controlled Ecological Life Support System (LCELSS) that will support a crew of 4 + 100. The system includes, or incorporates interfaces with, eight specific subsystems: air revitalization, water and waste processing, food and biomass production, extra habitat/ vehicular activity (EHVA), in situ resources utilization, and system monitoring and maintenance. Final results of an analysis of mass and energy flows are reviewed, along with an evaluation of system mass, volume, and energy requirements. Resupply mass requirements and accompanying breakeven points are presented, and the structure and contents of the data base constructed to support the development of this conceptual design are discussed.

Cusick, R. J. (JSC): Development of a Regenerable Metal Oxide CO2 Removal System. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

A regenerable metal oxide carbon dioxide (CO2) removal system was developed to replace the current means of a non-reusable chemical, lithium hydroxide, for removing the metabolic CO2 of an astronaut in a space suit. Testing indicates that a viable low-volume metal oxide concept can be used in the portable life support system for CO2 removal during Space Station extravehicular activity (EVA). A canister containing 2.8 liters of silver-oxide-based pellets was tested. Analysis indicates that 5.1 liters of the metal oxide will result in an 8-hour EVA capability. Testing suggests that this technology offers a low-volume approach for a reusable CO2 removal concept applicable for at least 40 EVA missions. The development and testing of the breadboard regeneration package is also described.

Cusick, R. J. (JSC); Kast, T. P.; Nacheff-Benedict, M.; Chang, C. H. (ASAC): Characterization of Metal Oxide Absorbents for Regenerative CO2 and H20 Vapor Removal for Advanced PLSS. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

Parametric studies were conducted to characterize the performance of a silver-oxide-based absorbent in terms of its ability to remove both gaseous CO2 and H2O vapor. This phenomenon is highly desirable and could lead to a much simplified portable life support system (PLSS). Studies included an investigation of the effects of preconditioning the absorbent and cooling the absorbent bed, and the impact of various levels of inlet CO2 and H2O vapor partial pressures. Results indicate that, by cooling the absorbent bed during use, significant amounts of CO2 and H2O vapor can be removed. Bed cooling was necessary to compensate for the exothermic nature of the gas/solid reactions. The bed operating temperature had a significant effect on H2O vapor removal performance. In addition, the method of absorbent preconditioning impacted initial H2O vapor uptake, so that the outlet dewpoint could be maintained above a lower limit. The behavior of the absorbent under various inlet conditions also showed characteristics which are advantageous for a PLSS application.

Harm, D. L. (JSC); Crosier, W. G.; Duncan, K.; Ferrar, F. (KRUG): A Trainer for Preadapting Astronauts to Sensory Rearrangements Produced by Microgravity. Presented at the 8th Annual Conference on Biomedical Engineering Research in Houston, February 15-16, 1990, Houston, Texas.

Space Motion Sickness (SMS) is a common occurrence experienced in space flight. Approximately 70% of the astronauts who fly on the Space Shuttle develop symptoms that can interfere with their productivity and sense of well being,

but almost all of them adapt to the conditions of microgravity within 2-5 days. Preflight Adaptation Training (PAT) is based on an improved understanding of neurosensory adaptation to the microgravity stimulus rearrangements, and offers a promising new technique for reducing SMS symptoms and improving neurovestibular performance during flight, entry, and landing. This paper describes the features of the newest PAT device, which is designed to reduce dependence on otolith information as an indicator of spatial orientation.

Huntoon, C. L. (JSC): Medical Requirements for the Human Exploration Initiative. Presented at the Annual Biomedical Engineering Conference, October 10-12, 1990, Adelaide, South Australia.

Fundamental differences between the environments of space and Earth challenge the ability of technology to sustain the astronauts who will establish human presence in the solar system. The research program that will pave the way for these pioneers must provide an understanding of the physiologic basis for human responses to space flight and develop appropriate treatments and countermeasures. The major areas in which information is needed to prepare for human exploration of the solar system are protection from radiation,countermeasures against microgravity, provision of medical care in space, and provision of a physically and psychologically habitable environment by life support and other measures. The interactions of these factors must be studied to ensure that crewmembers are physically and mentally able to perform the required tasks and that hardware and procedures are designed to promote safe and effective performance.

James, J. (JSC); Yang, L.; Martin, M.; Glazner, M.; Limero, T. (KRUG): Development of a Volatile Organic Analyzer for Space Station Air Quality Monitoring. Presented at the 38th ASMS Conference on Mass Spectrometry and Allied Topics, June 3-8, 1990, Tucson, Arizona.

The gas chromatography/mass spectrometry (GC/MS) analysis and data reduction of volatile organic compounds collected from the shuttle internal atmosphere can be a labor-intensive process since as many as 100 compounds may be identified in a single sample. It would be desirable to automate these compound identifications along with subsequent quantitation procedures so the analyst would be free to concentrate on the weak or unusual spectra that would be difficult to identify.

Juday, R. (JSC); Loshin, D. S. (University of Houston). Real Time Image Warping for Low Vision Prosthesis. Presented at the Electronic Imaging Conference, October 30, 1990, Boston, Massachusetts.

Some new classes of image warping for potential application in human low vision prosthesis are described. The notion is to present a retina, dysfunctional by reason of known field defects, with a representation of the world that maps more of the world onto its still viable portions. Some mapping functions are shown that embody differing constraints.

Kolodney, M. (LESC); Conger, B. (LESC): Integration of G189A and ASPEN-PLUS for the Transient Modeling of Extravehicular Activity Atmospheric Control Systems. Presented at the *AIAA* 15th Annual Technical Symposium and 20th Intersociety Conference, May 24, 1990, Houston, Texas.

A computer modeling tool is being developed for detailed transient modeling of the extravehicular activity atmospheric control subsystem (EVA ACS). An EVA ACS includes the astronaut, CO2 removal,

moisture control, temperature control, and oxygen makeup components. This modeling tool will be used in trade studies evaluating competing components and subsystems to guide the selection and development of hardware for lunar and martian missions. Several computerized modeling packages already exist, but no single program has all the capabilities needed. Therefore, the integrated modeling tool utilizes Advanced System for Process Engineering (ASPEN) to perform detailed pseudo-steady-state simulations, and General Environmental Thermal Control and Life Support Program (G189A) for transient input/out [I/O], transient model calculations, the data base functions, and plotting. This integrated program has the capabilities necessary to perform detailed evaluations of processes currently being considered for lunar and Mars EVA ACS applications.

Lawson, M. (JSC); Wilson, J. (LESC): Investigation into Venting and Non-Venting Technologies for the Space Station Freedom Extravehicular Activity Life Support System. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

NASA has researched and evaluated venting and non-venting technologies. NASA has concentrated on a system-level approach that emphasizes on-orbit regeneration capabilities, minimization of expendables, and minimal on-orbit maintenance requirements. This paper will describe the estimated weights and volumes for the options.

Lubin, D.; Loman, M. (MDSSC): Assessing Display Design for Optimizing Workload. Presented at the *SAE* Aerotech 90 Conference, October 1-4, 1990, Long Beach, California.

This report describes a methodology for designing optimal human-computer interfaces by automatically accessing and analyzing detailed measures of user interactions with a given system. The traditional approach to designing man-machine interfaces, which typically involves the application of psychological or human factors principles, was also reviewed. This report noted such principles typically fail to generalize or may not be logistically feasible across all possible types and contents of man-machine interactions. Specific issues related to the design of flight crew interfaces with Space Station Freedom systems were used to exemplify the application of both approaches. It was concluded that the two are not mutually exclusive. Contrarily, it was suggested that SSF user interfaces could be arranged to optimize crew workload through the application of both approaches at specific points in the design process. While most of the examples offered in this report focused on the design of Space Station Freedom (SSF) crew-system interfaces, the same methods should be applicable to other complex manned-vehicles, including military and commercial aircraft.

Maddox, L. M.; Jones, S. F. (MDSSC): Crew Interfaces with Automation and Robotics. Presented at the SAE Aerotech 90 Conference, October 1-4, 1990, Long Beach, California.

In order for the assembly and operation of the Space Station Freedom to become a reality, several key technologies are required. Two of the most important of these are advanced automation and robotics. The primary focus for automation will be the crew interfaces and human-computer interaction techniques which guide successful problem solving with complex, highly automated systems. The systems to be reviewed include the Maintenance and Diagnostic System, the Active Thermal Control System, an expert system for fault detection identification and recovery (FDIR), and the medical diagnosis expert systems for crew health care system (CHCS). In addition, a methodology for

developing and implementing advanced automation projects will be presented. The main focus of robotics will be the crew interface issues associated with external camera video viewing and window clearance problems, and operational timelines. Future plans for the evolution and evaluation of Space Station Freedom automation and robotics crew interfaces will also be discussed.

Michalek, W. F.; Grounds, P. F. (JSC); Reysa, D. (Boeing): Single Phase Laundry for Long Duration Space Missions. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

Long-duration space flights will require an on-board clothes laundering facility to reduce the logistic requirement of resupplying clean clothing. The concept investigated and discussed in this paper addresses two major problems associated with all microgravity clothes laundering facilities to date: high energy consumption and two-phase air/water waste streams. Foam and air bubbles decrease the efficiency of pumps, storage vessels, and water reclamation systems. This problem was overcome by eliminating all air additions during the wash/rinse cycles. Energy consumption is minimized by use of microwave energy for drying.

