NASA Technical Memorandum 102173

# The 1989 JSC Bibliography of Scientific and Technical Papers

January 1991

# NASA

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# The 1989 JSC Bibliography of Scientific and Technical Papers

*Compiled by*
Management Services Division
*Lyndon B. Johnson Space Center*

# PREFACE

This listing of the Johnson Space Center's scientific and technical publications and presentations is arranged alphabetically by first author within the JSC organization of that author's affiliation at the time the request for approval was initiated. Organizational groupings are made by directorate or major office, then if number of entries warrants, by division or suboffice.

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.

Citations are based primarily on information supplied by authors first on forms requesting approval and later on preliminary copies sent to them for review. If no confirmation of release status was received from the author, the citation was omitted from this document.

Only calendar year 1989 releases are included.

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# Organizational Abbreviations

Following are abbreviations of companies or agencies with which authors were affiliated at the time their articles were submitted. These abbreviations appear in parentheses after the author's name or after the name of the last author in a sequence of authors from the same organization.

| | | | | |
|---|---|---|---|---|
| AC | - Arkansas College | | IU | - Indiana University |
| ALMA | - Alma College | | | |
| AMNH | - American Museum of Natural History | | JHU | - John Hopkins University |
| | | | JHUMS | - The Johns Hopkins University Medical School |
| ANU | - Australian National University | | JPL | - Jet Propulsion Laboratory |
| ARC | - Ames Research Center | | JSC | - Johnson Space Center |
| ASAC | - Allied-Signal Aerospace Company/Airesearch Los Angeles Division | | KRUG | - KRUG International |
| ASEMRC | - Allied-Signal Engineered Materials Research Center | | LESC | - Lockheed Engineering and Sciences Company |
| AU | - Auburn University | | LINCOM | - LinCom Corporation - Houston Operations |
| BA | - Ball Aerospace | | LPI | - Lunar and Planetary Institute |
| BAC | - Boeing Aerospace Company | | LS | - Life Systems, Inc. |
| BCM | - Baylor College of Medicine | | LTV | - LTV |
| BFEC | - Bendex Field Engineering Corporation | | MDSSC | - McDonnell Douglas Space Systems Company |
| BT | - Barrios Technology, Inc. | | MMSS | - Martin Marietta Space Systems |
| BTX | - BTX, Inc. | | MT | - Mechanical Technology, Inc. |
| CSDL | - Charles Stark Draper Laboratory, Inc. | | MHI | - Methodist Hospital of Indiana |
| CTA | - CTA, Inc. | | MOOG | - Moog, Inc. |
| | | | MU | - Miami University |
| DAC | - Davis Aerospace Company | | NBS | - National Bureau of Standards |
| EE | - Eagle Engineering | | NRC | - National Research Council |
| EPS | - Ergenics Power Systems, Inc. | | NU | - Northeastern University |
| GRC | - Gerontology Research Center | | PSU | - Penn State University |
| GSFC | - Goddard Space Flight Center | | PU | - Perdue University at Indianapolis |
| GWU | - George Washington University | | RIC | - Rockwell International Corporation |
| | | | RICE | - Rice University |
| HSCA | - Harvard-Smithsonian Center for Astrophysics | | SATG | - Sundstrand Advanced Technology Group |
| HSMS | - Hamilton Standard Management Services, Inc. | | SC | - Springfield College |
| | | | SCS | - Supercomputing Solutions, Inc. |
| HU | - Harvard University | | | |
| IM | - Intermetrics, Inc. | | SI | - Smithsonian Institution |

| | | |
|---|---|---|
| SKFL | - | Smith, Kline and Frech Labs |
| SRI | - | Southwest Research Institute |
| SUNY | - | State University of New York |
| TAMU | - | Texas A&M University |
| TIL | - | Togai InfraLogic, Inc. |
| TRW | - | TRW Space & Technology Group |
| UA | - | University of Arizona |
| UC | - | University of Chicago |
| UCB | - | University of Colorado at Boulder |
| UH | - | The University of Houston |
| UI | - | University of Iowa |
| URC | - | Umpqua Research Center |
| USARIEM | - | U.S. Army Research Institute of Environmental Medicine |
| USBM | - | United States Bureau of Mines |
| USC | - | University of South Carolina |
| USGS | - | U.S. Geological Survey |
| USMC | - | United States Marine Corps |
| USN | - | United States Navy |
| USRA | - | Universities Space Research Association |
| UT | - | University of Tennessee |
| UTCAR | - | University of Texas Center for Aeronautical Research |
| UTHSD | - | United Technologies - Hamilton Standard Division |
| UTMB | - | University of Texas Medical Branch |
| UTMDACC | - | University of Texas M.D. Anderson Cancer Center |
| UW | - | University of Wisconsin |
| WU | - | Washington University |
| WEC | - | Westinghouse Electric Corporation |

1. Moorehead, Robert W. (JSC): America's Shuttle Return to Space. Presented at the 2nd European Aerospace Conference, May 22-24, 1989, Bonn-Bad Godesberg, FRG.

   The return of the United States National Space Transportation System (NSTS) to operational status was preceded by significant changes to the NSTS Program structure. NASA implemented a streamlined NSTS Program management approach that concentrated more authority at the Headquarters level while emphasizing communications throughout the Program. NASA also strengthened the check and balance role of its Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) Organization and encouraged it to vigorously interact with the NSTS Program. The NSTS Program implemented solid rocket booster modifications that eliminated the weakness that led to the Challenger accident. Additionally, the Program reviewed every element of the Space Shuttle system and implemented numerous improvements to enhance system safety. Recent flight experience demonstrates the effectivenesss of these changes.

1. Goldstein, Stanley H., editor (JSC): *NASA/ASEE Summer Faculty Fellowship Program - 1989*, Vol. 1-2. NASA CR 185601, December 1989.

Shock layer temperature profiles are obtained through analysis of radiation from shock layers produced by a blunt body inserted in an arc jet flow. Spectral measurements of N2+ have been made at 0.5", 1.0", and 1.4" from the blunt body. A technique is developed to measure the vibrational and rotational temperatures of N2+. Temperature profiles from the radiation layers show a high temperature near the shock front and a decreasing temperature near the boundary layer. Precise temperature measurements could not be made using this technique due to the limited resolution. The use of a high resolution grating will help to make a more accurate temperature determination. A laser induced fluorescence technique is much better since it gives the scope for selective excitation and a better spacial resolution.

1. O'Connor, Bryan D. (JSC): Safety and Rescue During STS Operations. Presented at the Crew Safety and Rescue in Space Workshop, June 7, 1989, Paris, France.

   During certain segments of the ascent trajectory, the pilot can fly a contingency abort profile for loss of two or three main engines. The end result may be a landing on a relatively short runway without Shuttle compatible navigation aids, or more likely a bailout over the ocean depending on when the engines fail. The crew escape system has been designed for this bailout case, and consists of a combination pressure/anti-exposure suit, autonomous oxygen, and parachute and raft for each crew member, as well as a jettisonable hatch, escape pole (to clear the crew member below the wing), and an automatic attitude hold mode for the flight control system.

   For postlanding mishaps, the crew has two ways to egress the vehicle unassisted. The primary mode is via an airline-type inflatable slide mounted on the side hatchway. Crew escape is not assured when catastrophic failures occur during launch pad operations or in flight.

   In summary, the Shuttle provides the crew adequate escape capability for various non-catastrophic mishap scenarios.

1.  Hauck, Frederick H. (Capt., USN) and David C. Hilmers (Lt. Col, USMC):  The
    Mission of Discovery.  *Naval Aviation Museum Foundation Magazine*, vol. 10,
    no. 1, Spring 1989.
       On the evening of September 28, 1988, my four crewmates and I were in the
    crew quarters at KSC.  We were to resume the journey cut tragically short by the
    Challenger accident.  We spent the day on last-minute preparations then drove
    back to the Operations and Cargo building where our rooms were.  As I slipped
    into bed, I thought that this was somewhat like the night before Christmas, the
    night before my first combat flight, and the night before my first football game all
    rolled into one.  I felt a mixture of eager anticipation for the adventure ahead and
    confidence in our readiness; but there were no guarantees.  I knew I had a great
    team that would provide us all possible support from the ground.  I knew that our
    machine, although it had had over 1000 hardware and software modifications
    since Challenger, was thoroughly tested.  And I knew I had a superb crew.  We
    were selected for flight in January 1987 and had been training for the mission ever
    since.

2.  Hoffman, Jeffrey A. (JSC):  Operational Complexities of Real Tether Systems in
    Space.  Presented at the AIAA NASA AST ESA Third International Conference on
    Tether in Space Toward Flight, San Francisco, CA, May 16-19, 1989.
       The basic laws governing the behavior of a two-body tether system are well
    understood.  However, the successful execution of a tether mission in space
    requires more than just an application of basic tether dynamics laws.  This paper
    presents some of the major operational concerns that have to be addressed in
    planning a real tether mission, specifically TSS-1, due to fly on the Space Shuttle
    in the early 1990s.  It is important that people thinking about future applications of
    tethers be aware of some of the problems in translating their ideas into real
    operations.  Specifically, this paper considers several operational hazards (such
    as tether reel overtorque and loss of tether system control) from the point of view
    of the flight crew, who must be able to detect the presence of a problem and
    figure out what corrective action to take.

3.  Thornton, Wiliam E. (JSC):  *A Method of Isolating Treadmill Shock and Vibration on
    Spacecraft*.  NASA TM 100474, April 1989.
    Stringent limits (one micro-g) for shock and vibration have been placed on
    Space Station.  There are many planned operations which will exceed this limit by
    one to two orders-of-magnitude or more.  One of the major shock and vibration
    sources is the treadmill (TM) exercise which produces cyclic forces of one to five
    Hz and up to three times body weight of the person using it.  Current isolation
    means, neither active nor passive, can attenuate such forces to the desired level,
    hence some alternative must be used.  One method for meeting such levels is to
    provide adequate counterpoise mass to the TM to allow it to be used while floating
    freely.  To prevent drift and structural contact, a dynamic tethering system, whose
    forces will never exceed allowable limits, yet will allow appreciable motion will
    maintain the assembly's position.  Concept and design of this system is
    described.

4.  Uri, John J.; Barry J. Linder; Thomas P. Moore; Sam L. Pool; and William E.
    Thornton (JSC):  *Saccadic Eye Movements During Spaceflight*.  NASA TM
    100475, February 1989.
       Saccadic eye movements were studied in six subjects during two Space Shuttle
    missions.  Reaction time, peak velocity and accuracy of horizontal visually-guided
    saccades were examined preflight, inflight and postflight.  Conventional electro-
    oculography was used to record eye position, with the subjects responding to

pseudo-randomly illuminated targets at 0° and 10° and 20° visual angles. In all subjects, preflight measurements were within normal limits. Reaction time was significantly decreased. A tendency toward a greater proportion of hypometric saccades inflight was also noted. Possible explanations for these changes are discussed, as in any correlation with Space Motion Sickness.

1. Ambrose, Frank (BT): Requirements Developing and Documenting. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    The development of a space program rests heavily on the foundation of written requirements. These requirements provide the basis for defining ground facilities, operations interactions, and the role of ground support personnel in the life cycle of the program. Therefore, it is of critical importance to understand the process of developing and documenting requirements. Often graduates find this task very frustrating since it is given little academic attention.

    This presentation addressed the documentation process. Two requirement development techniques were reviewed and the advantages and disadvantages of each noted. In addition, some of the conditions that must be considered when developing requirements were addressed.

2. Benavidez, Aide (Unisys): Overlapping Software Releases in a Multi-Project Environment. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    As a NASA subcontractor Unisys provides software sustaining engineering services for the Rockwell Space Transportation System Operations Contract (STSOC). The STSOC environment is a diverse and dynamic environment, requiring implementation of production software changes on a timely basis without conflicting with ever-changing flight schedules. Return to flight in 1988, along with projected increases in scheduled flights, brought about the need to develop Configuration Management (CM) procedures that would address demanding software release schedules and at the same time allow overlapping progression through the development life-cycle for Mission Control Center Front End Reconfiguration Software. This presentation provides an overview of the problems associated with the delivery of software changes in the STSOC multi-project environment and describes the procedures being used to provide CM guidelines to control a diverse environment with demanding schedules.

3. Cobb, Carey T. (BT): Space Station On-Orbit Maintenance Operations. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    To ensure Space Station Freedom has a safe operational lifetime of not less than 30 years, an effective on-orbit maintenance operations program must be included in overall program plans. With limited accessibility by ground maintenance support for long periods of time, adequate plans and resources must be available on-orbit to meet all feasible maintenance needs.

    This presentation outlined plans for performance of Space Station Freedom on-orbit maintenance. It included a description of types of maintenance performed on-orbit, maintenance resources available on-orbit, maintenance data use, and maintenance planning/scheduling. This presentation described support provided by ground personnel/facilities to perform on-orbit maintenance operations.

4. Ellis, Michael D. (BT): Skylab: A Historical Perspective. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    Early space pioneers, such as Tsiolkowsky and Oberth, believed that the first step in the exploration of the solar system would involve the establishment of a permanently manned space station in low Earth orbit. It might have happened that way except that the "Race to the Moon" became a national goal and placed the concept of a space station on hold. When the concept became a reality as "Skylab," it would not be designed as a true space station, but rather as a temporary man-tended orbiting laboratory. This presentation will briefly cover the background of the Skylab Program, its accomplishments, and the lessons learned that are applicable to the development of the Space Station Freedom Program.

5.  Ferguson, Melisa (BT):  Space Station Freedom Software Engineering.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    The principles of software engineering will be employed in the Space Station Freedom Program to ensure that all operational software developed for the program meets the overall criteria of schedule, cost, and performance requirements.  Software Engineering is a disciplined method of software development that provides a consistent, life-cycle approach to the creation of software systems that are modifiable, efficient, reliable, and understandable.  The life-cycle phases for Space Station Freedom Program software are initiation, requirements definition, preliminary and detailed design, implementation, integration and testing, acceptance and delivery, and sustaining engineering.

6.  Gains, Willie (BT):  Space Station Freedom Resource Allocation Concepts and Considerations.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    The purpose of this report is to provide the rationale and recommendations for the development of the Space Station Freedom's resource allocation and planning activity.  The deployment of an orbiting manned or man-tended space station requires proper resource management and planning due to the necessity of highly integrated core systems requirements as well as payload requirements.
    While certain aspects of consumables used onboard the Space Station Freedom are similar to that of the Shuttle, the 30-year life span and the Freedom's nominal operations and payload activities present several new considerations.  Those discussed are:  (1)  Integration of resource allocation and planning duties, (2) effects of Space Station configuration on resource allocation, usage, and availability, (3) system or component failure, (4) scheduled activities, and (5) payload operations requirements.

7.  Klaus, David M. (BT):  Cooperative Operations Between Crewmembers and Robots Onboard Space Station Freedom.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    This presentation addresses issues involved in defining the role of robotics in conjunction with the development of a manned space station.
    Extravehicular Activity (EVA) experience in space has demonstrated the ability to deal with unexpected situations.  Its capabilities and constraints have been defined, however, robotic experience gained primarily from industry has unique aspects which preclude direct analogy to microgravity applications.  Robots typically operate from a fixed base with redundant safety measures designed to prevent human intrusion into the working envelope.  Subsea telerobots operate in a relatively similar environment to space and are being studied to gain insight into space operations.
    When dealing with robotics, avoiding unintentional contact with crewmembers or Space Station elements is a key safety concern.  Operational procedures as well as system design will have responsible roles in this prevention.  As robotics evolve into autonomous systems, these preventative measures will require parallel reevaluation.

8.  Sepahban, Sonya (JSC):  Advanced EVA Portable Life Support System Technologies and Issues.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    The NASA/Office of Exploration (OEXP) has defined four principal lunar and Mars mission case studies to extend human activity in space to permanent presence on the Moon and exploration of Mars.  A study was conducted to assess the available and potential technologies and the related issues regarding

advanced ExtraVehicular Activity (EVA) life support for OEXP cases 3 and 4. These cases refer to the "Lunar observatories on the Far Side of the Moon, " and the "Lunar Outpost to Early Mars Evolution," respectively.

The relatively long mission durations, large crew sizes, long time lags in earth-based resupplies, and the potentially long mission abort times associated with these missions dictate a set of unique requirements compared to the Shuttle Orbiter and the Space Station Freedom (SSF) Life Support System (LSS). A survey of the available and potential technologies and subsystems, together with results of quantitative analyses and qualitative data will be presented.

9. Smith, T.; S. Temple; and L. Wooldridge (BT): Training Requirements Analysis for Space Station Freedom. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Crew and mission support personnel training must be developed and in place at JSC to support construction and operation of Space Station Freedom. On one hand, analysis and design of instruction must, as a consequence, take place in parallel with emerging station systems, operational requirements, and procedures. On the other, the analysis and design performed prior to completion of the station must provide a complete and viable framework for future generations of the training system. The cost effective coordination of major training hardware acquisitions, courseware production, and efficient mature training operations depend on the accuracy and timeliness of the training requirements analysis. To this end NASA is supporting a training analysis that will attempt to point mission operations training in the correct direction from day one. This presentation will discuss this innovative training requirements analysis being performed for the Space Station Freedom Program.

10. Walter, Patrick (BT): Data Driven Software Development. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Many different types of application generators are available on the market for the developer. One particular technique deals with the concept of "data driven" applications. A data driven system is a method of controlling the user interface and system flow by using data instead of code. This type of generator helps the developer with the specification and design process through a set of "knowledge" databases to produce a working application. In this development process, the design environment and applications are interdependent.

This development methodology has three main components: (1) configuration databases that act as the knowledge base for the interface control of the system, (2) database utility designer which the application developer uses to generate the system, and (3) the application implementor for the end-user.

There are numerous advantages in implementing this kind of database technology. They range from an excellent tool for prototyping applications as well as a standardization of user interfaces to an integrated development environment. This presentation describes the "data driven" development methodology including an example of its application to the development of the Payload Interactive Requirements Collection System (PIRCS).

1. Linde, Shirley (MITRE): Data Administration at NASA's Mission Operations Directorate. Presented at the DRMA Seattle Executive Day, February 15, 1989, Seattle, Washington.

2. Wegener, Richard E. (BFEC): Automatic Audio Delay Correction of Simultaneous Uplinked/Downlinked Voice Signals. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

   In order to retain redundancy with the Shuttle vehicle during launch, two diverse audio paths between the Mission Control Center and the vehicle are utilized. The signals on these paths carrying identical information, arrive at different times dependent on various configurations and may vary between 50 to 1233 ms, thus causing the receiving end to experience an echo. Automatic delay correction reduces the time required for echo elimination as well as operator intervention.

   The automatic delay correction process utilizes a digital storage oscilloscope to acquire the voice information. The acquired information is digitized and transferred over an IEEE-488 buss to an instrument controller. The controller software samples the data, performs a cross-correlation between the two sample strings, computes the delay and sets a voltage level corresponding to a millisecond delay difference. This voltage is applied to the VCO input of a digital delay processor which in turn "nulls" any transmission delay. The delay correction process continues until operator intervention releases the system to an "idle" condition.