Minchew, M. (LESC): The Future Direction of Human Engineering Standards in the Aerospace Industry. Presented at the *AIAA* 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The Man-Systems Integration Standards (MSIS) is a unique document in the aerospace industry. It represents the most comprehensive documentation of human engineering concerns as related to hardware design and is kept current through evaluation and review by both the user population and experts in the human engineering discipline of the aerospace industry. As NASA expands and enhances the direction of future space initiatives, the advanced technology involved will require a definition and clarification of human engineering requirements. These initiatives will necessitate the development and integration of a system to control the numerous specialized volumes of the standards. Specialized volumes currently being considered for development include the assured crew return vehicle (ACRV) and the Lunar and Mars Exploration Initiatives. The use of various tools, both software and hardware, will enable the system of control for the volumes to expand to fit the need of NASA's future initiatives.

Ouellette, F. A.; Winkler, H. E. (JSC); Smith, G. S. (United Technologies Corp.): Extended Duration Orbiter (EDO), Regenerable CO2 Removal System (RCRS). Presented at the International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

The extended duration orbiter (EDO) requirements of missions up to 18 days and the capability for future missions up to 30 days necessitated the development and implementation of an regenerative CO2 removal process. This new system will reduce the launch weight and stowage volume as compared to the present method of CO2 removal, lithium hydroxide, which is stowed in canisters. The selected design, called the Regenerable CO2 Removal System (RCRS), uses a solid amine material to adsorb carbon dioxide and water vapor and periodically desorb these to space vacuum. The RCRS, which is located below the mid-deck floor, interfaces with the orbiter's cabin Atmospheric Revitalization System (ARS) and is adjustable from four to seven crewmembers. The RCRS is designed to automatically cycle the beds from adsorb to vacuum-desorb every 30 minutes. Also incorporated into the design are features such as consumable recovery, external leak protection, trace contaminant control,

and automatic control logic operation. This paper describes the design and development status of the RCRS.

Schafer, L.; Squires, W.G.; Greenisen, M.C. (JSC): The Force Transmission Capability of Prototype Advance Space Suit Assemblies. Presented at the *ASMA* Annual Meeting, May 13-17, 1990, New Orleans, Louisiana.

This study investigated the force transmission capabilities of the AX-5 and MK III 57.2 kN . m-2, prototype space station EVA suits. The capabilities of these two suits were evaluated against those of the current, 29.6 kN . m-2, shuttle suit. The study population consisted of four male astronauts. The three suits were tested at random by each crewman. A series of defined static and dynamic exercises were then performed. These exercises were selected either to isolate a particular space suit articulation or to simulate actual EVA tasks. Weightlessness was simulated via neutral buoyancy in the Weightless Environmental Training Facility. The test article was an underwater dynamometry system, to which the astronauts were secured by foot restraints. The peak torques from three static and five dynamic trials were averaged for each exercise and converted to applied forces. Evaluation of percent differences indicated that differences in force transmission capability occurred in the suit comparisons. These results demonstrate significant operational performance differences between those prototype space suits.

Slavin, T. J.; Oleson, M. W. (Boeing): Physico-chemical Technology Tradeoffs Related to Advanced Mission Waste Processing. Presented at the Symposium on Waste Processing in Space for Advanced Life Support, September 9-11, 1990, Moffett Field, California.

This paper discusses the extent and impact of the life support system waste production problem for a lunar base for different life support system configurations, including the impact of using in situ resources to supply life support functions. Discussed in more detail are tradeoffs among six of the currently funded physiciochemical waste processing technologies being considered for use in space. The solution for short-term missions appears to be either to dispose of these wastes onsite or to convert them into useful byproducts such as methane, water, and gases for propellants. The solution for longer missions appears to be to make them part of a closed ecological life support system, recycling nearly all materials.

Stramler, J. (Barrios): A Review of the Habitability Aspects of Prior Space Flights from the Flight Crew Perspective with an Orientation Toward Designing Space Station Freedom. Presented at the *AIAA* Space Programs and Technologies '90 Conference, September 25-28, 1990, Huntsville, Alabama.

While habitability is a vital issue for humans on earth, in space flight, (with longer flight durations expected from Space Station Freedom and beyond) habitability becomes an even more vital issue for the astronauts. Work on this issue has indicated that personnel living and working in situations similar to what is expected for long-duration space flights (LDSFs) have certain needs and may experience certain problems. Analogous situations include nuclear submarines, Antarctic research stations, undersea habitats, and Arctic oil camps. The Biosphere II project, getting under way this year, may provide yet another analog. There is some disagreement as to how good these analogs are, but the similarities appear to outweigh the differences and comprise much of what data is available today. Conditions experienced by personnel in these situations as well as what LDSF data is available from the Soviet flights are included. Some typical human responses to such conditions are also provided.

Stuart, M. A.; Smith, R. L; Bierschwale, J. M. (LESC): Anthropometric Physiological Considerations for Space Based Telerobotic Operations. Presented at the 61st Annual Scientific Meeting of the Aerospace Medical Association, May 13-17, 1990, New Orleans, Louisiana.

During the performance of remote manipulation activities, certain anthropometric issues involve the placement and layout of the workstation with respect to other components of the space vehicle placement and type of physical restraint systems, and the placement and types of hand controllers which are used. From an anthropometric perspective, the selection of hand controllers is critical since the range of motion varies widely between hand controllers. From a physiological perspective, the selection of hand controllers is important since the physical workload requirements associated with different hand controllers can vary widely. Research is described that was conducted by the Remote Operator Interaction Laboratory (ROIL) at NASA JSC concerning anthropometric considerations in the design and layout of human-telerobot workstations.

Vincze, J. (MDSSC); Sauer, D. (JSC): Space Station Environmental Health System Water Quality Monitoring. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia.

One of the unique aspects of the Space Station is that it will be a totally encapsulated environment, and the air and water supplies will be reclaimed for reuse. The Environmental Health System must monitor the air and water on board the Space Station to verify that the quality is adequate for crew safety. Specifically, the Water Quality Subsystem will analyze the potable and hygiene water supplies regularly for organic, inorganic, particulate, and microbial contamination. The equipment selected to perform these analyses will be commercially available instruments converted for use on board the Space Station. Therefore, the commercial hardware will be analyzed to identify the gravity-dependent functions, and modified to eliminate them.

Woolford, B. (JSC): Operator Modeling at the Johnson Space Center. Presented at the 98th Annual Convention of the American Psychological Association, August 10-14, 1990, Boston, Massachusetts.

The Man-Systems Division at the Johnson Space Center (JSC) enhances the performance of crewmembers in space by assessing equipment before it is built and flown through the use of computer simulations of crew performance. Special emphasis is placed on physical capabilities. JSC can model a physical environment and place the image of any crewmember in the picture while checking for reach, access, and fit. Entire operations are animated and produced semiautomatically. Software models allow the engineers to evaluate a piece of equipment or an operation before building the prototypes or running elaborate tests in mockups. Emphasis is also placed on cognitive performance models. The long-term goal is to develop a combination of models which allows the engineer to specify a task, an environment, and the equipment required, and to produce outputs which describe times, difficulties, and procedures chosen by the modeled operator. These steps will substantially increase productivity in space flight.

STAR Category 55 - Space Biology

Ming, D. W. (JSC): Lunar Agriculture: A Reality in the 21st Century. Presented at the Seminar Series in Engineering and Sciences in Space Conference, September 18, 1990, Colorado State University, Fort Collins, Colorado.

Regenerative Life Support Systems (RLSS) will need to be developed to regenerate air, water, and wastes and to produce food for human consumption during long-duration space missions (e.g., lunar and Mars outposts). Biological systems will plan an important role in RLSS; however, there are a number of unknowns when dealing with biological systems in environments unlike those on the Earth. Research in RLSS will open up a variety of new opportunities. For example, it may be necessary to genetically alter plant species to adapt to space environments. In addition to genetic engineering, other research opportunities include plant physiology, toxicology, microbiology, etc., as they relate to plant production and reproduction. In order to efficiently produce food for human crew, it will be necessary to maximize plant production in closed, controlled environments that require as little power as possible. For atmosphere regeneration, gas exchange capabilities will have to be established for a number of potential plant species or other biological species (e.g., algae, microorganisms). Other possible biological research areas include water purification and waste recycling. It will also be necessary to integrate the biological components of an RLSS with physiocochemical components and spacecraft hardware.

Ming, D. W. (JSC): Opportunities in Clay Sciences: Lunar and Mars Exploration Initiative. Published in the CMS Newsletter.

Regenerative Life Support Systems (RLSS) will need to be developed to regenerate air, water, and wastes, and to produce food for human consumption during long-duration space missions, e.g., lunar and Mars outposts. It will be necessary to determine how biological components, e.g., plants, will behave in the hypogravity environments on the Moon and Mars, or in the microgravity environment of space. Research in RLSS will open up a variety of new opportunities. For example, it may be necessary to genetically alter plant species to adapt to space environments. In addition to genetic engineering, other research opportunities include plant physiology, toxicology, microbiology, etc., as they relate to plant production and reproduction. Research can be conducted on the factors that control the effectiveness of biological systems for use in RLSS. In order to efficiently produce food for human crews, it will be necessary to maximize plant production in closed, controlled environments that require as little power as possible. For atmosphere regeneration, gas exchange capabilities will have to be established for a number of potential plant species or other biological species, e.g., algae and microorganisms. Other possible biological research areas include water purification and waste recycling. It will also be necessary to integrate the biological components of a RLSS with physiocochemical components and spacecraft hardware.

GE Aerospace: Reusable Reentry Satellite Final Report. NASA CR-185639, September 21, 1990.

The Lifesat/RRS vehicle concept will provide life science researchers with relatively inexpensive and frequent access to the space environment on a long-term basis. It is a direct extension of the Discoverer/Biosatellite Program and the Space Shuttle middeck locker/Spacehab life sciences flight experiment data bases. The results of our RRS Phase B Study are described herein. A 79-inch Discoverer configuration was selected as the preferred design to accommodate 18 rats

in orbit for 60 days with subsequent recovery. This size and configuration also accommodates the European Space Agency (ESA) Botany Module. This final report of "Reusable Reentry Satellite" was prepared by the General Electric Company, Reentry Systems Department for the National Aeronautics and Space Administration, Lyndon B. Johnson Space Center (JSC) in accordance with Contract NAS9-18201.