1. Culp, Donald R. (RSOC): The Failure Analyzer as an RTDS Expert System. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

   The real-time interpretation of Space Shuttle telemetery by flight controllers presents a formidable manual task. The Mission Operations Directorate (MOD) is creating a Real-Time Data System (RTDS) for systems monitoring. The Payload Deployment and Retrieval System (PDRS) Failure Analyzer will be part of this monitoring system which will free humans of the repetitive nature of telemetry interpretation. The Failure Analyzer will originate as a rule-based system. The knowledge of this rule-based system will aid in the concurrent development of a CONFIG model-based system. This final product of the Failure Analyzer project will provide a complete model of the PDRS so that an input system will provide a complete model of the PDRS so that an input system failure will produce a failure signature and a degraded system simulation. The capabilities of present expert systems support this application. A well constructed expert system may prove valuable in areas beyond its initial requirements such as training, design, and the preservation of corporate knowledge. This paper describes the PDRS Failure Analysis and Diagnosis problem, our planned use of expert systems to solve it, and our progress to date.

2. Kalvelage, Thomas A. (RSOC): The Real Time Interactive Display Environment (RTIDE), A Display Building Tool. Presented at the Graphics Technology in Space Applications Conference, April 1989, Houston, Texas.

   NASA's Mission Control Center (MCC), located at JSC, is incrementally moving from a centralized architecture to a distributed architecture. Starting with STS-29, some host-driven console screens will be replaced with graphics terminals driven by workstations. These workstations will be supplied with realtime data first by the Real Time Data System (RTDS), a system developed in-house, and then months later (in parallel with RTDS) by interim and subsequently operational versions of the MCC Upgrade (MCCU) software package. The Real Time Interactive Display Environment (RTIDE) was built by Space Shuttle flight controllers to support the rapid development of multiple new displays to support shuttle flights. RTIDE is a display building tool that allows non-programmers to define object-oriented, event-driven, mouseable displays. Particular emphasis was placed on upward compatibility between RTIDE versions, ability to acquire data from different data sources, realtime performance, ability to modularly upgrade RTIDE, machine portability, and clean, powerful user interface. This paper discusses the operational and organizational factors that drove RTIDE to its present form, the actual design itself, simulation and flight performance, and lessons learned in the process.

1. Dean, Mark (RSOC); and Timothy Bogart (Wyle): Computers Procedures and Operations. Presented at the Space Week Exposition, July 19, 1989, Houston, Texas.

   Activities in manned spaceflight, like other complex operations, require more than a reliance upon the memory of a trained individual for operational success. Various means of displaying textual and/or graphical information have been employed for safety and mission success. Methods have included: cue cards or decals; text scrolls built into the instrument panel; traditional books including tables of contents and section tabs; and computer displays. Each method has its own unique mix of user acceptance, cost/ difficulty of construction or maintenance and its own reliability factor. For a variety of reasons, the future points toward the increasing use of computer displays and the corresponding decreasing reliance upon traditional books. These reasons include obvious advantages from the points of view of: information maintenance; availability to a wide audience; concurrency of information content; and potential for interactive feedback. There are difficulties, both obvious and subtle, in achieving widespread user acceptance when compared to traditional methods. Lessons learned from the realm of traditional procedural development, such as validation techniques, must be translated into the electronic world. Alternately, pitfalls must be avoided which are unique to the transfer of information into the electronic realm. For example, the confusion between procedural information and system operations software (the classic "flight software") could drive the Space Station Freedom program to carry tons of paper rather than pay the cost of software validation. Finally, the resulting integrated operations approach, utilizing the great advantages of electronic documentation while avoiding the potential pitfalls, will have a positive impact upon all operatons applications from the factory floor to nuclear power plants.

2. Kelly, Christine; Christopher Marsh (MITRE); Alain Jouchoux; and Fred Lacy (UCB): The Migration of an Expert System Application from LISP to Ada. Presented at the AI and Ada (AIDS '89), November 16-17, 1989, Fairfax, Virginia.

   The Operations Management System (OMS) has been defined by the NASA as a collection of automated and manual functions that is responsible for the integrated high-level management of the systems, elements, and payloads for Space Station Freedom. A prototype LISP- and SymbolicsTM- based expert system demonstrating a portion of the onboard OMS has been developed at JSC. Because Ada is the language mandated for onboard Space Station Freedom, this prototype is being migrated to an Ada-based environment. This paper describes the environment for the prototype, strategy for the migration from a "traditional" artificial intelligence platform to an Ada environment, and future directions for the project.

3. Marsh, Christopher A.; and Christine Kelly (MITRE): Space Station Freedom Operations Management Application Prototype. Presented at the IJCAI, August 21, 1989, Detroit, Michigan.

   The MITRE Corporation, in support of JSC, is designing and implementing a prototype that performs integrated management of Space Station Freedom (SSF) systems. The prototype has three functions: (1) the Diagnostic Reasoning Tool performs fault diagnoses in complex distributed systems; (2) the Objectives Manager performs replanning of SSF operations based on procedural knowledge; and (3) the Procedures Interpreter carries out the operations. The prototype is being integrated with SSF system simulations as a part of NASA's Space Station Information System End-to-end Test Capability (ETC) Test Bed. The prototype components described represent ongoing work that is an extension to existing

prototypes already in use as the Operations Management Application on the ETC Test Bed.

4.   Marsh, Christopher A (MITRE):  From a Lisp Machine to the PC – Migrating Expert Systems to the User Environment.  Presented at the JAIPCC Symposium, March 23, 1989, Houston, Texas.

A number of impressive prototype expert systems have been developed in the past.  Many have been written with expert system shells costing up to $60,000 and hosted on single-user Lisp Machines costing over $100,000.  It is often difficult to integrate these Lisp systems into the user environment.  With such high cost and integration problems, few prototypes will ever be delivered to the user as a finished product.  Managers today are very concerned over the difficulty of delivering expert systems to the users.  Even with the new Lisp co-processor boards and delivery shells, the end cost of an expert system can be too high to justify. Most low-cost PC-based expert system products are too slow, lack the impressive user front end of the Lisp Machine, and are little more than toys.  However, it is possible to migrate expert systems from a Lisp Machine environment to a lower-cost platform without losing speed and functionality.  The ISA expert system has been successfully moved from a Lisp Machine to a PC environment with a minimal loss of functionality.  This paper discusses the migration process.

1.  Barrett, Charlie (RSOC): Application of Lawton's Rapid Method for Calculating Radar Tracking View Periods. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    Finding satellite in-view-periods is currently being done by the "brute force" method. This method performs a simple check at a given time interval to see if the satellite is in view of each TDRS and/or ground tracking stations. This method is very time consuming and is undesirable when a quick accurate answer is desired. A faster way of determining satellite in-view-periods is obtained by using a well behaved sinusoidal function referred to as the visibility function as described by A. D. Parks. Numerical operations derived by J. A. Lawton are performed on the visibility function to determine the in-view-period of the satellite. This method gives accurate results in a fraction of the time required to perform the "brute force" method. These methods have been applied to tracking pass scheduling programs for mission support.

2.  Gutzman, Kenneth J. (RSOC): STS-31 HST Separation Techniques. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    This presentation describes the current separation techniques that will be used by the Space Shuttle Orbiter to separate from the Hubble Space Telescope (HST) on STS-31. The presentation includes a short overview of the HST mission and the separation techniques that were used. The history of these techniques is described as well as the HST and STS separation constraints involved. The presentation concludes a brief description of the science benefits expected after a successful HST deployment.

3.  Joosten, Burton Kent (JSC): Sanger Skip-Glide Maneuver Applied to Shuttle Launch Aborts. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    The National Space Transportation System was designed to allow intact recovery of the Shuttle Orbiter and crew in the event of the failure of a single Space Shuttle Main Engine during any portion of powered flight. This remains a mandatory requirement for mission design. Since the Challenger accident, increased attention has been given to methods of enhancing vehicle survivability and, where possible, vehicle recovery in the event of multiple main engine failures. One scenario that has proven particularly rewarding is the "contingency," or single-engine, Transatlantic Abort Landing (TAL). Unlike intact TAL aborts, which rely upon powered flight to deliver the Orbiter to conditions ensuring robust aerodynamic ranging capability, contingency TAL aborts require the ultimate in unpowered hypersonic flight performance. Range-optimizing hypersonic flight techniques, first described by the German engineer Eugen Sanger in 1933, consist of highly oscillatory, wings-level trajectories flown as near to the vehicle's maximum lift-to-drag ratio as aerothermal constraints will allow. This mode of flight was not anticipated when the Orbiter's entry autoguidance algorithms were formulated, therefore unique piloting procedures have been developed and are now exercised in flight crew training. In addition, the location of suitable African and European landing sites falling under the TAL sub-orbital groundtrack have been incorporated into the Orbiter's navigational software. This effort has reduced, by as much as two minutes, the flight crew's exposure to bailout due to a second main engine failure.

4.  Pearson, Don J. (JSC): The Glideslope Approach. Presented at the AAS/GSFC International Symposium on Orbital Mechanics, April 24, 1989, Greenbelt, Maryland.

Optimum approaches to an orbiting spacecraft at the completion of rendezvous have been the subject of much study during the past decade. Usually the work has focused on fuel optimal approaches. From an operations viewpoint, fuel is not the proper variable for optimization. Several other important factors creep into the design problem and fuel considerations during the last 300 meters of the approach generally end up low on the priority list. Some of the other factors which must be considered include orbital lighting, spacecraft pointing, relative navigation sensor accuracies, thruster plume impingement, collision avoidance philosophy, GN&C system redundancy, and computer hardware limitations. The design of optimal final approaches is further complicated by spacecraft design constraints where onorbit maneuvering thrusters are not placed optimally from a trajectory control viewpoint resulting in significant translational and rotational cross-coupling. The picture becomes even messier when the maneuvering spacecraft is required to dock with a large extended structure like the proposed NASA Space Station which also has a torque equilibrium attitude such that the docking port is not pointing directly into the orbital track.

This paper details these operational design considerations and reflects our focus here at JSC towards optimizing the design in their favor. The paper then describes a candidate "operationally optimum" approach to a local vertical local horizontal (LVLH) stabilized target. This GLIDESLOPE APPROACH is derived using Hill's relative motion equations which have been expanded to include constant relative accelerations in a closed form solution. The motion is described in polar coordinates and a candidate targeting/guidance scheme is presented.

5. Pearson, Don J. (JSC): Shuttle Rendezvous and Proximity Operations. Presented at the CNES International Symposium on Space Dynamics, November 6-10, 1989, Toulouse, France.

During the past ten years, trajectory control concepts for Space Shuttle rendezvous and proximity operations have been developed at the JSC. This paper describes the rendezvous flight segments: launch and early onorbit phase, the "rendezvous" phase, and proximity operations phase. For each flight segment, major design requirements are presented along with the resulting trajectory control plan. The plan is described in terms of standardized relative motion techniques, ground and onboard software algorithm support, and crew operations for trajectory control.

6. Repa, Kevin P. (RSOC): Trajectory Design Implications for the Orbital Maneuvering Vehicle. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The Orbital Maneuvering Vehicle (OMV) will perform at least one rendezvous during each of its missions. The performance characteristics and operational constraints of the OMV offer new problems in designing trajectory profiles. A great deal of flexibility exists in designing the trajectory due to a large propellant load and an efficient propellant-to-delta V ratio. However, the trajectory designer may be required to use this flexibility to compensate for the OMV's limited power resources. An additional complication, during STS-based missions the OMV must conform to the STS crew timeline constraints. A number of profile alternatives have been investigated, but none have yet been accepted as a standard. The profile alternatives may be chosen on a mission-by-mission basis depending upon the constraints and groundrules for a given mission.

7. Saha, Kanan B. (RSOC): Overview of the Use of Monte Carlo Method in Flight Design. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The Monte Carlo method is used to solve a wide variety of problems in science and engineering. A brief account of the method is given in this presentation. An example is cited to introduce the present form of the Monte Carlo method and the role of random number in the Monte Carlo method is emphasized.

The Space Shuttle's entry from orbit is analyzed by computer simulation of the event. The nominal simulation, as this simulation is generally referred to, deals with an idealized situation which is rarely encountered in actuality. A Monte Carlo simulation of the integrated G, N & C is used to study the entry of the Space Shuttle in the presence of navigation, aerodynamics, wind, and atmosphere dispersions. The method uses deterministic flight dynamics, with random number of proper distribution characteristic to simulate uncertainties. It simulates situations most likely to be encountered in an actual entry of the Space Shuttle. The performances of the navigation system with sensor error models turned on and the entry guidance are discussed and plots from a 50-cycle Monte Carlo simulation are presented. Monte Carlo provides a probability envelope of flight parameters from an analysis of deviated flight conditions and helps determine if flight guidelines and constraints are violated. The Monte Carlo role in flight design is emphasized.

8. Snow, Paul T.; and David P. Dannemiller (RSOC): Linear Quadratic Technique Applied to Orbital Relative Motion. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The linear quadratic (LQ) technique is reviewed and applied to two orbital relative motion problems: stationkeeping and maneuvering to a final relative state. Clohess-Wiltshire equations are used for the relative equations of motion.

9. Soileau, Kerry M. (JSC): Defining Optimal Point-to-Point Transfer Surfaces for Orbital Path-Constrained Rendezvous. Presented at the AAS/GSFC International Symposium on Orbital Mechanics and Mission Design, April 24-27, 1989, Greenbelt, Maryland.

Most scenarios of orbital operations involve operations in the proximity of large structures (e.g., the Space Station Freedom). Since in most cases accidental contact of a vehicle with another structure is dangerous, sophisticated, easily-implemented solutions to this problem must be developed. Classical rendezvous guidance equations are inadequate for this purpose because they recognize no constraint on the path between the point of departure and the desired arrival point. In addition to achieving intercept with the arrival point, a transfer must also avoid any contact with the structure.

In this paper we define a class of simply-described closed surfaces which may be parameterized by two real variables (two degrees of freedom). We then define the "goodness" of a surface according to the severity with which it is "injured" by transfers from point to point. A computer algorithm is presented which transforms any given surface of this type into another surface of this type which is less susceptible to injury. The existence and description of "relatively robust" surfaces is investigated.

1. Gerhardt, David; Paul Su; Tibor Lak; and Donna Brakeville (RIC): Development of a Generic Fluid Transfer Model. Presented at the 1989 JANNAF Propulsion Meeting, May 23-25, 1989, Cleveland, Ohio.

   The generic fluid transfer model (GFTM) is unique in the capabilities it provides for the rapid, accurate analysis of fluid transfer systems. For creating a schematic representation of the system to be analyzed, the user is provided with a high resolution color graphics display which uses icons for schematic components. The user creates fluid systems in a Schematic Manager and provides component and model information requested on full-screen panels or menus. The GFTM automatically defines the connectivity relationship between components and generates the specific simultaneous equations required for solution of any schematic constructed. This allows concentration on the creation and evaluation of fluid systems, and requires no coding on the part of the user.

2. Isenberg, Arnold O. (WEC): *Final Report for the Program Three-Man Solid Electrolyte Carbon Dioxide Electrolysis Breadboard*, NASA CR 185612, 1989.

   The development of the Three-Man Solid Electrolyte Carbon Dioxide Electrolysis Breadboard consisted of a phase I and II effort. The phase I effort started in May of 1986 and lasted until June 1987, at which time the phase II effort started. The phase I effort constituted fabricating three electrolysis cell types and performing parametric, off-design, and cell life testing. The cell type showing the best performance was selected for the breadboard system. Analysis of the test data led to the determination of a breadboard conceptual design and operating characteristics of the three-man (2.2 lb $CO_2$/man-day) $CO_2$ Electrolysis Cell Breadboard System. The phase II consisted of the preliminary design, incorporation of palladium (Pd) tubes for hydrogen separation from the electrolyzer cathode feed gases, design support testing, final design, fabrication, and performance testing of the breadboard system. Both phases I and II were successfully completed. The results of the performance tests have demonstrated the $CO_2$ electrolysis in an oxygen reclamation system for long duration space-based habitats (Lunar/Mars) is feasible. Closure of the oxygen system loop, therefore, can be achieved by $CO_2$ electrolysis. In a two step process the metabolic $CO_2$ and $H_2O$ vapor are electrolyzed into $O_2$, $H_2$, and CO. The CO can subsequently be disproportionated into carbon (CO) and $CO_2$ in a carbon deposition reactor, and the $CO_2$ in turn can be recycled and electrolyzed for total $O_2$ recovery. The development effort has demonstrated electrolyzed for total $O_2$ recovery. The development effort has demonstrated electrolyzer systems can be designed and built to operate safely and reliably, and the incorporation of Pd tubes for hydrogen diffusion can be integrated safely with predictable performance.

1.    Haas, Francis X. (LESC):  An Approach to Information Systems Engineering.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

One goal of the Engineering Directorate's Information Systems Office/EA131 is to develop advanced software engineering techniques and a supporting integrated tool set for use by the Directorate. While all of the tools and techniques have not yet been identified or integrated, success has been achieved with certain aspects of this task. I will present an overview of the approach and some examples as they apply to a current system development project.  ISO has taken the responsibility for the development of the Subsystem Managers Support System (SMSS) a database system that will support the Engineering Directorate personnel who manage Orbiter and Space Station subsystems.  This project serves as a test case opportunity to refine the approach.  One key activity in the gathering and analysis of requirements for SMSS is to identify the functions both recurring and specific to the life cycle of a given subsystem.  A structured analysis technique known as Functional Decomposition is being used for this identification activity. Functional decomposition is where high-level functions are broken down into lower-level activities showing more detail.  A function is the highest level in a hierarchy that groups activities/tasks/processes and transactions that together support the mission of the organization.  Decomposition continues until a meaningful level of detail is reached.  Functions are the basis for the development of processing and information requirements.  The Subsystem Technical Management Functional Decomposition was derived from the OMS Subsystem analysis provided to the National Research Council in conjunction with the 51L accident.  Milestones, products and activities were translated and reorganized by life-cycle phases.  The first cut was validated by current and former Subsystem Managers.

2.    Tucker, Pamela J. (LESC):  Lunar and Planetary Mission Scenarios (LPMS) Conceptual Data Model.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The Lunar and Planetary Mission Scenarios (LPMS) conceptual data model was created in support of the New Initiatives Office (NIO) to provide a road map for the design of a data base system which supports mission scenario development.  The Product Data Control Model (PDCM) developed by the Air Force's Integrated Design Support (IDS) Project served as a template for the development of the LPMS conceptual data model.  The PDCM proved to be a beneficial interface in the analysis and planning of the model.  Due to the increasing growth and complexity of system information, the LPMS project stresses the importance of information management and its relationship to data modeling.  Information is produced from equal, but separately managed activities consisting of processes and data.  Therefore, the data must be analyzed to produce meaningful data models which represent the necessary entities and their relationships.  The LPMS project resulted in the development of a conceptual data model which is composed of the following subject areas:  case study, mission and supporting elements, transportation elements, and lunar and planetary surface infrastructure. Lockheed contractors and personnel from Rice University School of Architecture participated in a joint effort to produce the LPMS conceptual data model.

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1.   Shields, Vernon (JSC):  Building a Space Station.  Presented at the National
     Technical Symposium, April 7-8, 1989, Houston, Texas.

        In January 1984, President Ronald Reagan directed NASA to develop and con-
     struct a permanently manned space station.  At that time, NASA was already
     engaged in defining the space station architecture and conducting engineering
     analyses of early space station design concepts.

        NASA had divided the responsibility for the space station development into four
     work packages, managed by four NASA centers (JSC, LeRC, MSFC and
     Goddard).  Each of these centers were designated as Level III management.
     NASA retained the responsibility for overall program management and work
     package integration with the Space Station Program Office, located at Reston,
     Virginia, and designated as Level II management.

        This presentation will show the baselined on-orbit Space Station Freedom
     assembly sequence for phase 1, using the NSTS as the transportation system.  In
     addition, congressional mandated features of the space station's design and
     operations will be addressed.

1.  Adlhart, Otto J.; Matthew J. Rosso, Jr. (EPS); and Jose A. Marmolejo (JSC):  A Fuel
    Cell Energy Storage System Concept for the Space Station Freedom Extrave-
    hicular Mobility Unit.  Presented at the 19th Intersociety Conference on Envi-
    ronmental Systems, July 24-26, 1989, San Diego, California.

    This paper gives an update on an advanced development effort carried out
    under NASA contract NAS 9-17775 by Ergenics Power Systems, Inc. (EPS).  The
    work was initiated in April 1987 and describes a fuel cell energy storage system
    (FCESS) for the Space Station Freedom extravehicular mobility unit (EMU).
    Fueled by oxygen and hydride stored hydrogen, the FCESS is being considered
    as an alternative to the EMU zinc-silver oxide battery.  Superior cycle life and
    quick recharge are main considerations.  Design and performance of a non-
    venting, 28-volt, 34-ampere-hour system with 7-ampere current rating are
    discussed.

2.  Alario, J.; M. League; F. Gisondo; and M. Hutchinson (GAC):  Grumman Prototype
    Space Erectble Radiator System Thermal Test  Bed Results.  Presented at the
    24th ThermoPhysics Conference, June 12-14, 1989, Buffalo, New York.

    The space erectable radiator system (SERS), being developed by JSC, uses
    modular, high-capacity radiator panels to provide a long-life, highly reliable, waste-
    heat rejection capability for Space Station Freedom and similar large space sys-
    tems.  The Grumman prototype SERS uses monogroove, heat-pipe technology for
    the radiator element with a simple "whiffle-tree" clamp.  Thermal vacuum testing
    was conducted in the JSC thermal test bed facility during July 1988.  Two sepa-
    rate evaluation series were run:  a single standalone radiator panel was tested to
    measure individual panel performance, and a separate six-panel subsystem (with
    whiffletree clamps) was integrated with the condensers of a two-phase thermal
    bus to determine overall system behavior.  In both cases, the Grumman SERS
    GTA hardware met or exceeded all performance requirements.  The standalone
    panel handled up to 2kW at high adverse tilt, and the six integrated panels con-
    sistently responded to the operational demands of the two-phase thermal bus.

3.  Andish, Kambiz Kheyr; and Robert S. Harris, Jr. (LESC):  An Integrated Model of the
    LMSC Two-phase Thermal Bus, Designed for Active Thermal Control System of
    Space Station Freedom.  Presented at the SAE, 19th Intersociety Conference on
    Environmental Systems, July 24-26, 1989, San Francisco, California.

    An integrated SINDA85/FLUINT model has been developed for the central
    active thermal control system (ATCS) of the Space Station Freedom (SSF).  The
    model is based on the Phase I configuration of SSF and a design similar to the
    LMSC thermal bus ground test unit.  It simulates the ATCS which utilizes ammonia
    as the working fluid and analyzes both 70° F and 35° F thermal buses at various
    thermal loads.  Both buses interact with nine heat acquisition devices representing
    the projected habitat and laboratory modules and attached payload heat
    exchangers.  Performance of gas blocked and liquid blocked condensers, shear
    flow subcoolers, cold plate evaporators utilizing self-regulating capillary fluid
    management, liquid flow control orifices, pump, bellows accumulator, and liquid
    and vapor pressure control valves have been simulated and implemented into the
    integrated model.  This model is capable of predicting flow rate, temperature, and
    pressure maps of the buses for steady-state and transient cases under cyclic
    environmental heat loads and variable module heat rejection requirements.  It also
    predicts the overall bus performance including sizing the orifices and setting valve
    stem positions and pump speed.

4.  Brown, Richard F.; and C. E. Kalb (GAC): Development of a Two-Phase Accumulator for a Space-Based Ammonia Thermal Bus System. Presented at the 19th Intersociety Conference on Environmental Systems, July 24-26, 1989, San Diego, California.

    Two-phase active thermal control systems have been identified as necessary to meet the demanding heat acquisition, transport, and rejection requirements of future large space platforms. An example is the two-phase ammonia thermal bus system (TBS) which Grumman has been developing under contract to JSC for application on the Space Station Program. Grumman recently delivered a second-generation system, the Prototype TBS, to JSC for testing. A unique two-phase accumulator was developed for this system. The accumulator maintains constant system operating temperature and pressure in the face of widely varying heat loads by adjusting the amount of liquid in the condensers ("condenser flooding" principle).

    The two-phase accumulator works on the principle of direct efficient energy transfer out of and into the vapor space of the accumulator via subcooled liquid spray (direct contact condensation) and warm vapor addition from an external vaporizer block (stored thermal energy). This paper describes the two-phase accumulator thermal control function, the theory behind its operation, and accumulator hardware design. A sampling of data from the Grumman acceptance tests on the Prototype TBS is presented which confirms satisfactory accumulator performance.

5.  Brown, Richard F.; Fred Edelstein; and Maria Liandris (GAC): Testing of a 30 KW Prototype Space Station Thermal Bus. Presented at the 24th Thermophysics Conference, June 12-14, 1989, Buffalo, New York.

    A prototype two-phase ammonia thermal bus has been built and tested for JSC for application on the Space Station. The system demonstrated its ability to operate in both a separated and a mixed two-phase flow mode. Temperature control is maintained via liquid blockage of the condensers as controlled by a two-phase accumulator. In the separated flow mode, evaporator liquid supply valves controlled by ultrasonic liquid presence sensors maintain phase separation. Overall, the ambient tests were very successful, with the bus demonstrating a high degree of isothermality under variable loads (0.25 to 26.5 KW) and environments. Operation at both 70°F and 35°F setpoints was achieved, with vapor line pressure drops of only a few tenths of a psi and pump power consumption of under 40 watts.

6.  Chu, Richard; and Frank Jeng (LESC): On Use of Process Simulators for ECLSS and Resource Management. Presented at the AICHE National Meeting, April 5, 1989, Houston, Texas.

    Several popular process simulators have been reviewed and/or briefly evaluated for their potential applications in the modeling steady-state Environmental Control and Life Support System (ECLSS), Electrical Power System (EPS), consumables system analysis, and resources processing on the Moon and Mars. For the Space Shuttle, an integrated model that incorporated Active Thermal Control Subsystem, Atmospheric Revitalization Subsystem, and Fuel Cell Powerplant has been prepared and verified on three popular process simulators.

    Process simulators have shown many advantageous features in comparison to existing "custom-made" programs in the space industry. One is the simple and time-saving preparation of process flow diagrams and data input, especially with the latest editions of graphical capability. Another is the updating of main programs on most of the recent and powerful mainframes, therefore, providing the-state-of-the-art speed and convenience for the users. In each process simulator, thermophysical property data has been set up and most process and heat

transfer equipment have already been modeled and available. For special equipment in spacecraft, such as the radiator panels and Flash Evaporator Subsystem, user's added routines can be accommodated. The selection of a suitable simulator for space industry applications will need to be based on hardware availability, graphical requirements, and application requirements.

7.  Cullimore, B. A. (MMSS): Applications of a General Thermal/Hydraulic Simulation Tool. Presented at the AIAA 24th Thermophysics Conference, June 12-14, 1989, Buffalo, New York.

    Analytic techniques, sample applications, and development status are presented for a general-purpose computer program used to simulate thermal structures and internal fluid systems. The program, called SINDA '85/ FLUINT (Systems Improved Numerical Differencing Analyzer, 1985 version with FLUid INTegrator), is being developed under NASA funding to standardize the analyses of complex spacecraft thermal management subsystems such as those encountered in NASA's Space Station. Because of its general formulation, transportability, and availability, the program is finding application in other aerospace missions as well as in terrestrial industries. While the program has extensive analytic capabilities for radiation and conduction heat, this paper emphasizes applications of the fluid system capabilities (e.g., FLUINT). Underlying assumptions, methodologies, and modeling capabilities are briefly summarized. Details of numerical methods have been provided in a previous conference paper. Sample applications include both component- and system-level simulations. Components include lines, cavitating venturis, and rotary separating pumps (Sundstrand RFMDs). A system-level analysis of a cryogenic storage system is presented. Other applications are briefly discussed. Finally, the development status is presented, and areas of planned improvements are outlined.

8.  Dawn, Frederic (JSC): *Development and Application of Nonflammable Beta Fibers.* NASA TM 102158, December 1989.

    Recent advances in fiber technology have contributed to the success of the U. S. space program. The inorganic fiber "Beta," developed as a result of efforts begun in the early 1960's and heightened following the January 27, 1967, Apollo fire, is unique among inorganic and organic fibers. It has been developed into woven, nonwoven, knitted, braided, coated, and printed structures. All of these were used extensively for the Apollo, Skylab, Apollo-Soyuz Test Project, Space Shuttle, Spacelab, and satellite programs.

    In addition to being used successfully in the space program, Beta fibers are being used commercially as firesafe fabrics in homes, hospitals, institutions, public buildings, aircraft, and public transportation, wherever total nonflammability is required. One of the most unique applications of the Beta composite structure is the roofing material for the 80,000-seat Detroit Lion's Silverdome and 5 square miles of the Jeddah International Airport in Saudi Arabia. This fiber has been successfully incorporated into 165 major public construction projects around the globe. The United States alone has used more than 12 million square yards of the material.

    Beta fiber has been used successfully to date and has a promising future with unlimited potential for both space and commercial application. Efforts are currently underway to improve Beta fiber to meet the requirements of extended service life for the Space Station Freedom, lunar outpost, and Mars exploration missions.

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9.  Doebbler, Thomas (LESC):  Shuttle Radiator Assembly Demonstration:  Radiator Assembly Carrier.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    The NASA JSC has proposed a flight experiment aboard the National Space Transportation System (NSTS) Space Shuttle to demonstrate the stowage, assembly, operation, and maintenance procedures of large modular heat pipe radiator arrays planned for use on the Space Station.  The demonstration will utilize manual and remote manipulator operations to verify construction techniques for the heat pipe radiators.

    This presentation describes the requirements and functions of the radiator assembly carrier (RAC) which houses the heat pipe radiators for launch, on-orbit operations, and reentry conditions on the Space Shuttle.  The design, development, testing, and training considerations of the RAC are briefly discussed.

10. Dominick, Jeffrey (JSC); John Bull (ARC); and Kathleen Healey (JSC):  NASA Systems Autonomy Demonstration Project – Advanced Automation Demonstration of Space Station Freedom Thermal Control System.  Presented at the Space Operations Automation and Robotics (SOAR) Conference, July 24-28, 1989, Houston, Texas.

    The NASA Systems Autonomy Demonstration Project (SADP) is a response to Congressional interest for a space station automation technology demonstration.  The SADP is a joint cooperative effort between ARC and JSC to demonstrate advanced automation technology feasibility using the Space Station Freedom (SSF) thermal control system (TCS) test bed.  A model-based expert system and its operator interface have been developed by knowledge engineers, Artificial Intelligence researchers, and human factors researchers at ARC working with the domain experts and system integration engineers at JSC.  Its target application is a prototype heat acquisition and transport subsystem for an SSF TCS.  This paper describes the SADP goals, objectives, and approach.  It also describes the Thermal Control Expert System that has been developed for demonstration and provides insight into the lessons learned during the development process.

11. Duschatko, R. John (LTV):  Contact Conductance Evaluation for Full-Scale Space Erectable Radiator Pressurized Interface.  Presented at the 19th Intersociety Conference on Environmental Systems (SAE), July 24-26, 1989, San Diego, California.

    Contact conductance evaluations were made for a prototype pressurized interface mechanism for space erectable radiators.  These evaluations were based on data taken from the thermal/vacuum test series conducted at JSC on the integrated system of a two-phase thermal bus, prototype radiators, and the pressurized interface.  The conductance evaluation methodology included test data and analytical techniques.

12. Dzenitis, J. M. (JSC):  Two-Phase Flow Regime Transition Under Microgravity Conditions.  Presented at the ASME Winter Annual Meeting, December 10-15, 1989, San Francisco, California.

    The results of extensive experiments with equal density, immiscible liquids to simulate microgravity buoyancy conditions were used to help develop a microgravity flow regime analysis based on observed flow regimes and pressure drops.  To extend the analysis to true microgravity vapor-liquid flows, a new model for slug flow was developed.  This slug flow model also uses the minimization of pressure drop principle to determine average slug geometry and the related velocities.  The model predicts a region of hysteresis along the slug-annular boundary.  The resulting analytical predictions of vapor-liquid flow regime are in good agree-

ment with the limited quantity of microgravity air-water flow regime data found in the literature. However, more true microgravity vapor-liquid pressure drop and flow regime data are needed to verify the proposed method for predicting flow regimes.

13.   Ellis, Wilbert E. (JSC):  The Space Station Active Thermal Control Technical Challenge.  Presented at the 27th Aerospace Sciences Meeting, January 8-12, 1989, Reno, Nevada.

    The overall conceptual design premise of the two major subsystems of the Space Station active thermal control system is discussed. The two subsystems discussed are the thermal loop to gather and collect the waste heat from the various systems, modules, and payloads of the Station and the large radiators necessary to dissipate the waste heat to space. The technology being applied to accomplish both of these subsystem functions is entirely new, when compared to other manned spacecraft such as the Shuttle. The technical challenges associated with meeting the unique Station design requirements for the two major active thermal control subsystems are addressed. The basic design concepts are described, and the ground and flight tests conducted to verify the design approaches are summarized. Future Shuttle flight tests planned to further verify the designs are discussed. This paper will show that the Space Station active thermal control system is a real and highly interesting development challenge and that, although the basic system concepts have been proven by the test described, the detail engineering design and manufacturing challenges necessary to provide reliable and cost effective flight systems is still ahead. However, when the development is successfully accomplished, the high efficiency and very user friendliness of two-phase systems will be a long term legacy of the Space Station Program and provide the basic active thermal control approach for manned spacecraft of the forseeable future.

14.   Hess, Clifford; and Larry C. Li (JSC):  Smart Hands for the EVA Retriever.  Presented at the NASA Conference on Space Telerobotics, January 31 - February 2, 1989, Pasadena, California.

    Dexterous, robotic hands are required for the EVA retriever system being developed by the NASA JSC. These hands, as part of the EVA retriever system, must be able to autonomously and securely grasp objects which inadvertently separate from the Space Station. Development of the required hands was initiated in 1987. This paper outlines the hand development activities, including design considerations, progress to date, and future plans. Several types of dexterous hands that were evaluated are described along with a proximity sensing capability that was developed to initiate a reflexive, adaptive grasp.

15.   Himel, Victor; Fred J. Abeles (GAC); James Auman (HSMH); and Terry O. Tri (JSC):  Automatic Sequencing and Control of Space Station Airlock Operations.  Presented at the 19th Intersociety Conference on Environmental Systems, July 24-26, 1989, San Diego, California.

    This paper describes the procedures that have been developed as part of the NASA JSC-sponsored preprototype Checkout, Servicing, and Maintenance System (COSM) program for pre- and post-EVA airlock operations. It addresses the accompanying pressure changes in the airlock and in the EMUs. Additionally, the paper focuses on the components that are checked out and includes the step-by-step sequences to be followed by the crew, the required screen displays and prompts that accompany each step, and a description of the automated processes that occur.

16.  Isenberg, Arnold O. (WEC):  Final Report for the Program Three-Man Solid Electro-
     lyte Carbon Dioxide Electrolysis Breadboard, NASA CR 185612, 1989.

     The development of the Three-Man Solid Electrolyte Carbon Dioxide Electroly-
sis Breadboard consisted of a phase I and II effort.  The phase I effort started in
May of 1986 and lasted until June 1987, at which time the phase II effort started.
The phase I effort constituted fabricating three electrolysis cell types and perform-
ing parametric, off-design, and cell life testing.  The cell type showing the best
performance was selected for the breadboard system.  Analysis of the test data
led to the determination of a breadboard conceptual design and operating char-
acteristics of the three-man (2.2 lb $CO_2$/man-day) $CO_2$ Electrolysis Cell Bread-
board System.  The phase II consisted of the preliminary design, incorporation of
palladium (Pd) tubes for hydrogen separation from the electrolyzer cathode feed
gases, design support testing, final design, fabrication, and performance testing of
the breadboard system.  Both phases I and II were successfully completed.  The
results of the performance tests demonstrated that the $CO_2$ electrolysis in an
oxygen reclamation system for long duration space-based habitats (Lunar/Mars)
is feasible.  Closure of the oxygen system loop, therefore, can be achieved by
$CO_2$ electrolysis.  In a two step process the metabolic $CO_2$ and $H_2O$ vapor are
electrolyzed into $O_2$, $H_2$, and CO.  The CO can subsequently be disproportionated
into carbon (CO) and $CO_2$ in a carbon deposition reactor, and the $CO_2$ in turn can
be recycled and electrolyzed for total $O_2$ recovery.  The development effort
demonstrated that electrolyzer systems can be designed and built to operate
safely and reliably, and the incorporation of Pd tubes for hydrogen diffusion can
be integrated safely with predictable performance.

17.  Jeng, Frank; S. L. Christian; W. C. Lee; and R. Chu (LESC):  Simulation of Cyclic
     Adsorption Process for Extended Missions.  Presented at the AICHE National
     Meeting, April 5, 1989, Houston, Texas.

     Non-regenerative lithium hydroxide canisters are presently used for Shuttle
$CO_2$ control.  For extended missions, the weight and volume penalties become
excessive; therefore, a regenerative $CO_2$ control process is more desirable.  A
solid amine $CO_2$ control process is considered viable among the regenerative
$CO_2$ control processes.  A model which simulates the heat and mass transfer of
the solid amine Flight Prototype System (FPS) is presented.  The existing pro-
gram, SAM, was modified so that test runs of the FPS can be simulated.  Mass
transfer coefficients of $CO_2$ and $H_2O$ from cabin air to FPS were obtained by
comparing the simulation results with test data.  Instantaneous rates of adsorption
and desorption, accumulated adsorption, and the driving forces are discussed.  A
plan for a breadboard test unit which was designed to support the modeling of the
cyclic adsorption systems is included in the presentation, and the operation and
ranges of operating parameters are discussed.

18.  Klaus, David M. (BT); and Philip R. West (JSC):  Performance Evaluation of
     Advanced Space Suit Concepts for Space Station.  Presented at the 19th Interso-
     ciety Conference on Environmental Systems, July 24-26, 1989, San Diego,
     California.

     Extravehicular activity (EVA) based from the Space Station Freedom presents
unique conditions in which a space suit must operate.  To accommodate the pre-
dicted demands, new technology is required in the suit design.  This paper
describes the requirements of an advanced space suit associated with Space
Station EVA, gives an overview of two candidate suits, and presents the methods
used to evaluate suit performance through testing.

19. Marmolejo, Jose (JSC); Robert Blaser; and Carolyn Gernux (UTHSD): A Helmet-Mounted Display Demonstration Unit for a Space Suit Application. Presented at the 19th Intersociety Conference on Environmental Systems, July 24-26, 1989, San Diego, California.