Lewis, M. L.; Damron, K. L. (KRUG); Nachtwey, D. S. (JSC): A Miniaturized Fibrionolytic Assay for Plasminogen Activators. Published in *Thrombosis Research.*

In all biological and most chemical assays, it is necessary to compare an estimate of the unknown amount of a substance in a specimen with a standard of know concentration. Statistical procedures are used to minimize the errors. The accuracy of these assays depends on rigorous experimental control of the testing situation and on the appropriateness of the technique used to analyze the data. We developed a miniaturized fibrinolytic assay to evaluate plasminogen activator in tissue culture medium of human kidney cells separated by continuous flow electrophoresis on NASA Shuttle flight STS-8 and on Earth. Out of this effort, an easy to use, interactive FORTRAN program was developed to apply accepted statistical techniques to the analysis of dose/response curves and to test the assumptions necessary for application.

STAR Category 59 - Mathematical and Computer Sciences

Chlouber, D.; O'Neill, P.; Pollick, J. (MDSSC): General Upper Bound on Single Event Upset Rate. Published in the *IEEE Transactions on Nuclear Science Journal*, Vol. 37, No. 2, April 1990.

A technique of predicting an upper bound on the rate at which single event upsets due to ionizing radiation occur in semiconducting memory cells is described. The upper bound on the upset rate, which depends on the high energy particle environment in Earth orbit and accelerator cross section data, is given by the product of an upper bound LET spectrum (I_{oo}) and the mean cross section of the memory cell. Plots of the spectrum (I_{oo}) are given for low inclination and polar orbits. An alternative expression for the "exact" upset rate is also presented. Both methods rely only on experimentally obtained cross section data and are valid for sensitive bit regions having arbitrary shape.

Grooms, H. R.; Hinz, P. J.; Commerford, G. L. (RSOC): A NASTRAN Trainer for Dynamics. Presented at the 18th NASTRAN User's Colloquim, April 26-27, 1990, Portland, Oregon.

A NASTRAN trainer has been developed as an automated tool to help new users become familiar with solving dynamics problems. This paper explains the scope, purpose, and organization of the system. A set of eight example problems that are part of the trainer are discussed. Typical user results for one of the examples are given. The dynamics trainer is a part of a larger system that includes a static trainer (complete), quick access on-line documentation(complete), and an advisor (in development).

Pearce, D. G. (LESC): Some Fun With 300 Dimensions. Presented at the *AIAA 28th* Aerospace Sciences Meeting, January 8-11, 1990, Reno, Nevada.

In this discussion, the optimization of discrete grids (for use in computational fluid dynamics, structural mechanics, or heat transfer) will be explored. In this approach, each coordinate of each point of the grid is treated as a variable that can change independently as if it were moving in its own dimension. As an example, a 10x10 grid in normal Euclidean 3-space can be described as a point in a 300 dimensional solution space. The equations that relate the variables can be combined to form a single scalar cost function which can be thought of as a 300 dimensional surface that defines the collection of all possible grids. The resulting problem then becomes one of finding the minimum of this surface. Results for several test cases show that the system is well behaved. Applications and future extensions of this method will be explored.

STAR Category 60 - Computer Operations and Hardware

Bierschwale, J. M.; Stuart, M.A.; Sampaio, C. E. (LESC): Investigation of Varying Gray Scale Levels for Remote Manipulation. Presented at the 4th Annual Workshop on Space Operations, Automation, and Robotics, June 26-28, 1990, Albuquerque, New Mexico.

A study was conducted to investigate the effects of monitor gray scale levels and work place illumination on operators' ability to discriminate between different colors on a monochrome monitor. It was determined that monitors used for performing remote manipulation tasks should have at least 16 shades of gray since this evaluation has found lower levels to be unacceptable for a color discrimination task. There was no significant performance difference found between a high and a low work place illumination condition. Further analysis was conducted to determine which specific combinations of colors used in this study can be used in conjunction with each other to ensure error-free color coding/brightness discrimination performance while viewing a monochrome monitor.

Donner, K.; McKay, T.; Gillan, D. J. (LESC); Rudisill, M. (JSC): The Effects of Display Format, Highlighted Item and Highlighting Technique on Search/Identification Tasks. Presented at the Computer-Human Interaction 1990 Conference, April 1-4, 1990, Seattle, Washington.

Color highlighting on computer information displays may affect the processing of non-highlighted information. Interfering with the processing of non-highlighting information may be beneficial when searching for highlighted information, but may limit performance when non-highlighted information is the task force (e.g., Fisher & Tan, 1989). Subjects searched Space Shuttle displays for requested information. Displays varied by display layout (current and revised), highlighted item (target and distractor), and highlighting technique (color, brightness, flashing, reverse video, and no highlighting). Color was not any more distracting than achromatic highlighting when applied to nontargets; and response times to current, poorly-formatted displays were improved, almost to the revised display level, with most highlighting techniques. The results are discussed in relation to human-computer interface design.

Gillan, D.; Holden, K.; Adam, S.; Magee, L. (LESC); Rudisill, M. (JSC): How Does Fitts' Law Fit Pointing and Dragging? Presented at the Computer-Human Interaction 1990 Conference, April 1-4, 1990, Seattle, Washington.

Two experiments examined the selection of text using a movement

sequence of pointing and dragging. Experiment 1 showed that, in the point-drag sequence, the pointing time was related to the pointing distance but not to the width of the text to be selected. In contrast, pointing time was related to both the pointing distance and the width of the text in the point-click sequence. Experiment 2 demonstrated that both the pointing and dragging times for the point-drag sequence were sensitive to the height of the text that was selected. The discussion of the results centers around the application of Fitts' Law to pointing and dragging in a point-drag sequence. This suggests that the target for pointing is the leftmost edge of the text to be selected, and the target for dragging is the rightmost edge of the text.

Jenks, K. (RSOC): Paperless Spacecraft. Presented at the *AIAA* 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

Automation is changing the way we operate spacecraft. NASA's Johnson Space Center is developing concepts which involve the use of computers to reduce the amount of paper-based documentation required to operate the Space Shuttle and Space Station Freedom. The implications of eliminating the use of paper from the daily operations of a spacecraft will be discussed. A brief review will be given of the current uses of documentation on orbit.

Lulla, K. P.; Helfert, M. (JSC): Macintosh-Based Image Processing for Shuttle Earth-Viewing Photography. Presented at the Association of American Geographers Annual International Meeting, April 1990, Toronto, Canada.

An innovative image processing system has been assembled using off-the-shelf scanning, digitizing, and processing components that are driven by a Macintosh II system having 60 Mb internal and 160 Mb external hard disks. Other output peripherals and input devices such as an optical disk drive, WORM drive, CD-ROM, Laser printer, and film printer are integrated into the assembly.

Rudisill, M. (JSC); Adam, S., Holden, K., Gillan, D. (LESC): Microgravity Cursor-Control Device Evaluation for Space Station Freedom Workstations. Presented at the Space Operations, Applications and Research Symposium, June 28, 1990, Albuquerque, New Mexico.

Computer workstations will control Space Station Freedom systems and payloads. These microgravity workstations will use direct manipulation interfaces rather than command-line interfaces because they significantly reduce the number of finite actions required to operate a computer, thus reducing errors and overall task completion times. This research addresses direct-manipulation interface (cursor-control device) usability in microgravity from KC-135 flights and an STS-29 Detailed Test Objective (DTO). Three commercially available devices: an optical mouse, a trackball, and a post-mouse, were chosen to determine the best characteristics for an optimal microgravity device. A text editing task was performed aboard the KC-135 flights which included pointing and dragging movements over a variety of angles and distances. Detailed error and completion time data, as well as crew comments from the DTO, provided information regarding cursor control shape, selection button arrangement, sensitivity, selection modes, and considerations for future research.

STAR Category 61 - Computer Programming and Software

Ames, B. E.; Iovine, J. V. (LESC): Advanced Mission EVA System Modeling and Trade Study Tool. Presented at the 20th International Conference on Environmental Systems, July 9-12, 1990, Williamsburg, Virginia, and at the *AIAA* 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

Trade study evaluations for various extravehicular activity (EVA) technologies can be accomplished using the Life Support Options Performance program version 2.0 (LSOPP II). LSOPP II is an interactive, menu-driven program based on a dual loop structure (Vent Loop-Water Loop). It solves for the outlet flow conditions of each component in a loop given the associated heat loads and inlet flow conditions. System and component results of LSOPP II include: Heat Load, Flowrate, Pressure, Temperature, Power, Weight, and Volume. System level parameters to be entered by the user include: Metabolic Rate, Suit Type, Environment, and Design Parameters. The user selects which technology should be used for CO2 removal, humidity control, thermal control, gas supply, power supply, liquid cooled garmet, vent fan, and water pump. The user also selects where to place each component on the vent loop or water loop. Component level parameters to be chosen by the user also include electronics heat load, and design EVA duration of each component.

Cernosek, G. J. (MDSSC): COMWG-A Common Models Working Group for Managing ADA Software Commonality. Presented at the *AIAA* 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

This paper presents the background, results, and directions of the Ada software commonality efforts at McDonnell Douglas in Houston. The Common Models Working Group (COMWG) is the latest activity and is responsible for the parts engineering of the Ada Reusable Components Library (ARCLib). Several simulation and analysis tasks are using the ARCLib in support of a parts-based approach to application development. The COMWG currently focuses on engineering models for NASA's Space Station Freedom and interplanetary domains.