This paper describes an advanced development effort carried out under NASA JSC contract NAS 9-17543 by Hamilton Standard Division (HSD), Windsor Locks, CT. The work was initiated in December 1985 and describes the design of a helmet-mounted display (HMD) demonstration unit delivered in June, 1988 for an advanced version of an extravehicular mobility unit (EMU) as an alternative to the current low resolution chest-mounted display and cuff-mounted checklists. Important design goals include the use of transmissive liquid crystal display (LCD) image sources with fairly high resolution (i.e., text, graphics, and video compatible), binocular viewing with total image overlap, virtual image projection, low-profile packaging, low-power design, and demonstration of voice control of the HMD data. Design and performance of an HMD demonstrator, which utilizes two 320 x 220 pixel LCDs to provide a 16.7-degree diagonal virtual, binocular, non-pupil forming image with adjustable focal length are discussed.

20. Mechanical Technology Inc.: *High Pressure Compressor System (HPCS) Development Program*, NASA CR 185515, 1989.

21. Meyer, D. Paul; Richard P. Reysa; and Thomas L. Slavin (BAC): A Study of Life Support Approaches for Advanced Missions. Presented at the 19th Intersociety Conference on Environmental Systems, July 24-27, 1989, San Diego, California.

When NASA returns to crewed missions beyond low Earth orbit, the system chosen to provide life support for the crew will have to keep pace. Whether the missions are to the Moon or Mars, reliable and efficient life support approaches need to be selected by mission planners. This paper describes a study underway to develop a Mission Planners Life Support System (LSS) Guidebook for providing information to help in making those selections. Elements of the tabular data being generated by the study are discussed. This discussion covers mission drivers for life support, life support systems approaches, and the impacts on mission design resulting from different LSS approach selections.

22. Nacheff, Maurena S. (ASAC); Craig H. Chang (ASEMRC); Gerald V. Colombo (URC); and Robert J. Cusick (JSC): Metal Oxide Regenerable Carbon Dioxide Removal System for an Advanced Portable Life Support System. Presented at the 19th Intersociety Conference on Environmental Systems, July 24-26, 1989, San Diego, California.

The extravehicular activity (EVA) requirements for Space Station Freedom and future long-duration space missions demand advanced technologies for the life support subsystems in the astronaut portable life support system (PLSS). A NASA funded program is currently underway to develop a full-scale, breadboard, regenerable metal oxide carbon dioxide ($CO_2$) removal system. This technology is a promising concept to replace the lithium hydroxide absorber presently used for removing $CO_2$ in the recycled breathing gas in the PLSS, but cannot be efficiently regenerated to be used for another EVA mission.

This paper discusses the factors which must be considered in selection of a metal oxide absorbent for $CO_2$ removal for space applications and the laboratory tests performed on metal oxide absorbent materials which were developed during the first phase of the program. These tests include both characterization studies and dynamic $CO_2$ uptake and regeneration measurements. The preliminary design of the breadboard system, which performs both the absorption and regeneration functions, is also presented.

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23.  Newbold, D. D.; Rod Ray; William A. Pledger (Bend Research); and Mariann F. Brown (JSC): Dehumidification via Membrane Separation for Advanced Extravehicular Mobility Unit (EMU) Application. Presented at the 19th Intersociety Conference on Environmental Systems, July 24-26, 1989, San Diego, California.

The humidity in the extravehicular mobility unit (EMU) must be controlled to prevent fogging of the visor to prevent water from accumulating and blocking the flow of air through the vent or from eventually corroding system components, and to keep the person inside comfortable and productive. This paper describes the development of a membrane-based process for dehumidifying the EMU.

The membrane process promises to be smaller, lighter, and more energy efficient than are other technologies under consideration, and it requires no expendables. The novel dehydration membranes developed were tested for 90 days at conditions expected to be present in the EMU. The results of these tests indicate that membrane-based technology can effectively control humidity in the EMU.

24.  Powell, F. T.; F. H. Schubert; and M. G. Lee (LS): *Impact of Low Gravity on Water Electrolysis Operation*, NASA CR 185521, 1989.

25.  Puskar, Michael C.; John A. Zagaja (HS); and Terry O. Tri (JSC): Test Results of High Pressure Electrolyzer for Space Station EMU Recharge. Presented at the 19th Intersociety Conference on Environmental Systems, July 24-26, 1989, San Diego, California.

A High Pressure Oxygen Recharge System (HPORS) is being developed to recharge the EMU on board the Space Station. The Hamilton Standard HPORS will be a solid polymer electrolyte water electrolyzer, similar to one already approved for use aboard U. S. Navy nuclear submarines at 3000 psia. It will be capable of producing oxygen at up to 6000 psia without the use of a mechanical compressor and utilizing only the electrical, nitrogen, and water facilities that will be available on board the Space Station. A description of the test rig and its performance at various operating pressures, temperatures, current densities, and water feed modes are discussed.

26.  Rankin, J. Gary; E. K. Unga; and S. D. Glenn (JSC): Development and Integration of the SHARE Flight Experiment. Presented at the 26th National Heat Transfer Conference, August 6-9, 1989, Philadelphia, Pennsylvania.

The Space Station Advanced Heat Pipe Element (SHARE) is scheduled to fly as a payload bay experiment on STS-29. This experiment will demonstrate the microgravity operation of a full-scale prototypic heat pipe radiator for the Space Station Freedom active thermal control system. The history of the SHARE experiment is traced in this paper from the conceptual design through the final preparations for flight. The typical development path for payload bay experiments that leads to flight certification and ultimately to space flight is described, with special emphasis on the SHARE experiment. Information is included on design, documentation, preflight testing, and preflight analysis of the experiment. The final preparations for the flight, plans for the flight itself, and post-flight analysis are also described.

27.  Tritsch, Constance (LESC); and Jose Marmolejo (JSC): A Helmet Mounted Display Application for the Space Station Freedom Extravehicular Mobility Unit. *SPIE Conference Proceedings*, Vol 1116. Presented at the SPIE Conference, March 28-29, 1989, Orlando, Florida.

The routine extravehicular activity (EVA) performed from the U. S. Space Station Freedom will require the astronaut to access large amounts of information during the EVA, especially for intensive EVA scenarios such as satellite servicing and

emergency or contingent operations. As a result, NASA is presently designing a helmet mounted display (HMD) into the Freedom Station extravehicular mobility unit (EMU) to aid the EVA astronaut. The HMD allows the astronaut to view a virtual image behind a transparent combiner located conveniently above his or her primary field of view (FOV). This HMD system can be voice-driven for "hands-free" operation.

NASA is currently exploring four HMD approaches. Two designs utilize cathode ray tubes (CRTs), while the other two use backlit liquid crystal displays (LCDs). Furthermore, two of these designs use purely conventional optics, while the other two employ conventional and holographic optics. A discussion of these designs and some key design issues, such as image source, FOV, exit pupil versus non-pupil-forming systems, monocular versus binocular and binocular viewing, degree of image overlap, and the use of holographic optical elements (HOEs), will be provided in this paper.

28. Verostko, Charles E. (JSC); and Arnold O. Isenberg (WEC): Carbon Dioxide and Water Vapor High Temperature Electrolysis Breadboard Development. *SAE 19th Intersociety Conference on Environmental Systems (ICES) Proceedings*, Paper No. 891506. Presented at the SAE 19th ICES, July 24-26, 1989, San Diego, California.

The development of solid oxide electrolysis cell technology has progressed to a level that allows for construction of a three-person breadboard system. This paper addresses the design, fabrication, and testing of the breadboard, and the database obtained for future electrolysis systems that have application for planetary manned missions and habitats. The breadboard contains 16 tubular cells in a closely packed bundle for the electrolysis of carbon dioxide and water vapor. Palladium diffusion tubes are arranged in the bundle parallel and symmetrical with the electrolyzer tubes for removal and separation of hydrogen from the process gases. Basic information on energy requirement, volume, and weight are described. The operational characteristics relating to measurement of the reactant and product gas compositions, temperature distribution along the electrolyzer tubular cells and through the bundle, and thermal energy losses are assessed. The reliability of individual cell performance in the bundle configuration is examined. The effects of long-term testing on the mechanical and electrical stability of the ceramic cells of the breadboard as compared to isothermal single cell testing is also examined. Performance goals are defined and discussed.

29. Verostko, Charles E. (JSC); Gerald Cooper; and Matthew Ratcliff (Photo-Catalytics, Inc.): Photocatalytic Post-Treatment in Waste Water Reclamation Systems. *SAE 19th Intersociety Conference on Environmental Systems (ICES) Proceedings*, Paper No. 891508. Presented at the SAE 19th ICES, July 24-26, 1989, San Diego, California.

A post-treatment concept of an ultraviolet photocatalytic approach for the purification of waste water distillates, reverse osmosis permeates, and spacecraft habitat atmospheric humidity condensates is presented. Experimental results show that organic impurity carbon content of simulated reclamation waters at 40 ppm level are reduced to <300 ppb using a batch reactor technique. Minimum expendables (stoichiometeric oxygen) are required and the organic impurities common to reclaimed waste waters are removed by oxidation. The technique is adaptable for integration with water reclamation processes. This paper discusses test results and parametric data obtained for design and fabrication of a bread-board system. The parametric testing includes evaluating UV light sources, catalyst particle sizes, oxygen consumption, operating temperature, power requirements, and disinfection features. This approach is a new post-treatment tech-

nology for waste water reclamation with application for integration in closed life support systems.

30. Verostko, Charles E.; Rafael Garcia; Richard Sauer (JSC); Richard P. Reysa (BAC); Arthur T. Linton; and Theresa Elms (HSMS): Test Results on Reuse of Reclaimed Shower Water. *SAE 19th Intersociety Conference on Environmental Systems (ICES) Proceedings*, Paper No. 891443. Presented at the SAE ICES 19th Conference, July 24-26, 1989, San Diego, California.

A microgravity whole body shower and waste water recovery system were evaluated in three separate closed loop tests at NASA JSC. These tests covered a period from August 1985 to June 1987 in which shower waste water was reclaimed and reused for showering. Test subjects showered in a preprototype whole body shower following a protocal similar to that anticipated for the Space Station. Each test was performed with using different water recovery system technologies which included phase change distillation and two separate reverse osmosis processes. These were integrated with post-treatment for the final purification of the reclaimed water. The phase change, a preprototype Thermo-electric Hollow Fiber Membrane Evaporation Subsystem was used for the initial test with chemical pretreatment of the shower waste water input. A reverse osmosis dynamic membrane system was used for the second test and a two-stage ultrafiltration/reverse osmosis system for the third test. The post-treatment consisted of filtration of all the reclaimed water through granular activated carbon, ion exchange resin beds, and a microbial treatment bed for residual disinfection.

This paper describes the test hardware; controls exercised for whole body showering; types of soaps evaluated; test subjects' response to showering with reclaimed water; the applicable chemical pretreatment for microbial control; and the procedures necessary to provide hygiene water for reuse. The reclamation system performance and effectiveness for providing water purity and microbial control are discussed. The chemical analysis and microbial evaluation result are also presented on the quality of water produced by the systems. Reclaimed water was successfully produced for reuse by all three waste water recovery systems.

1.  Bouslog, S. A.; W. C. Rochelle (LESC); and C. D. Scott (JSC): Evaluation of Aero-
    thermodynamic Surface Property Changes of Shuttle Tiles. Presented at the 14th
    Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
        A study to evaluate changes in the surface characteristic of Shuttle tiles that
    could cause an increase in reentry heating rates is in progress. Flight instrumen-
    tation data will be presented showing an increase in heating rates to the Orbiter
    with increasing number of flights. Tests have been planned to determine if the
    emissivity and/or the surface catalycity of the tile surface reaction cured glass
    (RCG) changes with reentry exposure and could, therefore, cause an increase in
    heating. These tests will include comparisons of surface elemental composition
    and of spectral emittance measurements for both virgin and flown tiles.

2.  Cerimele, Mary P. (JSC): Guidelines for Man-Rating Space Systems. Presented at
    the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
        A study was recently completed at the JSC which collects the current and past
    thinking on man-rating. The engineering disciplines were polled as to the pro-
    cesses and philosophies they have adopted for man-rating. In addition, the crew,
    the operations community, and the Safety Office contributed their input on what
    they feel are the man-rating requirements. It was agreed that a good set of guide-
    lines should cover all systems of a program and should treat each with equal
    vigor. This was the first time a multidisciplinary study had been done to discover
    and combine the prevailing trends in safety practices and philosophies. The pre-
    sentation will cover the issues that began this effort and the results of the study.

3.  Craig, Roy R., Jr. (UTCAR): Application of Attachment Modes in the Control of
    Large Space Structures, NASA CR 185604, 1989.
        This report covers research conducted during the three phases of the subject
    contract: phase I (October 1, 1984-June 30, 1986), phase 2 (July 1, 1986-July 10,
    1987), and phase 3 (July 11, 1987-September 1, 1989). The research, entitled
    "Application of Attachment Modes in the Control of Large Space Structures,"
    focused on various ways to obtain reduced order mathematical models of struc-
    tures for use in dynamic response analyses and in controller design studies.
    Attachment modes are deflection shapes of a structure subjected to specified unit
    load distributions and are frequently employed to supplement free-interface
    normal modes to improve the modeling of components (substructures) employed
    in component mode synthesis analyses. Deflection shapes of structures sub-
    jected to generalized loads of some specified distribution and of unit magnitude
    can also be considered to be attachment modes.

4.  Craig, Roy R., Jr. (UTCAR); and Zhenhau Ni (Xian Jiatong University): Component
    Mode Synthesis for Model Order Reduction of Nonclassically Damped Systems.
    *Journal of Guidance, Control, and Dynamics*, Vol. 12, No. 4, July-August 1989.
        Based on a component mode synthesis approach, a model-order-reduction
    method for linear structures with arbitrary linear damping has been developed.
    Projection matrices are introduced to make the method applicable to systems
    having rigid-body freedom. To test the method, eigenvalues of a reduced-order
    model of a free-free beam with nonproportional damping were compared to exact
    eigenvalues and to eigenvalues obtained using two other model-reduction strate-
    gies. The present model-reduction strategy proved to be decidedly superior.

5.  Deprang, Clifford; and Steve Fitzgerald (JSC): Space Station Freedom Aerodynamic
    Sensitivity Analysis. Presented at the 14th Annual AIAA Technical Symposium,
    May 18, 1989, Houston, Texas.
        An analysis is performed to assess the sensitivity of Space Station Freedom

(SSF) propellant requirements to free molecule flow (FMF) aerodynamic forces and moments. FMF aerodynamic coefficients, generated by the LESC Huntsville Onorbit Aerodynamic Prediction Code, are perturbed by varying surface accommodation characteristics from specular to diffuse, and variations of surface temperature. Stationkeeping and orbital reboost propellant requirements are calculated using a dynamic simulation code coupled with a realistic space station control algorithm. Both nominal and dispersed Jacchia orbital atmospheres are employed in the simulation. Results of the sensitivity analysis portray the impact of molecule-surface interaction models on free molecule flow aerodynamic coefficients and projected propellant requirements for SSF. The resulting sensitivities indicate that additional work in identifying true surface accommodation characteristics for Space Station materials is required to decrease uncertainties in Station aerodynamics.

6. Ess, Robert; and Stephen Munday (JSC): Aerodynamic Requirements for a Mars Rover Sample Return Aerocapture Vehicle. Presented at the AIAA 27th Aerospace Sciences Meeting, January 9-12, 1989, Reno, Nevada.
     NASA is currently increasing its plans to intensely study other planets in our solar system. While many planetary missions involve a spacecraft flying past or orbiting a planet, NASA is currently considering a mission to land and return a surface sample from Mars. This ambitious mission is called the Mars Rover Sample Return (MRSR) and is a joint project of the JSC and the JPL. In the MRSR mission, a spacecraft will travel to Mars and land a vehicle on the surface to rove around the planet for a year collecting samples. These samples will then be launched to a Mars orbiting vehicle that will return them to Earth. Many technology issues need to be addressed in a project of this magnitude. This mission will not only return valuable scientific Martian data, but will act as a precursor for a manned Mars mission.

7. Ferguson, Sharon (LESC): Shuttle Evolution Database Application. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
     The Shuttle Evolution Database (SEDB) Application was developed to tabulate suggested near-term and far-term changes/improvements to the National Space Transportation System (NSTS). The SEDB was designed for support of the NASA/JSC Shuttle Evolution Assessment Team (SEAT). The application allows the user to compile enhancements in several different ways. This allows for evaluation of suggestions based on cost, order of importance, time of implementation, etc. The SEDB application was developed in R:Base System V, and is completely menu-driven.

8. Ferguson, Sharon (LESC); and J. Akkerman (JSC): System Accounting Model: A Tool for Engineering Design. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
     Until recently, systems engineering design was undertaken by engineers with the intent to build the most technologically advanced equipment which met specification requirements. The cost of the system was not seriously taken into account until after the design work was completed. The System Accounting Model (SAM) was initially developed for the Space Station Program Office as a means to integrate the system design and system costing stages of a new program or project. SAM was later modified for similar use on the recent Liquid Rocket Booster Phase A design study. SAM is a tool which aids in the integrated design of a new or modified system by tracking the programmatic costs of the

system, as well as accounting for interface requirements between groups of functional systems or subsystems. This tool will aid in the assessment and development of new systems that seek to best meet their functional requirements by monitoring a direct cost common denominator.

9. Friesen, Larry J.; and Bridget Mintz Register (LESC): Space Station Accommodations for Manned Lunar and Mars Missions. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Results are reported from a study of requirements that will be imposed on a space station if it is to support a manned lunar base or manned Mars missions. Three cases are considered: (1) a lunar base with no Mars missions, (2) Mars missions with no lunar base, and (3) a lunar base initiative which leads to and supports Mars missions. Space Station support for such initiatives will be required for life science research and technology development during precursor phases of the programs, and for transportation support during mission operations. Requirements for additional Space Station modules, truss, facilities, power, and crew support are estimated. Effects that the lunar and Mars programs will have on other Space Station activities are demonstrated. To avoid interference with microgravity research and Earth or space observations, it will be important to separate lunar or Mars transportation operations from them. It is strongly recommended that a separate Space Station optimized as a Transportation Node be built to support the lunar and Mars transportation systems. One option is to reconfigure the present Space Station design and make it the Transportation Node.

10. Garcia, D.; J. W. Galate; R. L. Field; W. C. Rochelle (LESC); C. D. Scott; and D. J. Tillian (JSC): AFE Base Flow and Heating Experiment (BFHE) Thermal Analysis and Test Program. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

This paper presents the thermal analysis and preliminary test results from the Aeroassist Flight Experiment (AFE) Base Flow Heat Experiment (BFHE). The objective of this study is to develop a set of data which will define and characterize the base flow field of the AFE during its aerobraking pass to allow for validation of computational fluid dynamics (CFD) methods. Four instrumented pads at specific locations in the AFE base region were investigated: (1) carrier base, (2) aerobrake base, (3) avionics side panel, and (4) leading edge panel shield. These pads will contain "islands" of instrumentation such as thermocouples, radiometers, and pressure sensors. The pads will be made of fibrous refractory composite insulation (FRCI-12) or Lockheed insulation (LI-900) tiles, surrounded by advanced flexible reusable surface insulation (AFRSI) blankets. Underneath this insulation will be aluminum sheets or aluminum honeycomb structures with a back face of multi-layer insulation (MLI). Aerothermodynamic environments were based on both solid rocket motor (SRM) plume heating and aerodynamic heating in the shear layer/wake region. The Systems Improved Numerical Differencing Analyzer (SINDA) thermal analyzer program was used to generate four thermal math models (TMM) to predict in-depth temperatures. Pressure distributions used for AFRSI thermal conductivity were obtained from a NASA/Langley CFD Program. Predicted surface temperatures ranged from around 1000°F on the side panels and base to about 2000°F on the panel leading edge. Peak structure temperatures were less than the design value of 350°F for all cases. A test program at the JSC Radiant Test Facility will be conducted to determine thermal response of the test articles and verify the TMM. Test plans will be initiated for additional tests at the JSC Arc-Jet Facility.