Culbert, C. (JSC), ed.: First CLIPS Users Group Conference Proceedings. NASA CP-10049, 1990.

Papers presented at the First CLIPS Conference held at the Lyndon B. Johnson Space Center, August 13-15, 1990, are documented in this publication. CLIPS is an expert system tool developed by NASA JSC. During the 3-day conference, ~96 technical papers were presented by experts from NASA, other government agencies, universities, and industry. Technical topics included CLIPS, expert systems, and robotics.

Fox, B. (MDSSC): Automation and Expert System Applications to Space Flight Operations. [For release information contact the author.]

Contract NAS 9-17885 calls for support to JSC's Information Technology Division (formerly MPAD) in reviewing current planning and scheduling technology. It calls for the development of AI based application-independent planning and scheduling tools. These tools may be used to build feasibility demonstrations for a wide variety of planning and scheduling activities, including STS ground flight operations planning and scheduling. The demonstrations will illustrate interactive systems that guide a person to create schedules, modify and revise schedules, and monitor and maintain schedules as well as illustrate opportunities to automate tedious revision, monitoring, and maintenance of activities.

Fox, B. (MDSSC): COMPASS and Documentation for COMPASS. Presented at the 4th Annual Space Operations, Applications, and Research Symposium, June 26-28, 1990, Albuquerque, New Mexico.

Although LISP is typically used to solve computational problems using artificial intelligence, it is not well accepted for use in the commercial, space, or defense industries. Most scheduling systems are implemented in LISP; COMPASS (Computer Assisted Scheduling System) is an Ada- and X-Windows-based interactive scheduling system. Derived from a scheduler that was developed in LISP, COMPASS' implementation required careful engineering of symbolic data types, list data structures, garbage collection, string-based I/O, and other elements of the LISP language that were necessary for the application but not intrinsic to Ada. This paper describes implementation in detail, giving special attention to technology that was developed for COMPASS that can be easily adapted for the implementation of other AI applications in Ada.

Garman, J. A. (JSC): Perspective on NASA Flight Software Development, Apollo, Shuttle, Space Station. Presented at the AIAA/NASA Second International Symposium on Space Information Systems, September 17-19, 1990, Pasadena, California.

The programming of computers which support the mission of humans in space is both challenging and terrifying. It is challenging because the machines that we build to fly people in space can not be operated without computers. It is terrifying because those computers can affect not only the mission, but the safety and lives of those humans. During the last twenty-five years, the various metrics of power and capacity of flight-related computer systems all indicate increases of three orders of magnitude. There are few who would suggest that our capacity to create increasingly functional and reliable software has increased as rapidly, thus exacerbating the growing "gap" between this very unique form of "machine" and our ability to use it to its fullest potential. This paper examines the evolution of flight data systems, and in particular, flight software development. The characteristics and roles of the Apollo, Shuttle, and Space Station Freedom flight data systems are compared, as are the methodologies and "tools" used for developing their software. The principal challenges for the three programs are compared and discussed against the trends in today's information systems.

Jayatilaka, B. (GE): Distributed Data Simulator for Life Sciences Data System. Presented at the *AIAA* 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

A reliable experiment simulator must be capable of generating streams of data at high rates and performing time-critical functions. Such a system is being used in the Life Sciences section of the Johnson Space Center. It was a parallel processing environment that incorporates an easy-to-use interface running on a Macintosh platform. The system simulates a maximum of 8 data streams with a composite minimum throughput of 400 Kbps. A Macintosh acts as the user interface, allowing users to enter commands and see the status of the simulator while a MicroVax generates data streams and sends them to the appropriate receiving system. The connectivity between VAX and Macintosh, as well as the meticulous selection of data structures, has enhanced the efficient performance of the simulator system. This paper presents an overview of the simulator system with its intermachine correspondence and discusses the specific data structures and other features such as memory management and priority scheming.

Kolkhorst, B. C. (IBM): SID Houston Software Quality Improvement. Presented at the STC Technology Ltd. (England) and S/W Engineering Management Class (Belgium), May 7, 1990, England and Belgium.

This presentation addressed subjects such as the critical nature of onboard shuttle software; the high quality of shuttle software, IBM's Quality Improvement Process as key to software improvement; and productivity improvement as a yield of quality improvement.

Lubin, D.; Loman, M. (MDSSC): Assessing Display Design for Optimizing Workload. Presented at the *SAE* Aerotech 90 Conference, October 1-4, 1990, Long Beach, California.

This report describes a methodology for designing optimal human-computer interfaces by automatically accessing and analyzing detailed measures of user interactions with a given system. The traditional approach to designing man-machine interfaces, which typically involves the application of psychological or human factors principles, was also reviewed. This report noted such principles typically fail to generalize or may not be logistically feasible across all possible types and contents of man-machine interactions. Specific issues related to the design of flight crew interfaces with Space Station Freedom systems were used to exemplify the application of both approaches. It was concluded that the two are not mutually exclusive. Contrarily, it was suggested that SSF user interfaces could be arranged to optimize crew workload through the application of both approaches at specific points in the design process. While most of the examples offered in this report focused on the design of Space Station Freedom (SSF) crew-system interfaces, the same methods should be applicable to other complex manned-vehicles, including military and commercial aircraft.

Lund, C. (LESC): Expert System for Scheduling Simulation Lab Sessions. Presented at the First CLIPS Users Group Conference, August 13-15, 1990, Houston, Texas.

This paper discusses the implementation and results of an expert system used for scheduling session requests for the Systems Engineering Simulator (SES) laboratory at JSC. The system is comprised of two PASCAL programs run on a PC and a CLIPS program installed on a minicomputer. The weekly session requests come from astronaut crew trainers, procedures developers, engineering assessment personnel, and software developers who wish to access the computers, scene generators, and other simulation equipment available to them in the SES lab. A general overview of the system is provided, followed by a detailed description of the constraint reduction process and of the scheduler itself. Results from a 10-week period and a summary of this expert system's strengths and shortcomings are provided.

Neitzel, L. (CTA); Enos, V., Mallios, J. (MDSSC): Data and Object standards for the Space Station Freedom. Presented at the *AIAA* Meeting, September 17-19, 1990, Pasadena, California.

Because of the scale and distributed nature of the Space Station Freedom Program (SSFP), it is essential that uniform data standards be defined and baselined early in the program. This paper reviews an integrated set of object-oriented standards proposed for the definition of SSFP onboard and ground objects. These standards provide for object definitions that are consistent with the IRDS Dictionary Standard, the ISO Directory Standard, and the National Institute of Technology GOSIP standards.

O'Neal, M.; Manahan, M. (LESC): Spacecraft Crew Procedures - From Paper to Computers. Presented at the Space Operations, Applications, and Research Symposium, June 26-28, 1990, Albuquerque, New Mexico.

Currently, there is a desire to computerize the existing paper-based crew procedure systems. This paper describes a research project that uses human factors and computer systems knowledge to explore and help guide the transition from paper-based to computer-based crew procedure systems. The research project includes the development of computer-based procedure system prototypes, a complete system for experiments that measures the effectiveness of alternatives in order to make design recommendations. Progress on developing a prototype for a middeck experiment performed on Space Shuttle mission STS-34 is discussed. The status of the complete procedure system and experimental testbed are also discussed. Future implications and issues of computer-based procedure systems will also be discussed including the effect on user's cognitive workload, system versus user task allocation, and system adaptability to changing procedural environments.

Orr, L. S.; Woolford, B. (JSC): Graphics Analysis of Man-Machine Interaction in Space Environments. Presented at the National Computer Graphics Association (NCGA), March 19-22, 1990, Anaheim, California.

To assist NASA mission planners and spacecraft designers in performing man-machine evaluations, the Man-Systems Division uses an in-house computer graphics system called PLAID. PLAID has been used to help mission planners determine whether a given operation can be done with the Shuttle remote manipulator system (RMS), by an extra-vehicular activity (EVA) crewman, or by combined RMS/EVA operations. For Space Station Freedom design, PLAID is being used to define assembly procedures and identify problem areas early in the design process. PLAID computer-generated human models are being used to evaluate anthropometric issues in workstation design and window/camera/cupola viewing requirements for Station operations. This presentation will cover a discussion of present PLAID analysis capabilities, anticipated analysis expansion plans, present hardware limitations, and future hardware requirements.

Pierce, C. J.; Coleman, R. (MDSSC): Integrated Operations Requirements Development for Free Flyer Servicing at an Orbital Base. Presented at the *AIAA* 15th Annual Technical Symposium, May 1990, Houston, Texas.

The on-orbit servicing of free flyer satellites will engender a unique set of logistics and operations requirements. The planning and integration process must be modeled so that the activities, products, and interfaces associated with satellite servicing can be identified, scheduled, and integrated with other Space Station Freedom (SSF) and space transportation operations. Two families of satellites each present unique problems requiring analysis. Various software tools to model both the trajectories of co-altitude satellites and the nodal alignment/servicing opportunity schedules of the non-co-altitude satellites, along with the non-constant altitude of the SSF, have been developed and are being used in the development of a set of candidate traffic models and the associated integrated operations requirements.

Wessale, W. (CAE-Link): An Alternate Model for Real-Time Training Simulation Software. Presented at the Software Engineering Institutes Workshop on Computer Software Architecture, July 9, 1990, Somerset, Pennsylvania.

This paper presents the position that the traditional software model for training

simulation is no longer valid and suggests an alternate software model based on messages.

STAR Category 62 - Computer Systems

DeMasie, M. P. (JSC): Reconfiguration Management. Presented at the Real-Time Simulations for Aerospace Applications Series "Change Management," March 6, 1990, Houston, Texas.

Configuration management is the process of defining, controlling, and maintaining the baselined characteristics that define the particular state of a system, a software program, or a data object at a discrete point. Reconfigurability must be considered in the design of systems/data products. Reconfiguration involves the controlled process of defining and implementing required changes in hardware, software, and data to effect specific mission support and real-time mission objectives. Therefore, mission requirements must be clear, concise, and fairly stable prior to beginning the reconfiguration process. An offline ground data base that serves as the master repository for shared information (attribute and value) about all Space Station sensors and effectors, derived data parameters, commands, telemetry formatting, displays, and procedures is the master object data base (MODB). Data tables which are subsets of the MODB and contain current values for a configuration are maintained in the runtime object data base.

Gleason, W. R. (LESC): Space Systems Automated Integration and Assembly Facility (SSAIAF) Computer System Requirements Overview. Presented at the *AIAA* 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The mission of the Space Systems Automated Integration and Assembly Facility (SSAIAF), located at the Lyndon B. Johnson Space Center, is to support development of assembly and operation procedures, as well as to provide an engineering development tool for the assembly and support of large space structures. The SSAIAF computer system provides the computing resources required for simulation development, simulation execution, hardware control and monitoring, and data analysis. The assembly of Space Station Freedom was used as a baseline for developing user scenarios for SSAIAF. Assembly tasks were listed, and a hypothetical scenario was developed to perform the task. The resources required to simulate the performance of the task were divided into three categories: simulation, hardware control, and simulation and hardware monitoring. This list of resources provided a set of data from which definitive requirements could be derived for the SSAIAF computer system requirements. It describes how the requirements were developed, classified, and validated.

Scheffer, T. (MDSSC); Barry, T. (JSC): Integration by Parts. Presented at the 12th Aerospace Testing Seminar, March 13-15, 1990, Los Angeles, California.

Unique integration and, verification challenges associated with Space Station Freedom (SSF) require a solution - data management system (DMS) kits. Particular emphasis was placed on utilizing the capabilities and services of the on-board DMS to provide integration and verification tools, not only for the DMS but for other on-board distributed systems as well. DMS kits provided to system/software developers supplied a common set of integration and verification tools and hardware that were then used by individual system developers to simulate the complete data processing environment that will be available on board SSF. This paper describes the evolution of the integration process from the system level to final integration of multiple launch packages, addressing both ground and on-orbit aspects of the problem.

Smith, W. C. (LESC): Augmented Automation of Visual Readout Calibration Operations Using a Lap-Top Computer. Presented at the 1990 Measurement Science Conference, February 8-9, 1990, Anaheim, California.

Using lap-top computers to record visual observations and calibrations at calibration workstations reduces reentry errors and improves efficiency. Since the pointers of dial-type indicating devices, such as pressure gauges, must be manually observed and the data manually recorded at each workstation, on-site computers would allow accurate, one-time entry of the information. The data could be transmitted through the serial port of the lap-top, if applicable, or stored on disk and transferred to a central computer system later. Although individual computers at each station would be cost-prohibitive, a single portable lap-top computer could serve several stations. System design and operation is discussed, along with criteria for hardware selection and application program.

Valrand, C. B. (MDSSC): Space Station Data Management System Support of Automation and Robotics. Presented at the *AIAA* Space Programs and Technologies Conference, September 24, 1990, Huntsville, Alabama.

The Space Station Freedom Data Management System (DMS) has an open architecture with hardware and software components which support automation and robotics. The DMS provides a man-machine interface and data communications, data management, and data processing for Space Station distributed systems elements. The DMS has a distributed, modular architecture which supports stepped increases in operational capability. Multiple Standard Data Processors host onboard applications, are interconnected via fiber optic token ring networks, and through local buses, provide interfaces to sensors and effectors. External components are configured to support robotic handling. The basic design incorporates features, such as failure detection and recovery management, the User Interface Language, and network management, which support automation. Growth and evolution in support of advanced automation and robotics is accommodated by the modular design, which facilitates the addition of new hardware and software components and the replacement of old components with advanced technology components.

Welborn, C. R. (JSC); Robertson, C. (MDSSC): Multi-Threaded Procedural Reasoning in Real-Time Health Monitoring of Manned Spacecraft Systems. Presented at the First International Symposium on Ground Data Systems for Spacecraft Control, June 26, 1990, Darmstadt, Germany.

Health and status monitoring of onboard manned spacecraft systems today relies primarily on automatic detection of anomalies with manual diagnosis and reconfiguration for fault isolation performed by onboard crew and/or ground controllers. Two problems with this approach are (1) the requirement for large numbers of ground-based support personnel on a 24-hour basis during mission operations; and (2) the possibility of impaired ground controller "burnout" for long-duration missions. This manual approach will not be satisfactory for year-round health and status monitoring in future operations (e.g., Space Station). The solution is automation of the diagnostics and system reconfiguration recommendations as much as possible to facilitate rapid focused decisionmaking at the highest level by the crew or ground controller as described in this paper. The automated system executes standard diagnostics and malfunction handling procedures by focusing attention on a fault in a monitored subsystem, and can be interrupted to redirect focus to handle a more critical event occurrence. Thus, the automated system has the characteristics of both

goal-directed reasoning and real-time reactivity.

Wilhelm, P. P. ; Butler, G. V. (MDSSC): Space Station Data Management System Architecture. Presented at the 41st IAF Congress, October 6-12, 1990, Dresden, Germany.

The Space Station (SS) data management system (DMS) is the first large-scale distributed processing network for long-term use in space. The DMS provides a growth-oriented base for automation to increase crew productivity, thus enhancing SS operational capabilities. Space Station represents new and unique challenges for the U.S. space program. Among these are (1) an operational lifetime measured in decades, (2) incremental assembly, integration, and checkout on orbit, (3) continuous operations, (4) repair on orbit, (5) growth and expansion capability, (6) accommodation of new technology, and (7) support for automation and robotics, each element of which influences DMS architecture and design. Key features of the architecture are that it is (1) open and nonproprietary to avoid the cost of custom solutions, (2) structured and modular to support assembly/build up, growth, and technology insertion, (3) designed to accommodate standard hardware and software interfaces to isolate system complexity and simplify integration, and (4) capable of leveraging existing commercial and military hardware and software products to shorten design cycles and minimize development and maintenance costs.

STAR Category 63 - Cybernetics

Riley, G. D. (JSC). CLIPS: A Tool for the Development and Delivery of Expert Systems. Presented at the Technology 2000 Conference, November 26-28, 1990, Washington, D. C.

The 'C' Language Integrated Production System (CLIPS) is a forward chaining, rule-based language developed by the Software Technology Branch at the Johnson Space Center. CLIPS provides a complete environment for the construction of rule-based expert systems and was designed specifically to provide high portability, low cost, and easy integration with external systems. Other key features of CLIPS include a powerful rule syntax, an interactive development environment, high performance, extensibility, a verification/validation tool, extensive documentation, and source code availability. The current release of CLIPS, version 4.3, is being used by over 2,500 users throughout the public and private community including all NASA sites and branches of the military, numerous Federal bureaus, Government contractors, 140 universities, and many companies.

Ross, M. ; Shadle, G. (LESC): Computation of Inverse Kinematics of Redundant Manipulators Via Potential Functions. Presented at the JAIPCC Symposium, March 22, 1990, Houston, Texas.

A method of determining the inverse kinematics of a 7-jointed robotic arm is presented. The method minimizes an arbitrary configuration-dependent potential function in order to determine the joint angles. These functions allow the use of the robot redundancy to avoid obstacles, reach limits, boundaries, etc. A symbolic manipulation program is used to generate the lengthy expressions for the elements of a partial derivative matrix used in searching for the roots. Several different potential functions and their advantages and disadvantages are discussed. (A videotape of a simulation of these functions controlling a Robotics Research K-1607 redundant manipulator was shown.)

Wiesner, M.; Loftin, R. B. (JSC): Intelligent Tutoring Systems. Presented at the National Society for Performance and Instruction, August 23, 1990, San Antonio, Texas.

Since the early 1970's, substantial progress has been achieved in developing training and tutoring systems that incorporate artificial intelligence technology. Such systems are capable of "magnifying" the efforts of instructional personnel by providing each trainee or student with a personal trainer/tutor. Many subjects - e.g., computer programming, mathematics, electronic troubleshooting, and power plant operation - have been addressed by these "Intelligent" tutors or trainers. This paper focuses on a number of projects under way within NASA to develop intelligent training/tutoring systems for astronauts, flight controllers, system engineers, and computer operators supporting the Space Shuttle and Space Station programs. The widespread use of this technology could profoundly impact the delivery of instruction in Government, industry, and the nation's educational institutions.

Woods, D. (MDSSC): Space Station Distributed System Automation. Presented at the Artificial Intelligence for Space Applications Conference, May 22-23, 1990, Huntsville, Alabama.

In the development of a safe, productive, and maintainable space station, Automation and Robotics (A&R) has been identified as an enabling technology which will allow efficient operation at a reasonable cost. The Space Station Freedom's systems are very complex and interdependent. The usage of Advanced Automation (AA) will help restructure and integrate system status so that station and ground personnel can operate more efficiently. To use AA technology for the augmentation of system management functions requires a development model which consists of well-defined phases of evaluation, development, integration, and maintenance. During the integration phase the KBS software must be integrated with conventional software, and verified and validated. Applicable verification techniques are based on the ideas of consistency, minimal competency, and graph theory.

STAR Category 64 - Numerical Analysis

Badhwar, G. D. (JSC); Reynolds, R. C. (LESC): Velocity Perturbation Distributions in the Breakup of Artificial Satellites. Published in the *Journal of Spacecraft and Rockets*, vol. 27, May-June 1990, p. 299-305.