11.   Hartmann, L. N.; O. H. Rodriguez; W. C. Rochelle (LESC); and S. M. Derry (JSC):
      Shuttle External Tank Entry Heating, Surface Recession, and Structural Temp-
      erature Analysis.  Presented at the 14th Annual AIAA Technical Symposium, May
      18, 1989, Houston, Texas.
         This paper describes the results of a study to predict entry heating, surface
      recession, and structure temperatures on the Shuttle External Tank (ET).  The
      purpose of the investigation was to develop a simplified correlation to determine
      the approximate altitude of ET rupture during atmospheric entry.  Analyses were
      performed at two locations on the ET:  (1) $LH_2$ feedline on the aft dome, and (2)
      $LO_2$ feedline on the barrel section.  The Boundary Layer Integral Matrix Procedure
      (BLIMP88) program was used to predict convective heating rates for a hemi-
      sphere and a cylinder for the STS-26 NOM 1A ET entry trajectory.  Calculated
      heating rates were multiplied by heating factors to account for the characteristics
      of the critical location such as protrusions in the flow field and the distance from
      the stagnation point.  Surface recession of the foam insulation was predicted by a
      heating integral method for maximum and nominal recession rates.  The heating
      factors were then adjusted so that the predicted total recession matched that
      predicted by the more complex Martin/Marietta Reentry Heating (REHEAT) Pro-
      gram.  A simplified thermal math model (TMM) was used at the time from which
      all of the insulation receded to the time the rupture temperature (575°F for aft
      dome, 325°F for barrel section) was reached.  Results of the simplified TMM were
      in general agreement with those of the more complex Martin Marietta Thermal
      Analyzer System (MITAS) Program.  A generic analysis was then applied to arbi-
      trary trajectories (such as STS-30 NOM 2) to predict ET rupture altitudes for maxi-
      mum and nominal recession rates.

12.   Kennedy, Kriss. J. (JSC):  Space Transportation Node – Design of a Dual-Keel Han-
      gar Facility.  Presented at the National Technical Association Symposium, April 7-
      8, 1989, Houston, Texas, and the 14th Annual AIAA Technical Symposium, May
      18, 1989, Houston, Texas.
         This Space Transportation Node is a proposed concept for a Space Station
      which will support lunar base activities before, during, and after the base buildup
      phase.  The node will be a construction and assembly station for interplanetary
      spacecraft (manned and unmanned).  The Dual-Keel Hangar Facility is a compon-
      ent of the Transportation Node consisting of a series of support hangars that
      house individual translunar vehicle components.  The facility will have a total
      mass of approximately 610,000 kg.  This is the total gross mass, which includes
      the stored cryogenic propellant and the translunar vehicle.  The hangar skin has a
      mass of 63,500 kg. the largest single element; but the habitation and command
      facilities have a total mass of 101,000 kg.

13.   Kennedy, Kriss J. (JSC):  Lunar Crew Transfer Module Interior Design.  Presented at
      the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
         A lunar crew transfer module is a component of the space transportation infra-
      structure supporting lunar base development.  The module is used to transport six
      crewmembers to and from the Moon on an Orbital Transfer Vehicle.  It is a little
      larger than a Space Station Freedom resource node at 4.44 m dia. × 6.125 m
      and has a mass of approximately 6,000 kg.

14.   Letchworth, G. F. (LESC):  Abort Performance Enhancements for the STS Using
      Liquid Rocket Boosters.  Presented at the 14th Annual AIAA Technical Sym-
      posium, May 18, 1989, Houston, Texas.
         Increased safety is currently the primary reason for considering the use of liquid

rocket boosters (LRBs) to the current Space Transportation System (STS). Based on results of a recent Phase A study, an STS using LRBs can deliver up to 20 K lb. more payload to orbit than the current STS. Just as important, LRBs allow the STS to achieve increased intact abort coverage. Flight design results show that an overlap in return-to-launch-site (RTLS) and abort-to-orbit (ATO) is possible; transoceanic abort landing (TAL) may be eliminated from a performance standpoint. Two contingency aborts, Press-to-RTLS and bank return, may be added to the two current contingency aborts, downrange and split-S. Because LRB engines may be throttled or shutdown, the potential exists to upgrade some of these contingency aborts to intact aborts. Finally, LRB engine performance can be verified prior to liftoff, making on-the-pad aborts possible.

15. Lincecum, D. G. (LESC): Nominal Performance Enhancements for the Space Transportation System (STS) Using Liquid Rocket Boosters (LRBs). Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    During 1988 and 1989, a Phase A design study was conducted to ascertain the viability and desirability of utilizing liquid rocket boosters (LRBs) with today's STS. MSFC retained the services of two aerospace contractors, General Dynamics and MMSS, to provide Phase A conceptual designs for pump-fed and pressure-fed LRB configurations that would replace the existing redesigned solid rocket boosters. Analyses performed by LESC demonstrated that all of the contractors' finalized LRB configurations provided the performance margin required while staying within the ascent constraints for the STS integrated vehicle. The LRBs were assessed using the typical mission profile constraints projected for a 1994 timeframe. Two baseline reference missions were selected for performance evaluation, both using a 28.45 deg inclination due east launch from KSC to 160 n. mi. direct insertion orbits, with capabilities of 12,000 and 20,000 lbs above that of the current system. Due to the 58K lb downweight constraint, this additional performance can be traded for increased launch probability, intact abort coverage, orbital altitude/inclination, reduced STS main engine throttle, or maximum dynamic pressure reduction.

16. Mallini, Charles; and Charles Teixeira (JSC): Shuttle Evolution for the 1990s. Presented at the 26th Space Congress, April 25-28, 1989, Cocoa Beach, Florida.
    The Shuttle evolution strategies presented in this paper prove that reliable, low-cost transportation can be achieved through a process of continuous enhancement and evolution of existing systems. While this strategy incorporates new technology, it also takes into account experience with real, operational systems. Some Shuttle evolution options will be presented in this paper, and an assessment of impacts to fleet life (and the timing of formal development of an advanced manned launch system) as well as approaches to achieving projected requirements will be detailed. Development costs will be weighed against projected benefits including projected reduction in recurring costs.

17. Mallini, Charles J.; and Charles Teixeira (JSC): Shuttle Evolution Over-View. Presented at the 25th Joint Propulsion Conference and Exhibit, July 10-13, 1989, Monterey, California.
    A Shuttle Evolution Study was initiated in fiscal year 1988 in support of the Advanced Program Development Office, Office of Manned Spaceflight. The objectives of this study are to: (1) review past and ongoing studies, (2) implement a Shuttle Enhancement Data Base, (3) develop a methodology, and (4) develop a candidate evolution strategy. A study overview will be presented emphasizing enhanced reliability, crew safety, reduced operations cost, and enhanced capabilities required to meet projected long-range requirements. The strategy

includes definition of long-term goals and requirements, potential hardware and operations enhancements, and issues of fleet size and utilization. Propulsion hardware upgrades for near- and long-term evolution will also be highlighted.

18. Mallini, Charles J.; and Charles Teixeira (JSC): A Shuttle Evolution Strategy. Presented at the AIAA 27th Aerospace Sciences Meeting, January 9-12, 1989, Reno, Nevada.

The current Space Shuttle fleet will approach the end of its useful lifetime around the year 2010. Implementation of a new system will typically require a minimum of 12 years to go from Phase A studies to initial operational capability. Based on these two facts, the decision to develop a new manned launch system must occur within the next several years. Over the past 3 years, numerous studies have been performed addressing future space transportation systems for the United States. These studies have resulted in launch systems that project lower costs of operations by several orders of magnitude. Many of these cost reductions are based upon the development of new and unproven technologies; moreover, these future systems do not exhibit any real operational experience. An alternative to a new system is the evolution of the Space Shuttle system. This option has not been considered in any of the future launch system studies. This paper addresses the issue and presents several viable evolution strategies which will reduce the operational costs and increase the safety and reliability of the system.

19. McCurry, J. B. (LESC): Integration of Liquid Rocket Boosters with the STS: A Synopsis of Phase A Study Results. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

During 1988 and 1989, a Phase A design study was conducted to ascertain the viability and desirability of utilizing liquid rocket boosters (LRBs) with today's Space Transportation System (STS). The MSFC retained the services of two aerospace contractors, General Dynamics and Martin Marietta, to provide Phase A conceptual designs for a pump-fed and pressure-fed LRB configuration that would replace the existing redesigned solid rocket boosters. The KSC, as represented by the LSOC, assessed ground processing and launch operations impacts for the use of LRBs with the STS. The JSC, as represented by LESC, Advanced Programs Office and Mission Operations Directorate civil servants, and the Space Transportation System Operations Consolidation contractors, assessed STS Level II integration and JSC facility impacts for the use of LRBs. A synopsis of the STS/LRB integration issues and the associated Phase A design study results is presented. The results are indicative of the viability of using LRBs with the current STS stack.

20. McCurry, J. B. (LESC): The Effect of Protuberances on Booster Sizing for Application to the Space Transportation System. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

During 1988 and 1989, a Phase A design study was conducted to ascertain the viability and desirability of utilizing liquid rocket boosters (LRBs) with today's Space Transportation System (STS). As part of the design study, the MSFC conducted small-scale unpowered wind tunnel tests of STS/LRB mated vehicle configurations that varied in LRB length and diameter. The LRBs modeled had no external protuberances in the vicinity of the Orbiter wing, contrasting to the current redesigned solid rocket boosters that have a large aft attach ring and interface electronics assembly (IEA) hardware directly beneath the center of the Orbiter's wings. The results of the wind tunnel tests, and subsequent analysis by LESC personnel, preliminarily indicate that boosters of significantly greater length and

diameter can be designed for use with the STS without violating Orbiter wing root shear, bending, and torsion load constraints, if booster protuberances are judiciously located or avoided all together. The application of such booster size potential makes LRBs an attractive and viable concept for today's STS.

21. McCurry, J. B. (LESC): The Benefits of Liquid Rocket Boosters: An STS Application Who's Time is Now! Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    The original design studies for the Space Transportation System (STS) included the use of Liquid Rocket Boosters (LRBs) for two primary reasons: (1) reusability for cost effectiveness, and (2) inherent system safety via system redundancy and preflight verification testing. Budget constraints and political factors resulted, however, in an STS design that utilized Solid Rocket Boosters (SRBs). Recent Phase A LRB design studies have revisited the application of LRBs to the STS stack, and have produced booster configurations that offer substantial benefits in the areas of safety, reliability, maintainability, performance, and program cost savings potential. The immediate application of LRBs to today's Space Shuttle can be shown to be a viable means for safe, cost-effective, assured access to low Earth orbit.

22. Mueller, S. R.; W. C. Rochelle; L. N. Hartmann (LESC); C. D. Scott; and D. M. Curry (JSC): Aerothermodynamic Analyses for Advanced Reentry Vehicles. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    This paper presents the results of entry heating analyses for two general types of vehicles: (1) Crew Emergency Return Vehicles (CERV), and (2) Aeroassisted Space Transfer Vehicles (ASTV). The object of the study was to evaluate total heating rates and surface temperatures for three types of CERVs: (1) Discoverer, (2) Station Crew Return Alternative Module (SCRAM), and (3) Modified Apollo; and for three types of ASTV missions: (1) return from geosynchronous orbit, (2) return from the Moon, and (3) return from Mars. For the latter vehicle/mission, entry into the Martian atmosphere was also investigated. The majority of the cases used the Boundary Layer Integral Matrix Program (BLIMP) to evaluate the convective heating to the vehicles. Both equilibrium flow (approximating a fully catalytic wall) and nonequilibrium flow with a partially catalytic wall were evaluated. Gas cap radiative heating was predicted using the Jones/Park and the Ried/ Rochelle methods. Calculations were made as a function of time, distance from the stagnation point, and/or nose radius. A 5-species air model was used for all of the Earth entry cases; however, a 7- and 10-species $CO_2$ model was used for Martian entry with both boundary layer and shock layer options. The results showed that a modified Apollo was the most favorable of the CERVs from a thermal standpoint and could use Lockheed Insulation (LI-900) or Fibrous Refractory Composite Insulation (FRCI-12) tiles. The aerobraking ASTV returning from the Moon could possibly reenter using LI-2200 tiles. For the aerobraking ASTV returning from Mars, heating rates and surface temperatures would be so high that an ablative surface material would be required.

23. Ondler, R. Matthew (JSC): Aerocapture and Direct Entry for MRSR Earth Return Capsule. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    An analysis was conducted to investigate aerocapture and direct entry for the Earth return portion of the Mars Rover Sample Return mission. The study provided trajectory results which were used to design a vehicle to compare with a propulsive capture vehicle. The trajectory simulations were 3 DOF and assumed a spherical Earth with a 1962 standard atmosphere. The element that performs

the aerocapture is the Sample Return Capsule. Two different lifting vehicles were investigated for the aerocapture study: a biconic with an L/D of 1.0, and an Apollo-type configuration with an L/D of 0.3. The study objectives were to establish nominal trajectories, determine performance for various ballistic numbers, determine the effect of atmospheric and entry flight path angle variations on performance, and provide trajectories for heating analysis. Performance is measured by the delta velocity required for orbit trim after atmospheric exit. In addition, g-loads and heating are considered. For the direct entry, performance was measured by the errors in downrange and crossrange to the target.

24. Ondler, Matthew R. (JSC): A Three Body Dynamic Simulation of a Seated Tractor Rocket Escape System for the Space Shuttle. Presented at the AIAA Atmospheric Flight Mechanics Conference, August 14-16, 1989, Boston Massachusetts. Also published in a collection of technical papers from this conference.

In the wake of the Challenger accident, several studies were conducted to determine the feasibility of providing an escape system for the crew of the Space Shuttle. These studies generally fell into two categories: short-term implementation in which the escape system is relatively simple and provides escape only from a controlled gliding Orbiter, and long-term implementation in which the escape envelope is expanded to include ascent and loss of control. A potential candidate for long-term implementation is a tractor rocket seated extraction system. In this concept, the crewman is pulled from his seat and away from the Orbiter by a rocket to which he is attached by an elastic pendant. A system of rails would guide the crew and insure a clean exit from the Orbiter. The crewmen on the flight deck would be extracted out an opening cut around the overhead window frame. The crewmen on the mid-deck would be extracted out the side hatch. A 3-body simulation has been developed to model the flight mechanics aspects of this concept. The three bodies whose dynamics have been modeled are the crewman, the tractor rocket, and the Space Shuttle vehicle. The man and rocket dynamics are full six degree of freedom while the Space Shuttle vehicle is three degree of freedom. The intent of the simulation was to determine the crewmen's clearances of the Orbiter structure and engine plumes. Math models were developed for crewmen aerodynamics, crewmen mass properties, rocket aerodynamics, rocket thrust, rocket mass properties, pendant spring and damping characteristics, rail constraints, and plume boundaries. The simulation shows that the concept is viable and deserves further study. The method provides excellent escape for all entry conditions studied. The method also provides escape opportunities during parts of ascent.

25. Ondler, Matthew R. (JSC): Aerocapture and Direct Entry for MRSR Earth Return Capsule. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Analysis was conducted to investigate aerocapture and direct entry for the Earth return portion of the Mars Rover Sample Return mission. The study provided trajectory results which were used to design a vehicle in order to compare with a propulsive capture vehicle. The trajectory simulations were three degree of freedom and assumed a spherical Earth with a 1962 standard atmosphere. The element that performs the aerocapture is the Sample Return Capsule (SRC). Two different lifting vehicles were investigated for the aerocapture study. A biconic with L/D of 1.0 and an Apollo type configuration with an L/D of 0.3 were studied. The study objectives were to establish nominal trajectories, determine performance for various ballistic numbers, determine effect of atmospheric and entry flight path angle variations on performance, and provide trajectories for heating analysis. Performance is measured by the delta velocity required for orbit trim

after atmospheric exit. In addition, g-loads and heating are considered. For the direct entry, performance was measured by the errors in downrange and cross-range to the target.

26. Petro, Andrew J. (JSC): A Space Transportation System for a Lunar Base. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    Providing transportation will be a major challenge in the development and operation of a permanent human outpost on the surface of the Moon. Vehicles will be needed to deliver cargo to the lunar surface and to carry people who will prepare the base site and construct facilities. Once the base is established, there will be a requirement for periodic crew rotation and delivery of supplies. An assured transportation link will be vital.

    This presentation will describe a specific transportation system and an operational scenario which was designed to support a lunar base concept developed at the JSC. The base consists of an inflatable habitat housing up to 12 people along with support systems and facilities for physical science research and equipment to demonstrate the collection, processing, and use of lunar resources.

27. Petro, Andrew J. (JSC): A Transportation System for a Lunar Base. Presented at the 26th Space Congress, April 25-28, 1989, Cocoa Beach, Florida.

    This paper will discuss the conceptual design of a transportation system for supporting a permanent base on the surface of the Moon, early in the 21st Century. There is a brief description of a particular lunar base development scenario from which the requirements for the transportation system were derived. The system consists of a node in low Earth orbit, an orbital transfer vehicle (OTV), and a landing craft. Each of the vehicles can be operated in an expendable mode or a reusable mode. If the OTV is to be re-used, its return to Earth orbit is accomplished with an aerobraking maneuver. If the landing craft is to be re-used, it is stored on the lunar surface between missions and refueled in lunar orbit by an OTV. Both vehicles use liquid oxygen and liquid hydrogen as propellants.

    Trade studies that were performed in the process of selecting the proposed transportation system are summarized. The trade studies included investigations of staging options, propellant options, and aerobraking as an alternative to propulsive Earth-orbit insertion. Although this study concentrated on conventional propulsion methods, there are many alternative transportation concepts which require further study.

28. Plowman, Catherine M. (LESC): Phase 2 Transportation Node Study. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    With the advent of proposed advanced missions such as lunar base and Mars missions, a facility to provide onorbit support in assembly, servicing, and fueling of required vehicles will be necessary. This unique and complex spacecraft may be the proposed Space Station Freedom (SSF), an SSF derivative, or a dedicated transportation support facility. For this reason the study attempts to locate potential problems and define preliminary guidelines for designing a Transportation Node facility.

29. Roberts, Michael L. (JSC): Inflatable Habitation in Space. Presented at the National Technical Association Symposium, April 7-8, 1989, Houston, Texas.

    Inflatable structures have a number of advantages over rigid modules in providing habitable volume in space. Inflatables offer greater packaging efficiency, convenience of expansion, flexibility, and psychological benefit, to the inhabitants.

    The relatively small rigid cylinders capable of fitting in the payload compartment

of a launch vehicle are not as efficient volumetrically as a collapsible structure which, when packaged, fits into the same space but when deployed, is much larger. Pressurized volume is a valuable resource. By providing that resource efficiently, in large units, labor-intensive external expansion (such as adding additional modules to the existing complex) can be minimized. The expansive interior in an inflatable would facilitate rearrangement of the interior to suit the evolving needs of the inhabitants. This large, continuous volume also relieves claustrophobia, enhancing habitability and improving morale.

This presentation will review the history of inflatable structures and explain some of the fundamentals of inflatable habitat design, including structural and architectural considerations. As a specific case, the conceptual design of an inflatable lunar habitat will be described.

30. Rochelle, W. C.; P. C. Ting; S. R. Mueller; S. A. Bouslog (LESC); C. D. Scott; and D. M. Curry (JSC): Aerobrake Heating Rate Sensitivity Study for the Aeroassist Flight Experiment (AFE). Presented at the 24th AIAA Thermophysics Conference, June 12-15, 1989, Buffalo, New York.

This paper presents a description of the sensitivities associated with predicting the aerothermodynamic environment on the Aeroassist Flight Experiment (AFE) vehicle. The purpose of the study was to assess the heating rate uncertainties for the aerobrake portion of the AFE as a function of time in various trajectories and as a function of distance around the aerobrake. Principal areas of uncertainty include trajectory parameters, catalycity of the Thermal Protection System (TPS) tiles, nose radius variation/surface pressure distribution, and viscous interaction (shock layer vs boundary layer) effects. Other areas of concern include gas cap radiation prediction methods, wall temperature variation, and thermodynamic/transport properties. This paper assesses the relative importance of each of the above effects on heating rates predicted using the BLIMP Program, and presents sample results for each of the sensitivity parameters.

31. Scott, Carl D. (JSC): Wall Catalytic Recombination and Boundary Conditions in Non-equilibrium Hypersonic Flows - With Applications. Presented at the Second Joint Europe/US Short Course on Hypersonics, January 15-21, 1989, Colorado Springs, Colorado.

The lecture discusses the meaning of catalysis and its relation to aerodynamic heating in nonequilibrium hypersonic flows. The species equations are described and boundary conditions for them are derived for a multicomponent gas and for a binary gas. Slip effects are included for application of continuum methods to low density flows. Measurement techniques for determining catalytic wall recombination rates are discussed. Among them are experiments carried out in arc jets as well as flow reactors. Diagnostic methods for determining the atom or molecule concentrations in the flow are included. 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 Columbium (Nb).

32. Simpson, D. B. (LESC); and C. J. Cerimele (JSC): Aerodynamic Data Extraction with Applications to Space Shuttle and the Aeroassist Flight Experiment (AFE). Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

This presentation will discuss Aerodynamic Data Extraction as applied to the Space Shuttle and the aeroassist flight experiment (AFE) vehicles. In particular, it will define aerodynamic data extraction in general, what data is extracted, and its uses. A review of the problems associated with the aerodynamic extraction pro-

cess and a brief outline of the different methods used will also be discussed. Finally, the application and benefits of aerodynamic data extraction to the Space Shuttle and the AFE programs will be reviewed.

33. Su, T.; and Roy R. Craig (UTCAR): Controller Reduction by Preserving Impulse Response Energy. Presented at the AIAA Guidance, Navigation, and Control Conference, August 14-16, 1989, Boston, Massachusetts.

A model order reduction algorithm based on a Krylov recurrence formulation is developed to reduce order of controllers. The reduced-order controller is obtained by projecting the full-order LQG controller onto a Krylov subspace in which either the controllability or the observability grammian equal to the identity matrix. The reduced-order controller preserves the impulse response energy of the full-order controller and has a parameter-matching property. Two numerical examples drawn from other controller reduction literature are used to illustrate the efficacy of the proposed reduction algorithm.

34. Su, T.; and Roy R. Craig (UTCAR): Model Reduction and Control Flexible Structures Using Krylov Subspaces. Presented at the 30th AIAA/ASME/ASME/ASCE/ AHS/ ASC Structures, Structural Dynamics, and Materials Conference, April 3-5, 1989, Mobile, Alabama.

Krylov vectors and the concept of parameter matching are combined together to develop a model reduction algorithm for a damped structural dynamics system. The reduced-order model obtained matches a certain number of low-frequency moments of the full-order system. The major application of the present method is to the control of flexible structures. It is shown that, in the control of flexible structures, there generally exist three types of control energy spillover. The formulation based on Krylov subspaces can eliminate the control and observation spillover while leaving only the dynamic spillover to be considered. Two examples are used to illustrate the efficacy of the Krylov method.

35. Tam, Luen; and Chien Li (LESC): Three-Dimensional Thermochemical Nonequilibrium Flow Modeling for Hypersonic Flow. Presented at the 20th AIAA Fluid Dynamics, Plasma Dynamics and Lasers Conference, June 1989, Buffalo, New York.

A three-dimensional thermochemical nonequilibrium model has been developed and applied to the study of entry flows surrounding space vehicles. The model accounts for both chemical and vibrational nonequilibrium phenomena behind the bow shock. The thermodynamic state of a real gas is modeled with a translational-rotational temperature and an electron-vibrational temperature. Their internal energies are averaged to determine the temperature used in the reaction rates calculation. In order to establish the validity of the selected models, both one- and two-temperature models with 7 and/or 11 species were investigated. Several numerical experiments that include a sphere, the RAMC vehicle and 3D AFE forebody flows were performed. Preliminary results were compared with RAMC-II experimental data. Good agreement was obtained after a two-temperature model with 11 species and 30 reactions was incorporated into the study.

36. Teixeira, Charles (JSC); and Hubert P. Davis (DAC): A Next Generation Space Shuttle Concept. Presented at the AIAA 27th Aerospace Sciences Meeting, January 9-12, 1989, Reno, Nevada.

Future activities in and capabilities for manned space flight have necessarily been given little attention in the United States during the interval of recovery of the NASA Shuttle and initiation of the Space Station Freedom Program. Assembly

and test of the replacement orbiter, OV-105, is now underway to restore the Shuttle fleet to four orbiter vehicles. The Atlas, Delta, and Titan expendable launch vehicle programs have all been returned to active status, with launches expected to resume in the near future. The Advanced Launch System (ALS) and Shuttle C Programs are examining the needs for and means to produce additional lift capacity. The Defense Advanced Research Projects Agency (DARPA) and the private sector are both examining the miniaturization of sensors, satellites, and their launch systems to produce more cost effective space mission products. The joint USAF/NASA National Aeorspace Plane (NASP) Program is exploring the benefits of air-breathing propulsion to acquire orbital energy.

37. Ting, P. C.; W. C. Rochelle; S. R. Mueller; J. E. Colovin (LESC); C. D. Scott; and D. M. Curry (JSC): Prediction of Aeroassist Flight Experiment (AFE) Aerobrake Aerothermodynamic Environment. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

This paper presents the aerodynamic heating distribution over the Aeroassist Flight Experiment (AFE) aerobrake during its atmospheric entry. The major purpose of this task is to develop the AFE Aerothermodynamic Databook which is being used by the thermal analysis engineers and principal investigators for the AFE flight experiments at various NASA centers. The optimized 4100-lb AFE Baseline V trajectory was defined as the trajectory for the AFE aerobrake aerothermodynamic environment. The environment described herein is presented as total, convective and radiation heating rates, radiation equilibrium surface temperatures, and local surface pressures along the pitch plane and the nine off-pitch planes.

38. Ting, P. C.; W. C. Rochelle; S. R. Mueller; J. E. Colovin; (LESC); C. D. Scott; and D. M. Curry (JSC): Development of AFE Aerobrake Aerothermodynamic Data Book. Presented at the 24th AIAA Thermophysics Conference, June 12-15, 1989, Buffalo, New York.

This paper presents a description of the methodology and sample results for the NASA Aeroassist Flight Experiment (AFE) Aerobrake Aerothermodynamic Data Book. The purpose of developing this data book and its corresponding data base was to generate a design reference for the AFE aerobrake aerothermodynamic environment. This environment will be used by thermal analysis groups and Principal Investigators for AFE flight experiments at the various NASA centers. The environment will be generated for more than 50 AFE body points over a 180-degree section of the vehicle along 11 angular surface planes for the 4100-lb AFE optimized trajectory Baseline V. The heating rates were predicted for a partially catalytic wall using the BLIMP88 Program with input CFD pressure distributions supplied by NASA/Langley.

39. Toups, Larry (LESC): A Comparative Catalogue of Lunar Construction Techniques. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The speculation on a lunar base and its design has been the subject of much technical work over the past 30 years, particularly during the excitement and success of Apollo. Ambitious schemes have proposed housing initial crews, possibly 4-8 people, to creating whole lunar cities of thousands. The techniques utilized for creating the shelter needed for working and living on the lunar surface cover a broad range. They include the use of materials delivered from Earth, the use of natural surface features, using lunar resources for fabricating building materials, and hybrid structures incorporating a number of techniques. This paper presents and defines 13 techniques that could be utilized for providing

habitable as well as unpressurized volumes on the Moon. The techniques identified are prefabricated modules, pneumatic structures, prefabricated frame structures, tent structures, crater applications, lava tube applications, tunneling techniques, concrete (cement-based material) structures, basalt structures, glass structures, metal structures, lunar assembled canopies, and hybrid structures. An assessment of these techniques is made using a fixed set of 14 criteria with considerations of safety, physical exertion on crewmembers, structural integrity, special tooling requirements, ease of construction, flexibility of the structure, and efficient use of *in-situ* resources. Potential applications of these techniques are also discussed based on quantitative and qualitative evaluations.

40.  Wiederhoeft, C. J. (LESC); and D. S. Whitehead (JSC): A Rocket Plume Photographic Simulator for Confirmation of Measured Winds. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Confidence in measured wind conditions is of great importance to the Space Shuttle Launch Systems Evaluation Advisory Team. Winds measured by balloon several times prior to launch are the primary means of determining the anticipated ascent environment. These winds can cause a launch scrub if they are strong enough to predict a structural load that will be exceeded during ascent. The last measured wind data prior to launch is approximately 1.5 hours old by launch time. Unanticipated wind features, primarily shears and gusts, might move into the vehicle's path during this time.

A system has been devised to detect unmeasured features in the wind experienced by the launch vehicle. A camera simulator was created to generate "pictures" of the first-stage Shuttle SRB exhaust plume. The simulated photos show how the plume trail would appear as influenced by the winds measured near the launch time. After the mission, these are compared with photographs taken several times during the flight. Wind shears or gusts not accounted for by the measured wind data would then be visible as deviations in the plume's horizontal movement in the photo.

41.  Willcockson, Bill (MMSS): Application of Aeroassist to the Mars Rover Sample Return. Presented at the AAS/GSFC International Symposium on Orbital Mechanics and Mission Design, April 24, 1989, Greenbelt, Maryland.

Mars Rover Sample Return is being studied by NASA and industry as a major new unmanned planetary mission for the late 1990s to place a rover on the surface of Mars, acquire a surface sample, and return the sample to Earth. By using aerocapture for Mars planetary injection, a savings of 20 to 30 percent of effective vehicle mass is possible over an all-propulsive capture approach. The desire to visit a more scientifically varied (thus hazardous) landing site (like that accomplished by Viking) has resulted in stringent accuracy requirements for the entry to landing process which demand loop trajectory control of the entry process. This paper summarizes some of the issues and results associated with the use of aeroassist technology for Mars aerocapture and precision entry to landing.

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1.  Aucoin, P.J. Jr. (JSC): An AI-Based Approach to Initial Requirements Specification. Presented at the JAIPCC Technical Symposium, March 23, 1989, Houston, Texas.

    A novel new approach is being considered for the handling of requirements in the beginning and early stages of system development. In these initial stages, requirements are specified in terms of functionality, performance, operational characteristics, and overall architecture. Typically, the process involves episodes of intense verbal exchange of information and opinion on the part of several persons involved. Hence, a paradigm based upon human behavioral principles is appropriate. The use of CASE tools or detailed implementation considerations may not be useful or even advisable in these early stages--that comes later.

    The approach being considered furnished an abstract representation of the proposed system at the logical level at each episode of information and opinion exchange. This representation can be reviewed by each person involved to facilitate his or her understanding of the issues brought to bear so far and thereby to respond more effectively and responsibility in the next round of negotiations.

    The end product of this approach will provide a system representation in terms of categories of object, processes, events, and states-of-affairs. This provides the basis of a mapping to design and implementation constructs such as Ada, object/ message, and so on. By virtue of the process by which it evolved, feasibility issues will have been taken into account.

2.  Bates, Paul C.; and Martha F. Evert (LESC): Real-time Serialization of Data Using a VAX-11/785 and an Aptec IOC-2400 Front End Processor. Presented at the JAIPCC Symposium, March 23, 1989, Houston, Texas .

    The Aptec/Serializer software program was developed to support the Space Telescope and Space Radar Laboratory tests for the Electronic System Test Laboratory at JSC. The VAX/Aptec system accepts data frames from a Manned Spaceflight Telemetry Processor (MSFTP). The data consist of payload data frames with an attached time tag and fill words. The Aptec IOC-2400 validates the payload data frame and outputs valid frames to the CAMAC Serializer board. Invalid and missing payload data frames are replaced with frames of fill data to maintain a constant output data rate. The program allows the operator to input the payload frame sync pattern, payload data frame size, MSFTP frame size, output fill pattern, and time tag length. Analysis of the payload data includes: (1) bit error rate on a selectable portion of the payload data frame, and (2) frame rejection rate on a given number of frames.

3.  Davidson, Shayla E. (JSC): A Locator System for Wandering Individuals. Presented at the Conference on Exploration: Technological Innovations for an Aging Population, January 30 - February 1, 1989, Orlando, Florida.

    This project is being sponsored by the National Aeronautics and Space Administration, the Administration on Aging, National Institute on Aging, Veterans' Administration, and National Institute on Disability and Rehabilitation Research. The mission of these federal agencies is to combine their expertise and resources to identify and support technology-based solutions to problems faced by the aging population. By working with Cortrex Electronics, Inc., the agencies are sponsoring the development of a notification and locator system to aid in the moderately cognitively impaired elderly. The federal agencies' goals for applications of technology to health-related problems are discussed. A definition of wandering behavior and an assessment of the need for a system to manage wandering individuals is presented. The plan for the project and the development of the system which will solve the problem of wandering behavior are functionally described.

4.  Davidson, S.E.; and R. Taylor (JSC):  United States Manned Space Flight Spectrum Support.  Presented at the 9th Space Frequency Coordination Group Meeting, August 28 - September 1, 1989, Kiruna, Sweden.

As man begins to leave the surface of the Earth and visit space for longer periods of time, he must have adequate spectrum support to provide the necessary communications and tracking functions that living and working in space requires.  Adequate spectrum support becomes even more critical as man establishes a permanent presence in space.  Allocations for use on a temporarily protected basis will no longer be adequate.  This paper is an initial attempt at defining those spectrum requirements based on United States manned space flight history and current United States manned space flight activities.

It is essential that the frequencies assigned to current and future manned space flight activities be allocated on a PRIMARY basis and be accorded international recognition so that the interference risk to such vital communications links can be minimized.

It must be recognized that the Space Research and Space Operations service users cannot continue to carry the exorbitant burden of developing the new technology needed to establish communication links in the higher frequency bands.  In the real world, even with the advent of international cooperation, resources are limited.  In addition, newer technology usually brings higher risks.  Astronaut safety cannot be traded for newer technology.  Frequency bands must be found which will permit safety service operations using proven techniques.

5.  Early, Timothy W.; Phong Ngo; and Nanci Olson (JSC):  Space Station Space-to-Space Subsystem Single Conversion User Breadboard.  Presented at the 14th Annual AIAA Technical Symposium,  May 18, 1989, Houston, Texas.

The Single Conversion User Breadboard evaluates a candidate architecture for users of the Space Station Space-to-Space Communications Subsystem.  The breadboard is part of a test bed of the Space-to-Space Communications Subsystem which will provide communications between the Space Station and various users such as the extravehicular mobility unit, the Space Shuttle Orbiter, free flyers, and the orbital maneuvering vehicle.  Data, voice, and video are transmitted over the system using frequency division multiple access techniques.

6.  Fisher, Timothy E.; and Richard D. Juday (JSC):  An Improved Architecture for Video Rate Image Transformations.  *SPIE Technical Symposium on Aerospace Pattern Recognition Proceedings*, Vol. 1098.  Presented at the SPIE Technical Symposium on Aerospace Pattern Recognition, March 27-31, 1989, Orlando, Florida.

Geometric image transformations can simplify some aspects of pattern recognition.  (For example, the log-polar transformation evokes shift invariance as an imaging sensor makes a perpendicular approach to a plane or rotates about the line of sight.)  Pattern recognition at video frame rate is necessary for many aerospace applications.  The existing NASA/Texas Instruments Programmable Remapper has been unique in the image processing community in its ability to do completely arbitrary image warpings at video rate with very little latency.  We present an architecture that extends the Remapper's abilities and ameliorates the shortcomings we have experienced.  New abilities achievable with the new architecture world include overlapping pre-images of output pixels, a single image flow through the machine, and larger output displays.  We discuss the need for the improvements in the context of the initial Programmable Remapper and its benefits and limitations.

7. Fotedar, Sunil (LESC); Rui J.P. deFigueiredo (Rice); and Kumar Krishen (JSC): Determination of Motion Parameters of a Moving Object from Moving Camera Data. *ROBEXS Proceedings*, Vol. 4, pp. 143-154, August 2-4, 1989. Presented at the JAIPCC Technical Symposium, March 23, 1989, Houston, Texas.

The determination of 3-D motion parameters of an object from its image-sequences is discussed for three types of motion analysis: (1) monocular vision, (2) stereo vision, and (3) stereo motion. These parameters enable one to obtain attitude, attitude rate, surface shape, identification/recognition, and track of the object. Under suitable conditions, these parameters can be estimated from 2-D image coordinates of a set of points on the object's surface in consecutive images, using the Image Point Correspondence (IPC) algorithm. In this paper, a computation of motion parameters for a general configuration where both the object and the camera are moving. Furthermore, this algorithm was successfully tested on both simulated and video-acquired data.

8. Fotedar, Sunil (LESC); Rui J.P. deFigueiredo (Rice); and Kumar Krishen (JSC): Error Analysis for an Image Point Correspondence Algorithm. *ROBEX Proceedings*, Vol. 4, pp. 131-141, August 2-4, 1989. Presented at the Workshop on Robex 1989, August 2-4, 1989, Palo Alto, California.

An Image Point Correspondence (IPC) algorithm enables the determination of 3-D motion parameters of an object from its image sequences. This method is currently being explored for various robotic vision applications, especially those involving motion of video as well as the object under observation. In this paper the sources of error in the motion estimation of objects/scenes are reviewed. The estimate of the error in the determined parameters is developed using a mathematical formulation. Errors in the output are plotted experimentally as a function of the errors in the input.

9. Grimes, J. Speight (LESC): Radio Frequency Interference Test for the Infrared Background Signature Survey Television Link. Presented at the JAIPCC Symposium, March 23, 1989, Houston, Texas.

This paper presents the results of tests performed in the Electronic Systems Test Laboratory (ESTL) on the Infrared Background Signature Survey (IBSS) Television (TV) Radio Frequency (RF) link. The compatibility of the RF link with the Space Shuttle Orbiter (SSO) and its susceptibility to inference were tested. Problems with the system were discovered that would have impacted its ability to meet mission requirements. These problems included both incompatibility with SSO systems and RF interference. From engineering data gathered during the first ESTL test, design changes were proposed for both IBSS and SSO hardware. These changes and their impact on the system performance will be discussed.