A method is presented for calculating the three orthogonal components of the velocity perturbations of satellite fragments, with a view to ascertaining the nature and intensity of the satellite breakup. The method employs three simultaneous equations furnished by changes in fragment specific energy, specific angular momentum, and plane orientation.

Badhwar, G. D. (JSC); Tan, A. (Alabama A. M. U.);Reynolds, R. C. (LESC): Velocity Perturbation Distributions in the Breakup of Artificial Satellites. Published in the *Journal of Spacecraft and Rockets*, Vol. 2, pp. 299-305, May-June 1990.

The magnitude, variance, and directionality of the velocity perturbations of the fragments of a satellite can provide information regarding the nature and intensity of the breakup. It has significant bearing on the distribution of debris around the Earth and is needed for the modeling of the debris environment in the low Earth orbit (LEO). The standard method of calculating the velocity perturbations from a fragmentation event is the one based on the rendezvous equations. This method, however, fails in many of the observed breakups. This paper describes a method of calculating the three orthogonal components of the

velocity change using three simultaneous equations provided by the changes in specific energy, specific angular momentum, and plane orientation of the fragments.

Bond, V. R.; Holloman, V. E. (MDSSC): Evaluation of the Element Propagator Method - BG14. Presented at the AIAA 15th Annual Technical Symposium, March 23, 1990, Houston, Texas.

This study evaluated several efficient, high-speed propagators/predictors for use in Space Station Freedom's on-board flight software. Of the propagators examined, two were evaluated in depth - BG14 and NLZ6/6. It soon became apparent that BG14 is the most efficient and accurate propagator of those mentioned in this study. BG14 is a modification of the Burdet method and utilizes a constant of the motion called the Jacobi integral which remains constant under the influence of a time-dependent potential function such as the geopotential. This enables the solution of the equations of motion to be expressed in terms of a function equal to a constant. To remove singularities from the differential equations of motion, BG14 executes a regularizing process by introducing an independent variable proportional to the eccentric anomaly. A short-term propagator for providing state vectors between GPS updates is also introduced. This semi-analytic method also has promising advantages.

Bond, V. R.; Fraietta, M. F.; Sponaugle, S. J. (MDSSC): A Unique Method for Analyzing Round Trip Missions from a Regressing Space Station Orbit to Lunar Orbit and Return. Presented at the 1990 AIAA Symposium - Space 1990's Countdown to the 21st Century, September 25-28, 1990, Huntsville, Alabama.

STAR Category 66 - Systems Analysis

Badhwar, G. D.; Konradi, A. (JSC): Conversion of Omnidirectional Proton Fluxes into a Pitch Angle Distribution. Published in the *Journal of Spacecraft and Rockets*, Vol. 27, No. 350, 1990.

Analysis of the AP-8 trapped radiation model has shown that at low L values omnidirectional fluxes of trapped protons as a function of the magnetic field for a fixed energy and L value can be approximated very well using thee parameters: scale, shape, and loss cone magnetic field which is related to the height of the atmospheric absorption. Using this insight we constructed an algorithm that allows us to convert the omnidirectional fluxes at all points along a field line into an equatorial pitch angle distribution, which in turn may be used to define the local pitch angle distribution at any point along the field line. This distribution is expressed as a function of a scaling constant K, a shape parameter β, and the pitch angle of the loss cone α_L.

Bedrossian, N. S.; Paradiso, J.; Bergmann, E. V. (CSDL): Redundant Single Gimbal Control Moment Gyroscope Singularity Analysis. Published in the *AIAA Journal of Guidance Control and Dynamics*, July-August 1990.

The singularity problem associated with single gimbal control moment gyroscopes (SGCMGs) is examined in detail, and a test for the possibility of escape is presented in the case when nontorque producing gimbal motion is possible at a singular configuration. The robotic manipulator is proposed as the mechanical analog to SGCMG systems and is used to define families of gimbal angle solutions for any momentum state.

Bedrossian, N. S.; Paradiso, J.; Bergmann, E. V.; Rowell, D. (CSDL): Steering Law Design for Redundant Single Gimbal Control Moment Gyroscope Systems. Published in the *AIAA Journal of Guidance Control and Dynamics*, November - December, 1990.

Two steering laws are presented for a system composed of four single gimbal control moment gyroscopes (SGCMGs) that realize commanded torques while avoiding internal singularities. A null motion algorithm using the Moore-Penrose pseudoinverse is shown to provide singularity robust inverse (SR-inverse) with appropriate null motion is shown to provide superior performance through limited introduction of torque error.

Malin, J. T.; Basham, B. D. (JSC); Harris, R. A. (MITRE): Use of Qualitative Models in Discrete Event Simulation for Analysis of Malfunctions in Continuous Processing Systems. Published in the *Artificial Intelligence in Process Engineering Academic Press*, pp. 37-79, 1990.

Qualitative modeling and discrete event modeling have been independently developed to analyze the behavior of complex systems on the basis of simulations of configurations made up of discrete models of the behavior of system components and processes. The purpose of the CONFIG project described here is to develop a practical combination of these lines of work, to address the challenges of analyzing the effects of faults and malfunctions in complex continuous processing systems. Each of these lines of work has strengths and weaknesses, and this approach is intended to retain the strengths of each line of work, while compensating for its weaknesses, often with strengths from the other.

STAR Category 74 - Optics

Boord, W.T. (APA Optics, Inc.): Flat Panel Multicolor Display Final Report. NASA CR-185635, September 1990.

The CRT is hard to beat for cost, brightness, resolution, and ease of driving. However, the size, weight, relative fragility, and high drive voltage limits the environments in which a CRT can be used. Thus, a compact, rugged, low electrical operating power display is needed. APA Optics has been developing a solid state laser scanner which is small size with a low electrical operating power requirement. Quantex Corporation supplies electron trapping (ET) materials that emit visible light when illuminated with infrared radiation. The phosphor materials have been formulated to emit several colors of visible radiation. APA Optics proposed scanning an infrared laser beam to an array of ET phosphor pixels to generate a visual display. The use of an APA Optics scanner and an ET phosphor screen could offer the potential for low electrical operating power requirements and light weight. However, to determine feasibility, the performance parameters of the laser scanner and ET phosphors had to be analyzed relative to the requirements of NASA's flat panel display specifications. This report summarizes the results of a design analysis to determine whether the concept warrants a program to experimentally demonstrate a laser-based video display.

Pendleton, T. W. (JSC); Defigueiredo, R. J. P. (Lab for Intelligent Sensors and Systems): Recent Advances in the Development and Transfer of Machine Vision Technologies for Space. Presented at the SPIE Applications in Optical Science and Engineering, Boston, Massachusetts, November 4, 1990.

Some of the recent work, in which the authors have been involved, on machine vision and technology transfer to space robotics is briefly described. Machine

vision is expected to play an increasingly significant role in space operations and robotics. A major problem in machine vision is that of object recognition and scene understanding. The process of recognizing objects and understanding the scene in which they appear involves going from a viewer-centered representation. The object-centered representation is usually designed to capture some invariant property such as what is intuitively known as the "shape." Thus, "understanding" the scene is the process of extracting and identifying the different objects and the spatial relationships among them. The illuminants are the source of the light energy incident on the scene. It is common to analyze illuminants as being either point sources (like the sun), diffuse extended sources (like the sky), or imaginary sources (e.g., we may wish to model a specular highlight on a surface as an imaginary point source of radiation.) The imaging system is the set of optics, sensory devices, and some form of data conversion that converts the incident light energy onto the system into a set of numbers that represents the intensity.

STAR Category 91 - Lunar and Planetary Exploration

Allton, J. H. (LESC); Lyons, D. M. (Phillips Labs): Achieving a Balance Between Autonomy and Teleoperation in Specifying Plans for a Planetary Rover. Presented at Conference on Coop. Intelligence Robotics, November 6-7, 1990, Boston, Massachusetts.

This extended abstract documents our ongoing work in the area of determining what autonomy a planetary rover should exhibit and how the autonomy can be interfaced to the human users of the rover. A key constraint on the autonomy is that human user and machine must be able to cooperatively carry out planetary geological sampling and field work. We describe an approach that uses an icon language to advise an autonomous rover and to present rover feedback to the user. The icon language can be translated to plan networks in the RS model. We present an extensive pencil and paper example of using the interface to carry out cooperative exploration.

Allton, J. H.; Lauer, H.V. (LESC): Volatile-Laden Martian Regolith Sealed in a Container: Using Martian and Terrestrial Sorbents to Manage Pressures. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas and at the Case for Mars 4 Conference, June 4 - 8, 1990, Boulder, Colorado.

Allton, J. H.; Lauer, H. V. (LESC): Preservation of Martian Soil Volatiles: Status of Leak Rate Experiments with Dust-Laden Sample Containers. Presented at the AIAA 15th Annual Technical Symposium Conference, May 24, 1990, Houston, Texas.

The volatile chemical species in the martian regolith are critically important in understanding Mars. Samples of this volatile-laden regolith, to be returned to Earth, will be collected in a very dusty environment. Thus, good sample preservation depends on containers capable of retaining volatiles, even when these containers are sealed under dusty conditions. Experiments to measure the effect of dust on the sealing capability of regolith sample containers have been initiated. Leak rates for clean teflon o-rings and gaskets, pressure activated seals, and an Apollo lunar soil can were measured by a pressure rise technique at delta P of 0.5 atm. Although no leak rate requirements have been defined, the 10-5 atm-cc/sec leak rate for the Apollo soil can serve as a benchmark. Likely, a smaller leak rate will be required. Amounts of 45-70 um sized silica gel dust, ranging from 0 to 2.2 mg/cm2 of sealing surface, have been applied to teflon o-

rings and gaskets. With our spring pressure container closures, relatively low leak rates (10-4 atm-cc/sec) can be maintained up to 1.3 mg/cm2 dust concentration. Leak rates increase rapidly past this threshold.