The importance of compatibility testing is well illustrated by the failure of the initial design of the IBSS TB link. Many system engineering concerns go unnoticed until the integrated system is tested.

10. Haddick, Clyde M.; Nancy S. Marshall; and C.J. Spain; (LESC): A Proposed Space Station Internal Audio System-to-Communication and Tracking System Interface. Presented at the JAIPCC Symposium, March 23, 1989, Houston, Texas.

A proposed method for interfacing a Space Station internal audio distribution system to communication and tracking signal processors is described. The proposed interface uses physical, network and link layer protocols which are in accordance with recently adopted International Telegraph and Telephone Consultative Committee (CCITT) recommendations for the Integrated Services Digital Network (ISDN).

The implementation of these CCITT ISDN recommendations would allow the

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use of existing circuit devices and software, facilitate equipment compatibility, and provide compatibility for ground distribution of voice and data via the public telephone network.

11. Juday, Richard D. (JSC); and Stanley E. Monroe (LESC): Extension of the Synthetic Estimation Filter to Joint Transform Correlation. Presented at the SPIE Spatial Light Modulation and Application III Conference, August 6-11, 1989, San Diego, California .

The synthetic estimation filter (SEF) combines a set of input images into a much smaller set of filters. Those input images correspond to views of a known object taken with a variety of values of the pose parameters to be estimated. The response of the filter to variations in the pose parameter is tailored so that estimation can be done to a precision considerably finer than the intervals between filters in the pose space. Here the technique to the joint transform correlator is extended; the composite image is used as a reference from which the SEF is conventionally calculated. Precautions are necessary for practical reasons (e.g., the SEF algorithm may call for negative values in the image, an unrealizable condition with amplitude encoding, whereas with phase-mostly filtering in the SEF, negative image values are easily accommodated).

12. Juday, Richard D.; and Timothy E. Fisher (JSC): Geometric Transformations for Video Compression and Human Teleoperator Display. *OE/LASE 1989*, Vol. 1053, Los Angeles, California.

In order to compress video signals for transmission, it is often necessary to compromise some quality of the data. Presented here is a technique utilizing geometric coordinate transforms to reduce the amount of data in a video signal that is intended for presentation to a human teleoperator. In this technique, high visual acuity is maintained at the focus of attention of the teleoperator while the acuity decreases radially in accordance with human visual system's characteristics. A hardware implementation of this technique using the NASA/TI Programmable Remapper is demonstrated.

13. Juday, Richard D. (JSC); Stanley E. Monroe (LESC); and Jerome Knopff (UM): Laboratory Comparison of Continuous vs Binary Phase-only Filters. Presented at the SPIE Optical Pattern Recognition Conference Symposium on Lasers and Optics, January 15-20, 1989, Los Angeles, California.

Various techniques have been reported in the literature for the binary phase modulation of optical signals. Several researchers have stated that the binary phase-only filters are often as good as, if not better than, continuous phase-only filters for some applications. Recent developments in Spatial Light Modulators have led to devices which are capable of continuously modulating phase, if only over a limited range. One of these devices, the Deformable Mirror Device, has been used to compare the relative merits of binary and partially-continuous phase filters with respect to the specific problem of position estimation. The parameters measured include response to rotations as well as the effects of noise.

14. Kwon, Hyuck M. (LESC): Imperfect Jamming State Information Generators for Coded FH/MFSK Under Partial-Band Noise Jamming. Presented at the IEEE Military Communications Conference, October 15-18, 1989, Boston, Massachusetts.

Three imperfect jamming state information (JSC) generators for coded, memoryless, noncoherent, frequency-hopped MFSK (FH/MFSK) systems under partial-band noise jamming (PBNJ) are introduced. These are then compared in

the bit-energy-to-jamming-noise power spectral density ratio (Eb/NJ) required to achieve cutoff rates.

15. Kwon, Hyuck M.; and P. Joong Lee (LESC);   Performance of Viterbi's Ratio Threshold Receiver Against Mixed Jamming. Presented at the IEEE Military Communication Conference, October 15-18, 1989, Boston, Massachusetts.

 A performance analysis is presented for a coded FH/MFSK system under a combination of tone jamming and full-band noise-jamming (FBNJ) †. A maximum likelihood metric former with Viterbi's ratio threshold techniques is assumed to support the decoder in the system. It is shown that the most efficient FBNJ portion of the total jamming power depends on M and the symbol energy-to-jamming power density ratio.

16. Lichtenberg, Christopher L. (JSC); Jaroslaw Wosik; Matthew Davis; and J.C. Wolfe (UH): Microwave Measurements of $Y_1 Ba_2 Cu_3 O_{7-x}$ and $Bi_2 Sr_2 Ca_1 Cu_2 O_{8-y}$ Thin Films. NASA TM-102159, November 1989.

 Radio frequency (RF) surface resistance measurement experiments on high-$T_c$ thin films were performed between July and November 1988. The method uses a microstrip resonator comprising a top gold conductor strip, an alumina dielectric layer, and a separate superconductivity ground plane. The surface resistance of the superconducting ground plane can be determined, with reference to a gold calibration standard, from the measured quality factor of the half-wave resonator. Initial results near 7 $GH_2$ over the temperature range from 25 to 300 K are presented for $Y_1 Ba_2 Cu_3 O_{7-x}$ and $Bi_2 Sr_2 Ca_1 Cu_2 O_{8-y}$ thin film samples deposited by an electron beam flash evaporation process. The RF surface resistance at 25 K for both materials in these samples was found to be near 25 milliohms.

17. Loh, Y.C.; P. Land (LESC); D. Arndt; and S.W. Novosad (JSC): Ku-Band Interferences for the Space Station Multiple Access Link. Presented at the IEEE Globecom Conference, November 28, 1989, Dallas, Texas.

 The Multiple Access (MA) system, an essential part of the United States Space Station (SS) for the 1990's, will be used to provide simultaneous communication services, voice and command, telemetry and video, between the Space Station and all the different co-orbiting user vehicles. Presently, the system is designed to operate in the Ku-band frequencies between 14 Gz and 14.89 Ghz. Within this band, there are other users that could pose serious interference potential. This paper intends to explore the issues in detail. The problem with the present Space Station hardware design will be examined. The extent of the interference and its impact to the system operations will be analyzed using a monte-carlo simulation. Mitigation techniques involving both hardware changes and operation constraints will be presented.

18. Mathur, Serweshwer N. (RSOC): Quaternionic Fields and Hilbert Space. Presented at the 14th AIAA Annual Technical Symposium, May 18, 1989, Houston, Texas.

 Quaternions were introduced to solve the problem of transformation of the coordinate systems. In SAIL they are used in determining the orbiter attitude and the orientation of the Inertial Measurement Unit (IMU) platforms. By the turn of the 20th century, the classical rotation problem was solved completely, and scientists thought that no further use of the quaternions could be made.

 Interest in quarternions was revived in the 1980's when some physicists thought that quantum chromodynamics may not provide an answer to the confinement of the colored states of quarks in particle physics. They started to think of changing the mathematical approach to the problem.

 Until now, the Hilbert space of functions defined on complex fields were used to

solve the different problems of quantum mechanics and field theory. The only other algebra available, other than that of real and complex numbers, was that of quaternions. Researchers started developing a completely new mathematical approach by defining quaternionic Hilbert space and functions defined on quaternionic fields. Quaternionic field theory is being developed to solve the confinement problem of the quarks which will ultimately help solve the unified field theory of the four known forces of nature.

The quaternionic field theory is still in the developing stage, but by using this entirely different mathematical approach, some progress has been made in solving the quark problem. Only time will tell how far the theory will hold. In this paper we shall introduce and discuss the quaternionic Hilbert space, functions defined on the quaternion fields, and the quaternionic group. The Phase change of the quaternion basis (or units) will also be discussed.

19. Monroe, Stanley E. (LESC); and Richard D. Juday (JSC): Laboratory Results Using the Synthetic Estimation Filter. Presented at the Technical Symposia on Aerospace Sensing, May 27-31, 1989, Orlando, FLorida.

The synthetic estimation filter (SEF) is a method of reducing the number of "matched" filters necessary to span a region of poor space. That is, fewer filters need to be stored to use optical correlation as a method of estimating the yaw, pitch, and roll of an object. Like the synthetic discriminant filter, the SEF is also created from a composite image of the object. Computer simulations of the expected effectiveness of the SEF method have previously been presented. Now the results from laboratory implementation of the technique are shown. Several practical aspects of working with the SEF are presented. The observed robustness against detector noise and partial obscuration of the object are demonstrated, as is an observed optimum pose-space interval between the finely-spaced views composited into an SEF. Also discussed are improved methods of converting the ratio of correlation peak values to their interpolated pose parameter.

20. Paz, I.; J. R. Carl; R. V. Shaw; J. K. Kovitz (LESC); and G. D. Arndt (JSC): Design of an Orbital Debris Radar Ground Demonstration. Conference Proceedings & Symposium Digest, February 12, 1989, Breckenridge, California.

This paper describes a breadboard radar system that is being designed and tested at JSC for dealing with the space debris problem which could present a growing threat to the planned Space Station Freedom (SSF). Major problems that a system design faces are due to the small radar cross section of such debris (below -30 dBm2), the high closing velocities of particles with respect to the SSF (10 km/sec and higher), and the stringent constraints involved with its implementation as a spaceborne system. Constraints include weight, prime power consumption, maintenance, and reliability. This paper deals with the preliminary implementation of a ground demonstration radar for testing concepts, technologies, and performance envelopes that will eventually carry over to the spaceborne Debris Detection and Tracking Radar. Simulation results and techniques developed for predicting system performance and evaluating antenna parameters are also given. The design process of the electronically steered Phased-Array antenna is briefly described, and block diagrams for the implementation of the radar system are given.

21. Raffoul, George W. (LESC): An S-Band Distributed Array Antenna for Space to Space Communication. Presented at the IEEE Antenna & Propagation Society International Symposium, June 26 - 30, 1989, San Jose, California.

This paper describes the development of a planar medium gain distributed

array antenna to be flush mounted on the surface of a spacecraft in low earth orbit. The antenna will support low data rate communication with the Tracking and Data Relay Satellite (TDRS), that is located in geosynchronous orbit, from a low earth orbiting spacecraft like the Space Shuttle or the Space Station. The array is actually composed of two side-by-side arrays with eight active elements in each. One array is designated for transmittal and the other for receiving. The transmit array consists of 4 x 2 circularly polarized patch elements, eight 7-watt high power amplifiers, eight 3-bit phase shifters, and one 8-way power divider. The receive array is similarly equipped with eight circularly polarized patch elements, eight low noise amplifiers, eight 3-bit phase shifters, and one 8-way power combiner. An additional solitary L-band element supports low gain receive-only communication from a host of ground stations. The three signals (S-band transmit, S-band receive, and L-band receive) are multiplexed into a single input/output port with a triplexer.

The array is designed to point its beam toward the TDRS anywhere within one quadrant of space extending 90° in roll and 180° in pitch. Pointing within this coverage zone is done by a microprocessor-based beam-steering controller which receives the TDRS look angles from the spacecraft's onboard navigation computer. Full spherical coverage of the TDRS is obtained by strategically locating four of these antennas around the body of the spacecraft and switching between them as the spacecraft attitude changes.

Performance data covering antenna gain, axial ratio, circuit losses, and radiation patterns will be discussed. Also, composite coverage of four antennas located around the Space Shuttle cockpit will be illustrated using three-dimensional graphics software.

22.   Villarreal, Robert A . (LESC): Implementation and Applications of the 7KHZ Audio CODEC. Presented at the Joint Applications in Instrumentation Process and Computer Control Conference, March 23, 1989, Houston, Texas.

The International Telegraph and Telephone Consultative Committee (CCITT) has developed a recommended international standard for coding wideband speech and music (50-7000 Hz) within a bit rate of 64 Kbits/s or less (CCITT Rec. G.722). The coding scheme uses sub-band adaptive differential pulse code modulation (SB-ADPCM) to enable the transmission of wideband audio signals over a standard 64 Kbit/s B-channel in an ISDN environment. This coding algorithm offers a considerable increase in bandwidth over the current 64 Kbit/s standard of u-law or A-law PCM coding (300-3400 Hz), and a significant reduction in bit rate for a comparable level of audio quality to the current 7 Khz coding standard of 192 Kbits/s channel. A codec implementing this algorithm has recently been developed at the Johnson Space Center. Implementation of this coding scheme for space-to-ground transmisison and on-board communications in an application such as the Space Station would provide commentary quality voice channels and possible use for crew audio entertainment distribution.

1.  Bhatta, M.G. (LESC): A Resolved Rate Processor and Kinematic Data Generator for the Kinematically Redundant Seven Joint Mobile Servicing Center. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    The first part of this paper presents the derivation of the Jacobian for an arbitrary seven joint manipulator in explicit form. This Jacobian is then reduced to an elegant and compact form for the MSC. The closed form of solutions is generally preferred for real-time simulations than the recursive form because of their accuracy and less computation time. The Jacobian is then used to generate the Kinenmatic Data Generator (KDG) Function for MSC.

    The second part of this paper derives the Resolved Rate Law (RRL) for MSC by using Whitney's pseudo-inverse algorithm for the kinematically redundant manipulators. This control law results in a solution involving the least amount of instantaneous motion in all joints.

    These KDG and RRL Functions were used to develop a kinematic simulation of the MSC on a PC. Results from this simulation will be used to illustrate the working of this control law with numerical results.

2.  Bourgeois, Ben J. (LESC): Orbit Mode Control for Seven-Jointed Manipulators. Presented at the 14th Annual Joint Applications in Instrumentation Process and Computer Control, March 23, 1989, Houston, Texas.

    Seven-jointed manipulators have one more degree of freedom than is needed to span the work space. This extra degree of freedom exhibits itself in the ability to "orbit" the manipulator while holding the same end-point position and attitude, which can be used to avoid obstacles. The orbit mode is defined and a control law, which allows control by actively commanding one of the joint rates, is described. The motivation for orbit mode and applications are identified for seven-jointed space manipulators.

3.  Campbell, Perry D. (LESC): Real-Time Cartesian Force Feedback Control of a Teleoperated Robot. *NASA Conference on Space Telerobotics Proceedings*, 1989.

    Active cartesian force control of a teleoperated robot is investigated. An economical micro-computer based control method is tested. Limitations are discussed and methods of performance improvement suggested.

    To demonstrate the performance of this technique, a preliminary test was performed. A force/torque sensor was mounted on the tool plate of a PUMA robot. The VAL controller was operated in the ALTER path mode which requires new position commands every 28 ms  The force/torque data was shaped into position commands. A personal computer was used to obtain force/torque data and transform this data into the cartesian position commands required by VAL. Various shaping functions were implemented to make the payload move according to different physical laws. Good force control performance was observed.

    Because this method is implemented entirely in cartesian space, it is well suited to applications in which a single force reflecting hand controller is required to operate several robots with different geometries. Because this control method closes an outer loop in the control system, manipulator dynamics may be compensated for without any apriori knowledge of their characteristics.

4.  Christianson, David C. (JSC): History of Visual Systems in the Systems Engineering Simulator. Presented at the Graphics Technology in Space Applications Conference, August 12-14, 1989, Houston, Texas.

    The Systems Engineering Simulator (SES) houses a variety of real-time, computer generated, visual systems. The earliest machine dates from the mid 1960's

and is one of the first real-time graphics systems in the world. The latest acqui-
sition is the state-of-the-art Evans and Sutherland CT6. Between the span of time
from the mid 1960's to the late 1980's, tremendous strides have been made in the
real-time graphics world. These strides include advances in both software and
hardware engineering.

The purpose of this paper is to explore the history of the development of these
real-time computer generated image systems from the first machine to the pre-
sent. Hardware advances as well as software algorithm changes are presented.
This history is not only quite interesting but also provides us with a perspective
with which we can look backward and forward.

5.  Draeger, Billy G. (LESC): An Application of the Robust Inverse for Singularity Pro-
    tection of the Space Station Manipulator Control System. Presented at the 14th
    Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    As redundant manipulators become more prevalent in space related work,
    singularities associated with the manipulators Jacoblan are more likely to be
    encountered. The robust inverse (an alternate to the pseudo inverse) can be
    used to protect the seven jointed Space Station arm control systems near singu-
    larities. An offline simulator shows how a seven jointed Space Station arm control
    system employing the robust inverse is protected against a singularity in the
    unloaded mode using the underdetermined form of the robust inverse. Also it is
    shown how "orbit submode" for the Space Station arm can be protected using the
    overdetermined form of the robust inverse. The ability to operate manipulators
    through singularities can be a huge aid to the manipulator operator.

6.  Erickson, Jon D.; Kenneth H. Crouse (JSC); Donald B. Wechsler (Mitre); and
    Douglas R. Flaherty (MDSSC): Considerations for a Design Knowledge Support
    System for Space Station Freedom. NASA TM 102156, September 1989.

7.  Grimm, Keith A. (JSC): Utilization of Transputer Networks In a Free Flying Auton-
    omous Robot. Presented at the International Transputer Seminar, Transputers for
    Industrial Applications II, October 23-24, 1989, Antwerp, Belgium.

    The Extra-Vehicular Activity (EVA) Retriever robot has been developed as a
    ground demonstration project and a precursor to a flight experiment at JSC  It
    utilizes an array of twenty transputers to perform vision processing and sensor
    fusion, mission control and arbitration, world model construction and update, crew
    interface support, inertial measurements data processing, and robot arm control.
    Currently, the robot can execute a simple target track and retrieval scenario.

8.  Healey, Kathleen J. (JSC): The Systems Autonomy Technology Program: Today's
    Research for Tomorrow's Space Station. Presented at the Space Artificial Intelli-
    gence/Robotics/Automation Symposium '89, October 16 - 19, 1989, Tokyo, Japan.

    NASA's Space Station Freedom Program (SSFP) presents significant technical
    challenges to those responsible for its design, development, operation, and evolu-
    tion over its projected lifetime. Many of these challenges can be met only through
    the application of mature advanced automation technology, much of which is not
    currently available. Many OAST Systems Autonomy Technology Program (SATP)
    goals have been selected to address those challenges. Requirements for the
    application of advanced automation to Space Station will be discussed with
    respect to the OAST research and development projects which have been
    designed to develop and mature the necessary and enabling technologies.

9.  Hwang, James (LESC): Design of a Hierarchical Parallel Processing Robot Con-
    troller. *ROBEX Proceedings*, 1989.

This paper outlines the research work of the robot controller design conducted at NASA JSC's Robotics Laboratory. The major goal of this research is to design and build a hierarchical robot controller with multilevel parallel processing capabilities.

For most of industrial robot controllers only some limited control functions are programmable, such as end-point positions or position trajectories, while other control functions are either implemented in non-programmable hardwares or not implemented at all. In order for integration of high level model-based vision, a high power computation and graphics computer will be required. On the other hand, a programmable digital servo processor will be needed for advanced servo control laws realization.

In this Lab, two Robotic Research manipulators, 1607 and 2107, were acquired for this research. The original controller is modified to host four levels of control processors for implementing a hierarchical control architecture. The lowest level is the servo level controller. A parallel processor DSP (digital signal processor) board is used to implement this level. A level above the servo is the coordinate transform level where a 386-based processor is used for the inverse kinematic and redundant degree-of-freedom solutions. The next level above the coordinate transform processor is the E-move/Primitive level where various sensors and human operator input will be interfaced. The highest level is the task level where the vision and CAD model will be integrated and a completed user and programming interface will be established. A high power graphics work-station is used to implement this level. With architecture implemented in this research, a very flexible operator and programming environment will be obtained and various control functions can be realized.