Allton, J. H.; Lauer, H. V. (LESC): Robotic Geology Field Trip to Mars: The Preservation of Martian Rock and Soil Samples. Presented at the Space 90 Conference, April 23 - 26, 1990, Albuquerque, New Mexico.

The terrain is rocky and dusty, the temperature range 150 to 250 degree K, atmospheric pressure 10 mb of 95% CO2, gravity 40% of Earth's, and sunlight 40% of Earth's. In addition, dust blows seasonally and frost forms on winter nights. The lone explorer is an intelligent roving robot equipped with a scoop, a rake, a rock drill and possibly a regolith drill to acquire samples. This explorer may traverse by day and collect samples at night, when volatile species are less active. The samples are imaged and analyzed to decide whether or not the sample is a "keeper." But how shall the keepers be packaged so that they will remain pristine and unchanged when they are opened on Earth at least a year later? This study integrates the scientific and engineering requirements for packaging 5 kg of martian rocks and soil and proposes a sample packaging plan. Essential to preservation of volatile-bearing samples are containers with extremely low leak rates. Thus, the results of initial testing of teflon seals for performance when challenged by varying amounts of "martian" dust is presented, along with plans to further screen a variety of seals at martian temperatures.

Allton, J. H. (LESC); McKay, D. S. (JSC): Martian Regolith Sample Studies: Lessons from the Acquisition and Analysis of Lunar Cores. Presented at the Case of Mars IV Conference, June 4-8, 1990, Boulder, Colorado.

The Moon has provided some basic lessons in how to acquire and analyze planetary samples, lessons which are applicable to martian regolith studies. Cores, a good way to sample a regolith in three dimensions, have been taken at 24 Apollo and 3 Luna sites and used to provide insight into the evolution of the lunar regolith. Although lunar surface processes such as micrometeorite impact gardening, solar wind ion implantation, and ion sputtering erosion will not likely be the dominant processes operating on Mars, the 3-dimentional information provided by soil cores may be essential to interpreting aeolian transport of dust grains, diurnal and seasonal cycling of volatiles, and other processes unique to the martian surface. Samples of martian regolith taken from below the surface are deemed highly desirable. Core samples remain options for both robotic and piloted missions to Mars. The Soviet luna cores were taken and returned to Earth by robotic spacecraft, while the American Apollo crewmembers were able to apply on-the-spot human skills in acquiring cores.

Basu, A. (Indiana University); Wentworth, S. (LESC); McKay, D. S. (JSC): Soils in 15009 and the Geology of the Apollo 15 Site. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

Apollo 15 core 15009 is from Station 4 near Dune Crater. Station 4 is the mare station furthest from Hadley Rile, so comparisons of 15009 with other mare core soils are useful in understanding the effects of the rile on Apollo 15 regolith evolution. Modal analyses were completed for (90-150 micron fractions) samples from six intervals of the drive tube. High ratios of quartz normative to

olivine normative mare basalts suggest that the olivine normative basalt layer is very thin at Station 4, and that the Dune Crater penetrated this layer and excavated substantial amounts of the underlying quartz normative basalt. A high KREEP basalt proportion indicates that Dune Crater also penetrated the Apennine Bench Formation.

Bogard, D. D. (JSC); Rao, M. N. (NRC); Garrison, D. H. (LESC); Murali A.; Black, D. C. (Lunar & Planetary Institute): Composition of Solar Flare Argon Deduced from Kapoeta Etched Mineral Separates. Presented at the Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

Several recent investigations have shown that the 20Ne/22Ne isotopic ratio in neon implanted by solar flares is 11.6 $\pm$0.2, which is -15% smaller than this ratio in solar wind neon. The isotopic composition of solar flare (SF) neon is also considerably different from neon in the terrestrial atmosphere and neon trapped in carbonaceous chondrites. A 20Ne/22Ne ratio of 11.6 is, however, similar to a neon-C component derived from neon data for gas-rich meteorites and suggested to be from solar flares. It is pertinent to ask whether the isotopic composition of argon in solar flares differs from solar wind argon. The 36Ar/38Ar ratio, unlike the 20Ne/22Ne ratio (hereafter referred to as 36/38 and 20/22, respectively), shows little variation among various preserved gas components in the solar system. Furthermore, one of the isotopes of argon, is almost entirely derived from the radioactive decay of 40K during the solar system history. Consequently, examination of possible isotopic components on a three-isotope correlation plot is not possible for argon, as it is for neon. We have recently acquired data for SF Ne and Ar implanted in the Kapoeta howardite, which we believe shows a SF 36/38 ratio of 4.8 $\pm$0.2, significantly lower than the value of -5.32 found in other argon.

Bogard, D. (JSC); Ryder, G. (Lunar & Planetary Institute); Garrison, D. (LESC): A Major 2.1 GA Impact Event Recorded in Some Apollo 15 Kreep Basalts: Autolycus. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

Cintala, M. J.; Horz, F. (JSC): Regolith Evolution in the Laboratory: Scaling Dissimilar Comminution Experiments. Published in *Meteorics*, Vol. 25, pp. 27-40, 1990.

Repeated impacts into fragmental targets simulating unconsolidated debris on planetary surfaces have provided empirical insight into the evolution of planetary regoliths. Quantitative understanding and interpretation of these results, however, are often made difficult by the complex, multivariate nature of the impact process, even under controlled laboratory conditions. The techniques of dimensional analysis have been employed to quantify and examine the relationships between the more important variables in the evolution of these experimental regoliths. Tests show that the quantity of comminuted target mass is directly proportional to many factors, such as number of impacts and total target mass, and is inversely proportional to the density of the target rock and the sorting of the regolith. More experiments will be necessary to further establish exact contributions of various factors.

Gooding, J. L. (JSC): Differential Scanning Calorimetry (DSC) of Meteorites: Overview of Possible Applications. Published in *Meteoritics*, Vol. 25, p. 367, 1990.

Differential scanning calorimetry (DSC) measures the flow of heat energy into or outward from a solid or liquid as the sample is heated or cooled at a controlled rate. Although it superficially resembles differential thermal analysis (DTA), DSC is fundamentally quantitative,

whereas DTA is not. DSC data can be treated by methods similar to those used in spectrophotometry, including peak integration, peak stripping, and derivative analysis. Measurements of heat-capacity functions, temperatures, and enthalpies of phase transitions, and kinetics of reactions can be made on milligram quantities of sample. DSC can also be used for determinative mineralogy, especially when coupled with evolved-gas analysis and as a simulation tool in studies of volatile/mineral reactions. DSC is a candidate experiment for future in situ analyses of planetary materials.

Gooding, J. L. (JSC); Aggrey, K. E.; Muenow, D. W. (UHA): Volatile Compounds in Shergottite and Nakhlite Meteorites. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas and published in *Meteoritics*, June 1990.

Since discovery of apparent carbonate carbon in nakhla, significant evidence has accumulated for occurrences of volatile compounds in shergottites and nakhlites. Gooding and Muenow showed that at least one shergottite (EETA79001) contains substantial sulfur in a highly oxidized form and that all oxidation must have occurred on the shergottite parent planet. Burgess et al. also found oxidized sulfur in ALHA77005, shergotty, nakhla, and chassigny. Kerridge reported carbon and deuterium of apparent preterrestrial origin in shergotty and lafayette (a nakhlite). In addition, discrete grains of salt minerals have been documented in EETA79001 and nakhla. Here we present final results from our study of volatile compounds in three shergottites, one nakhlite, and three eucrite control samples.

Jones, J. H. (JSC): Isotopic Relationships Among the Shergottites, the Nakhlites and Chassigny: Implications for Volcanism on Mars. Presented at the MEVTV Workshop January 1990, La Jolla, California.

The results of the exercise conducted in this study reinforce the idea that the SNC meteorites are all young volcanics and have not undergone extensive resting of their various radiometric chronometers. If so, martian volcanism has continued until very recent times and may be active today. If the model is correct, some portions of the martial mantle may have retained the chemical signatures of an early differentiation event, unmodified, until very recent times.

Jurewicz, A. J. G. (LESC); Jones, J. H. (JSC); Mittlefehldt, D. W. (LESC): The Effect of FO_2 on Partial Melts of Allende. Published in *EOS*, December 1990.

Eucrites and angrites are distinct types of basaltic meteorites whose origins are not well known. New results indicate that partial melts of the Allende (CV3) carbonaceous chondrite can resemble either eucrites or angrites, depending only upon the oxygen fugacity (fO2). Melts are eucritic if the fO2 is below that of the Fe-FeO buffer or are angritic if the fO2 is above that of the buffer. By changing pressure, the Gr-O redox reaction can produce oxygen fugacities that are above or below the Fe-FeO buffer. Therefore, a single, homogeneous, carbonaceous planetoid <80 km radius could produce melts of drastically different composition depending on the depth of melting.

Kantara, J. (LESC): Thermal Assessment of ATCS Radiator on the Moon and Mars Surface. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The FORTRAN codes were developed to simulate the steady-state effects of lunar and martian environments on a radiator. The first assumed that the radiator was exposed to planetary and solar fluxes. The second simulated the presence of a radiator inside a parabolic reflector that shields the radiator from planetary and albedo fluxes. With no parabolic reflector, the radiator absorbed heat during some of the lunar day. With a

parabolic reflector, the radiator was shielded from incident planetary and albedo fluxes, enhancing its performance. Although the maximum heat rejected remained unchanged, the radiator rejected heat to its environment during the whole lunar day cycle. With no reflector, the radiators performed better during the winter than during the summer. With a parabolic reflector, maximum heat rejection remained unchanged, but average heat rejection increased by ~10%. From this, it is clear that a parabolic reflector significantly increases the radiator heat rejection capability per unit area. Such a reflector should therefore be considered for active thermal control system radiators on the lunar and martian surfaces.

Kennedy, K. J. (JSC): Interior Design of the Lunar Outpost. Presented at the 2nd International Conference of SPACE 90, April 23-26, 1990, Albuquerque, New Mexico.

This concept is part of NASA's ongoing effort to explore alternative options for planet surface systems habitation, and represents the work done up to and including August 1989. Results of a volume analog study to determine the required pressurized volume will be presented along with an internal layout of the habitat facility. The concept is a constructible lunar habitat that provides a living and working environment for a crew of 12. It is a 16-m diameter spherical pneumatic structure that contains 2145 cubic meters of volume. Five levels of living and working areas make up the 742 m^2 of floor space. A 2-m vertical circulation shaft at the center allows for transfer of crew and equipment. The fully outfitted inflatable lunar habitat weighs 49.5 MT.

Lazaroff, S.; Miller, K. (JSC): Radiation Design Considerations for the Lunar Base. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

In support of the Human Exploration Initiative, radioisotope and nuclear reactor power systems were investigated for various lunar surface elements because they provide large amounts of power with relatively low volume and system mass. However, both sources create potential radiation hazards for any manned application. As a result, a study of the radiation that will be experienced during a lunar base mission was initiated. The primary goal of this study was to examine design considerations that would attenuate the radiation produced by the nuclear power systems to acceptable levels. Included in this investigation was the determination of the potential sources and harmful components of the radiation that would be experienced on a lunar base mission. In addition, the safe radiation dosage limits for humans were identified.

Lindstrom, M. M. (JSC); Marvin, U. R. (Harvard-Smithsonian Center for Astrophysics, Cambridge): A Geochemical-Petrologic Study of the Populations of Coarse-Fines Particles in Apennine Front Soils. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

In an attempt to identify new Apennine Front rocks and evaluate the proportions of rock types at various sites, we have begun a study of coarse-fines from Apennine Front soils 15313 (Sta 7) and 15403 (Sta 6a). These soils were chosen because they were expected to exhibit extremes in highland rock populations.

Lindstrom, M. M. (JSC); Mittlefehldt, D. W. (LESC); Marvin, U. R.; Holmberg, B. B. (Harvard-Smithsonian Center) New Observations on the Quartz-Monzodiorite Granite Suite. Published in the *Proceedings of the 21st Lunar and Planetary Conference*, March 1990.

Petrographic studies and major and trace element analyses of four clasts of quartz monzodiorite (Qm1) and one of

granite from the 2-4 mm fraction of Apollo 15 soil sample 15403 demonstrate the extreme variations found in small particles. One QMD clast, 15403.71A, contains 18% of modal phosphates in grains > 1 mm long. This is the most phosphate-rich lithology reported from the Moon. A second QMD clast, 15403.7001, contains only a few 0.04-mm grains of phosphates. Clearly, QMD particles must be viewed as a suite and their compositions averaged for purposes of calculating modes of origin. Soil 15403 was derived from rock 15405 which consists of a dark, KREEP impact melt containing fragments of QMD, granite, KREEP basalt, and one clast of a primitive Mg-alkali norite. To evaluate the significance of this association, we have reviewed data on these and other evolved highland lithologies from each Apollo landing site. It seems most probable to us that QMDs and granties were formed mainly by the fractional crystallization of a KREEP-rich basaltic magma.

Nelson, D. O. (NRC); Phinney, W. C. (JSC): Production of Evolved Planetary Crust Through Partial Melting of Basalt. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

The interaction of basaltic magma with granitoid crust is a common mechanism of magma evolution of Earth and an evolved crustal signature has been recognized in the Apollo 14 VHK basalts and in the shergottites of the SNC suite. The origin of this evolved crustal signature is controversial, as are the implications of its suspected presence in the process of planetary crustal evolution. In particular, does the requirement of an evolved crustal component necessarily imply the existence of a significant silicic crustal reservoir similar to that on the Earth, or could its presence simply reflect processes that occur during the under-and interpreting of large-scale basaltic magmas in a precursor mafic crust?

Phinney, W. C. (JSC): Anorthosites, Melts and the Bulk Moon. Presented at the 21st Lunar and Planetary Science Conference, March 12-16, 1990, Houston, Texas.

Most lunar anorthosites have been analyzed as whole rocks. Therefore, reconstruction of the parent liquids of the anorthosites using plagioclase-liquid distribution coefficients is impossible because of the few percent nonplagioclase phases that contain 10 to 100 times more of some elements than the plagioclase. Analyses of FeO and MgO in plagioclase by electron microprobe produce reliable values if done in areas that have no inclusions and are well removed from mafic minerals that can produce interference. Very few attempts have been made to separate plagioclase from anorthosites for mineral analysis. Those that have were plagued by contamination. Comparison of probe analyses for FeO and MgO against INAA or MSID analyses of whole rocks, or even most plagioclase separates, show probe values to be lower by factors of 4 to 10. Analyses of selected plagioclase fragments display inconsistencies. Those that match well between probe and INAA for Fe do not always match well for REEs. Anomalously low values occur for Fe, Mg, and some other trace elements in plagioclases from terrestrial anorthosites that have undergone granulite metamorphism. Subsolidus reequilibration with pyroxene and garnet results in redistribution of the components. There is abundant textural evidence for extensive recrystallization of lunar anorthosites.

Pieniazek, L. A.; Toups, L. (JSC): A Lunar Outpost Surface Systems Architecture. Presented at the 2nd International Conference on Engineering, Construction and Operations in Space - "Space 90," April 23-26, 1990, Albuquerque, New Mexico.

Proposed objectives for an extraterrestrial outpost or base are sundry: science and exploration, testing and

learning, local resource development, and infrastructure development. Any initiative will likely embrace a blend of objectives and the outpost will have to integrate diverse systems and activities. These incorporate elements that support mission objectives directly such as science equipment and elements related to support of the base itself such as habitation, power, communications, and space transportation. This paper discusses deriving appropriate architectures for planet surface systems, with focus on top-level structure and integration. Considerations include mission objectives, system concepts, designation of elements, and element placement. Concepts include functional area, activity area, and activity zone. To illustrate these, a representative planet (lunar) outpost is developed; however, much is appropriate for other terrestrial-like planets such as Mars.

Sullivan, T. A. (JSC): Process Engineering Concerns in the Lunar Environment. Presented at the AIAA Space Programs and Technologies Conference and Exhibit, September 25-27, 1990, Huntsville, Alabama.

The paper discusses the constraints on a production process imposed by the lunar or martian environment on the space transportation system. A proposed chemical route to produce oxygen from iron oxide-bearing minerals (including ilmenite) is presented in three different configurations which vary in complexity. A design for thermal energy storage is presented that could both provide power during the lunar night and act as a blast protection barrier from the outpost. A process to release carbon from the lunar regolith as methane is proposed, capitalizing on the greater abundance and favorable physical properties of methane relative to hydrogen to benefit the entire system.

Zipay, J. J. (JSC): Mars Rover Sample Return - Mars Ascent Vehicle. Presented at the AIAA 15th Annual Technical Symposium, May 24, 1990, Houston, Texas.

The Mars Rover Sample Return Mission (MRSR) is intended to collect five kilograms of martian surface samples and return them to Earth for study. The Mars Ascent Vehicle (MAV) will carry the five kilograms of samples collected by the Mars Rover on the surface of Mars and from the surface of Mars to Mars orbit. Once in Mars orbit, the MAV will transfer the samples to the Earth Return Vehicle (ERV) for the journey back to Earth. This presentation describes the MRSR mission and the MAV in detail. The subsystems inside the MAV and the subsystem trades that were performed are described. Critical areas in the overall MAV design and in the MAV structure are identified. Finally, the relative advantages and disadvantages of robotic exploration and manned exploration of the solar system are assessed.

STAR Category 92 - Solar Physics

Badhwar, G. D.: Exospheric Temperatures During Solar-Cycle 22 Derived from the Decay of Long Duration Exposure Facility. Published in the *Journal of Astronautical Sciences*, May-June 1990.

The current solar cycle, twenty-two, is the highest intensity cycle recorded so far and has provided an opportunity to develop an empirical model of the solar radio flux at 10.7 cm and the exospheric temperature that drives the current atmospheric density model at high solar radio fluxes. This was done by an analysis of near-daily observations of the orbital decay of the Long Duration Exposure Facility. This satellite is in nearly circular, fixed attitude low Earth orbit, for which atmospheric drag is the principal force leading to its orbital decay. Using the Jacchia-Lineberry atmospheric model, a set of observations of the semi-

major axis of the orbit, for a fixed $F_{10.7}$ flux (F), are fitted to a predicted set where the only free variable is the exospheric temperature, T_∞, in the Jacchia model. A comparison of this temperature with Jacchia's, $T_{1/2}$, the arithmetic mean at the global extrema of diurnal variation in Too under quiet geomagnetic conditions, shows excellent agreement for $T_{1/2}$ values below about 100 · K but increasing difference for higher values. A new expression for T_∞ is suggested that limits T_∞ to a maximum value for very large values of F.

STAR Category 99 - General

Hunsucker, J. L. (Univ. of Houston): An Investigation of Transition Management Problems for the NSTS at NASA. CR-185634, October 1990.

The purpose of this report is to provide NASA a quarterly report and an interim overview of the results obtained by the University of Houston team to date. Documentation of the ideas and concepts developed in collaboration with the Management Integration Offices of NASA is also provided. This report, the second quarterly report of a 6-year research contract, describes help provided to achieve routine, timely production of flights, with major emphasis on adapting concepts, investigations, and theoretical techniques for their use. For a full understanding of the concepts presented, reports of the last 5 years should be perused.

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