10.  Killingsworth, Scott G. (LESC):  Real-Time Man-in-the-Loop Simulation of Space Shuttle Remote Manipulator System.  Presented at the 1989 Summer Computer Simulation Conference, July 24-27, 1989, Austin, Texas.

The deployment and retrieval of payloads while on orbit are important parts of the Shuttle's mission. A main component required to achieve this task is the Remote Manipulator System (RMS). This system is modeled in a real time man-in-the-loop simulator in the Systems Engineering Simulator (SSES) laboratory at JSC. The SES supports a variety of users with separate simulations of the on-orbit, ascent, and entry flight regimes. The on-orbit simulator is made up of a number of subsystems. One of these, the RMS subsystem, is discussed in detail. An overview of the SES is presented containing descriptions of orbiter cockpit mockups, computer generated imagery systems, and simulator host computer configuration.

11.  Li, Yvonne (LESC):  Real Time Video Bandwidth Compression Using Pseudo-random Sampling Pattern and Image Digitization. *SPIE Conference Proceedings*, August 1989.

Pseudorandom sampling pattern and image digitization have been investigated as a technique to reduce the video bandwidth before transmission. Most techniques commonly used involve some sort of transformation which makes transmission in real time impossible. In order to transmit in real time, video quality may be affected in one or more ways:  possible loss of data during compression, reduction in sharpness of the picture when played back, and the possibility of having unwanted video effects such as dot crawling and dot patterning. Hughes Aircraft Company has conducted a study on these video effects versus different sampling techniques and part of the system design is based on their findings. The pseudorandom pattern sampling and image digitization was investigated for JSC as a part of the Space Station development

activities. The need for this development is to avoid a signal overload condition in the multiple access communication link. All downlink signals will be assigned levels of priority before transmission and video signals are usually assigned a lower priority. Therefore, the bandwidth available for video transmission will be limited. This creates the situation where an image must be compressed before downlink. The advantage of using the pseudo-random sampling pattern and image digitization technique is that real time information can be obtained and the viewability of the displayed picture can be maximized even in the high compression ratio mode.

12. Malin, Jane T.; and Bryan D. Basham (JSC): Adapting Qualitative Modeling and Discrete Event Simulation for Design of Fault Management Systems. *AIAA Computers in Aerospace VII Proceedings*, October 4-6, 1989, Monterey, California.

CONFIG is a modeling and simulation tool prototype for analyzing the normal and faulty qualitative behaviors of engineered systems. Qualitative modeling and discrete event simulation have been adapted and integrated to support early development of software and procedures for management of failures during system design, especially diagnostic expert systems. Qualitative component models are defined in terms of normal and faulty modes and processes, which are defined by invocation statements and effect statements with time delays. System models are constructed graphically by using instances of components and relations from object-oriented hierarchical model libraries. System failure syndromes are simulated using a modified form of discrete event simulation. The declarative and modular model representation permits other forms of graph analysis and simulation. Extension and reuse of CONFIG models and analysis capabilities in hybrid rule- and model-based expert fault management support systems are discussed.

13. Malin, Jane T.; and Bryan D. Basham (JSC): CONFIG: Combining Methods from Qualitative Modeling and Discrete Event Simulation to Analyze Malfunctions in Processing Systems. Presented at the Fourth Artificial Intelligence and Simulation Workshop of the 11th International Joint Conference on Artificial Intelligence, August 20-25, 1989, Detroit, Michigan.

Both qualitative modeling and discrete event modeling have been independently developed to analyze the behavior of complex systems based on discrete models of the behavior of individual system components and processes. The CONFIG project provides a framework for combining methods from both these lines of work to address the challenges of analyzing the effects of faults and malfunctions in continuous processing systems. Discrete event simulation systems are reasonable candidates for analyzing qualitative models of dynamic processing systems. There is considerable overlap in the definition of the objects and events. However, discrete event simulation has been used primarily to solve queueing-oriented service scheduling problems, and the basic modeling objects and simulation control programs have been tailored to these problems. CONFIG uses a modified discrete event simulation approach tailored to handle types of qualitative variables, relations, algebras, and deductive strategies. CONFIG defines the primary types of discrete events as changes in the qualitative value of a variable or in the operating mode of a component. Components, the basic constituents of CONFIG models, are connected together using relations. A component model includes mode independent processes and modes which contain mode dependent and mode transition processes. The concept of operating modes and mode

transition processes provides a capability for representing process-oriented quali-
tative model information. A change in a component variable or a mode is equiva-
lent to reaching a new qualitative range. CONFIG includes a Process Language
for defining a number of types of qualitative operations and variables, including
higher order derivatives, and for implementing various qualitative-value-based
approaches to controlling qualitative ambiguity.

14. Martin-Marietta Astronautics Group: *Research and Design of Manipulator Flight
    Testbeds*, NASA CR 183511, 1989.

15. Nasser, Mahmoud G. (LESC): A Recursive Newton-Euler Formulation of Manipula-
    tor Dynamics. Presented at the 1989 IEEE International Conference on Robotics
    & Automation, May 14, 1989, Scottsville, Arizona.
       This paper presents a new recursive rigid dynamics formulation which results in
    a decoupled set of second order ordinary differential equations in hinge accelera-
    tions. The procedure may be viewed as a generalization of Armstrong's method.
    This formulation includes translational joints and a topological tree and eliminates
    the need for the computation of reaction forces and torques. However, if these
    reaction forces and torques are needed, closed form expressions are available
    for their computations. A $6 \times 6$ formulation is adopted which greatly simplifies the
    algebra involved. All recursive coefficients have direct physical interpretation and
    a counterpart in the Lagrangian formulation. Explicit expressions are obtained for
    the individual links' inertial cross coupling terms.
       From a computational standpoint, this model results in a number of computa-
    tions that grow linearly as a function of the number of links in the tree. The
    computational efficiency of this formulation is compared to that of Walker-Orin.

16. Nasser, Mahmoud G. (LESC); and Roland Glowinski (UH): A New Recursive
    Formulation for the Equations of Motion of Multibody Elastic Systems. *STAM
    Conference Proceedings*, 1989. Presented at the 1989 STAM Conference on
    Control in the 90's, May 17, 1989, San Francisco, California.
       This paper presents a new recursive algorithm for the formulation and solution
    of the equations of motion for a system of elastic bodies undergoing rigid and
    elastic motion. A primary application for this algorithm is the Space Station
    Mobile Servicing System (MSS). The algorithm results in a system of ordinary
    differential equations of very simple structure. Two types of fixity conditions are
    discussed and analyzed: local and global type. The technical difficulties arising
    in the discretization of the continuum equations at the link level using non-
    autonomous boundary data will be discussed. From a computational standpoint,
    the required number of computations grow as a linear function of the number of
    bodies in the system.

17. Poritz, Darwin H. (LESC): Attitude Matrix Over Time for Free Rotation. Presented at
    the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
       It is shown how to compute the time-dependent orthogonal transformation matrix
    from body to inertial coordinates of a rotating rigid body not subject to torques.
    The solution is exact in the sense that no numerical integration is required.
    Although the solution for angular velocity has been known since the nineteenth
    century, the algebraic computation of the body attitude matrix has not been
    addressed. This situation is most probably due to the fact that the algebraic com-
    putation of the attitude matrix is built upon the matrix representation of the joint
    differential equations for the attitude and angular velocity. This latter result will be
    reviewed, as well as the well-known solution for the angular velocity in terms of the

Jacobian elliptic functions, before the algebraic derivation of the attitude matrix is presented.

18. Poritz, Darwin H. (LESC): Matrix Differential Equations for the Motions of Articulated Rigid Bodies. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The coupled matrix differential equations for the attitude and angular velocity of a single rigid body are used in the development of the system of equations for the motions of several rigid bodies connected together by articulating joints. Examples of such assemblages of rigid bodies are robots, the Space Shuttle's Remote Manipulator System, and the Space Station's Mobile Remote Manipulator System. The matrix form of the single-body differential equations, which was presented to this Symposium in 1987, is reviewed. It is this matrix form which permits the use of simple rules for writing the system of equations of the articulated assemblage and which provides a compact, economical, yet explicit, notation for the system. Equations for both translation and rotation of each body are given, as well as for translation of the assemblage center of mass. The method for developing the system of equations is illustrated by an assemblage of four bodies joined sequentially by three joints. In the illustration, the assemblage is assumed to be in free fall (e.g., Earth orbit). Each joint contains a motor and a brake, and a body at one end has means for applying forces and torques (e.g., rocket motors).

19. Price, Charles R. (JSC): Force Torque Control for the Space Shuttle Remote Manipulator System. Presented at the Space Artificial Intelligence and Robotics Symposium, October 16-19, 1989, Tokyo, Japan.

The Space Shuttle Remote Manipulator System (RMS), today's only operational space robot arm, is an operator-in-the-loop, rate command, position controlled teleoperator that has flown on 19 missions. The RMS has met and exceeded all of its design requirements for payload deployment and retrieval, extravehicular activity (EVA) astronaut support, and local illumination and closed circuit television (CCTV) camera positioning. An upgrade to the RMS is being investigated to provide force torque control capability in order to meet emerging requirements for constrained motion tasks to support on-orbit assembly of large structures such as Space Station Freedom. Concepts involving both force torque display to an operator and automatic servo control of force torque feedback are being evaluated. These evaluations are being conducted on ground based non-real-time and real-time simulators, robotics testbeds, and a Space Shuttle flight experiment. Implementation of this upgrade will support the initial Space Station assembly flight in 1995.

20. Price, Charles (JSC): Telerobotics Activities at Johnson Space Center. Presented at the NASA Conference on Space Telerobotics, January 31 - February 2, 1989, Pasadena, California.

Telerobotics activities at JSC have been ongoing for 15 years and follow the general top down/bottom up philosophy. At present, about 200 employees are active in telerobotics projects throughout JSC which address all aspects of this multifaceted emerging discipline. Major programs supported include Space Shuttle, Space Station, Flight Telerobot Servicer, Office of Aeronautics and Space Technology, Small Businesses Innovative Research, several university programs, Office of Space Commercialization, and the JSC Director's discretionary fund.

For the Shuttle Program, JSC continues to refine the Payload Deployment and Retrieval system which consists of the Remote Manipulator System and its ancillary equipment. The PDRS has performed successfully on all of its 18 flights, both

for its nominal functions and also as a source for innovative solutions for problems arising in real time. For the Space Station, JSC is defining the functional and performance requirements for the Mobile Service Center in general and the JSC deliverable, the Mobile Transporter, in particular. These requirements are being based largely on the non-real time and real time simulations activities at JSC. For the Flight Telerobot Servicer, JSC is providing to GSFC analyses on crew workstation concepts, robotic task definitions, and integration support for both the Shuttle and the Space Station. Telerobotic research at JSC spans the five component disciplines: Sensing and perception, planning and reasoning, control execution and mechanisms, crew interface, and system architecture and integration. JSC active telerobotic demonstrations include the successful ground demonstration of the EVA Retriever and the on orbit Dexterous Manipulation Demonstration manifested for February 1992.

21.  Red, Michael T.; and Philip W. Hess (LESC): Real-time Graphics for the Space Station Freedom Cupola, Developed in the Systems Engineering Simulator. Presented at the Graphics Technology in Space Applications Conference, April 12-14, 1989, Houston, Texas.

Among the JSC's responsibilities for Space Station Freedom is the cupola. Attached to the resource node, the cupola is a windowed structure that will serve as the Space Station's secondary control center. Operations involving the mobile service center and orbital maneuvering vehicle will be conducted from the cupola.

The Systems Engineering Simulator (SES), activated a real-time man-in-the-loop cupola simulator in November 1987. The SES cupola is an engineering tool with the flexibility to evolve in both hardware and software as the final cupola design matures. Two workstations are simulated with closed-circuit television monitors, rotational and translational hand controllers, programmable display pushbuttons, and graphics display with trackball and keyboard.

The displays and controls of the SES cupola are driven by a Silicon Graphics Integrated Raster Imaging System (IRIS) 4D/70 GT computer. Through the use of an interactive display builder program, SES cupola display pages consisting of two-dimensional and three-dimensional graphics are constructed. These display pages interact with the SES via the IRIS real-time graphics interface. This paper focuses on the real-time graphics interface applications software developed on the IRIS.

22.  Reuter, G. J.; C. W. Hess; D. E. Rhoades (JSC); L. W. McFadin; K. J. Healey; J. D. Erickson; and D. Phinney (LESC): An Intelligent Free Flying Robot. Presented at the NASA Conference on Space Telerobotics, January 31 - February 2, 1989, Pasadena, California.

The ground-based demonstration of EVA Retriever, a voice-supervised, intelligent, free-flying robot, is designed to evaluate the capability to retrieve objects (astronauts, equipment, and tools) which have accidentally separated from the Space Station. The major objective of the EVA Retriever Project is to design, develop, and evaluate an integrated robotic hardware and on-board software system which autonomously: (1) performs system activation and check-out, (2) searches for and acquires the target, (3) plans and executes a rendezvous while continuously tracking the target, (4) avoids stationary and moving obstacles, (5) reaches for and grapples the target, (6) returns to transfer the object, and (7) returns to base.

23.  Rob, Khandker K. (LESC): Validation of Mobile Service Center Simulation in the Systems Engineering Simulator at Johnson Space Center, National Aeronautics and Space Administration. *Summer Computer Simulation Conference (SCSC)*

*Proceedings*, Group XIX, p. 907, 1989. Presented at the SCSC, July 24-27, 1989, Austin, Texas.

The Systems Engineering Simulator (SES) at the JSC is currently the sole real time man-in-the-loop engineering simulation facility supporting the National Space Transportation System (NSTS). Design and construction of an entirely new simulator software architecture is in process to meet the expanding simulation requirements over the next decade to support future Space Station/Shuttle Programs.

One of these expansions is the capability to simulate a Space Station Mobile Service Center (MSC). With the completion of the MSC project, a new 7-joint manipulator (as opposed to the 6-joint Remote Manipulator System currently available) will be added to the simulation which will more accurately represent the latest concept of Space Station manipulators. The MSC capability will be instrumental in simulations of Space Station assembly and repair, orbiter/station berthing and docking, and payload handling between the orbiter and the Space Station. The simulation includes crew displays and controls for maneuvering the MSC as well as closed circuit television to aid in positioning the MSC on the Station.

24. Ross, Michael L.; and David A. McDermott (LESC): Optimal Joint Rate Limit Algorithm for Zero-g Manipulators. *Conference on Space Telerobtics Proceedings*, 1989. Presented at the Conference on Space Telerobotics, January 31, 1989, Pasadena, California.

An algorithm for continuously computing safe maximum relative velocities for two bodies joined by a manipulator is discussed. The maximum velocities are such that, if the manipulator brakes are applied in an emergency, the relative motion between the two vehicles will not exceed a specified distance. The current method of computing these velocity limits for the Shuttle's remote manipulator system assumes a worst case manipulator configuration at all times, so only one set of limits is computed for a payload. It also assumes that the Shuttle is fixed in space (infinite mass), which causes the safety limits to approach zero as the payload mass approaches that of the Shuttle. In addition, since the length (and thus the resolution) of the rate command word is fixed, very small limits will cause increased uncommanded motion by increasing the percentage quantization error in the rate command. A method of computing these velocity limits continuously as the manipulator configuration changes is herein proposed and derived.

25. Saha, Himankush (Unisys): Improvement of Shuttle Navigation Through Tunable Integration Scheme. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

In Shuttle simulation different algorithms like Super-G, Universal Formulation, etc., are used to predict the Shuttle State Vector. This paper uses a Tunable Integration Scheme to predict the Shuttle State Vector. Tunable Integration has the advantage that integration coefficients can be changed to suit a particular simulation. Accuracy can be increased to a great extent by suitable choices of tunable integration coefficients.

26. Spofford, John (MMSS): Satellite Servicing Telerobotic Testbed. Presented at the Satellite Services Workshop IV, June 21-23, 1989, Houston, Texas.

The goal of this paper is to let the servicing community know what teleoperation and robotic technology is available now and what will be available soon. This paper presents current and planned testbed capabilities for satellite servicing via robotics and teleoperations. A flight testbed for manipulator development, currently under study, can also be used to demonstrate servicing operations and qualify equipment in a flight environment. Ground testbeds include multimanipulator fixed-base testbeds and single-manipulators mounted on positioners or

vehicles. Experience shows that manipulators can perform servicing operations on the ground; the next step is flight demonstration.

27.   Taylor, Edith C. (JSC); and Michael Ross (LESC):  A Comparison of the Shuttle Remote Manipulator System and the Space Station Freedom Mobile Servicing System.  Presented at the NASA Conference on Space Telerobotics, January 31 - February 2, 1989, Pasadena, California.

The Shuttle Remote Manipulator System is a mature system which has successfully completed 18 flights. Its primary functional design driver was the capability to deploy and retrieve payloads from the Orbiter cargo bay. The Space Station Freedom Mobile Servicing System is still in the requirements definition andearly design stage. Its primary function design drivers are the capabilities to support Space Station construction and assembly tasks; to provide external transportation about the Space Station; to provide handling capabilities for the Orbiter, free flyers, and payloads; to support attached payload servicing in the extravehicular environment; and to perform scheduled and unscheduled maintenance on the Space Station. This paper discusses the differences between the two systems in the areas of geometric configuration, mobility, sensor capabilities, control stations, control algorithms, handling performance, and effector dexterity and fault tolerance.

28.   Thomas, Segun (LESC):  Coupling Dynamics for Flexible Robots.  Presented at the 1989 JAIPCC Symposium, March 23, 1989, Houston, Texas.

Dynamical equations for flexible multibodies, such as the shuttle remote manipulator system (RMS), are quite extensive and were derived and implemented as "stand alones." With the advent of the flight telerobotic servicer or flexible payloads on the RMS, there is a need to determine the combined dynamic behavior of the entire system. The achievement of this for real-time simulation would require rederivation of dynamical equations for the system and availability of enormous computing capabilities if a new substructuring technique is not utilized.

This paper outlines a procedure for determining the dynamic response of large interconnected flexible systems by a substructuring technique. First, the dynamical equations for each substructure are formulated. Next, compatibility equations are established at the interface of the substructures. Interface accelerations are then solved for utilizing the predicted value of its time derivative. Interface accelerations are used to obtain interface forces. Finally, interface forces are substituted into the dynamical equations of each individual substructure to obtain the dynamic response of the entire system. Mathematical models for coupling dynamics of the RMS and a flexible radiator panel are presented as illustrative examples.

29.   Thomas, Segun (LESC):  RMS/Flexible Panel Dynamics Using a Substructuring Technique.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Dynamical equations for the simulation of the RMS are computationally very intensive. Routine extension of these equations to simulate manipulator handling of flexible panels or flexible payloads would require enormous computing capabilities while rederivation of the entire RMS/flexible panel dynamical equations would be too time consuming. Both approaches would create serious validation problems. Therefore, there is the need for a procedure that correctly analyzes RMS flexible panel dynamics by utilizing existing RMS dynamical equations.

This paper outlines a procedure for determining RMS/flexible panel dynamical equations by utilizing a special substructuring technique. First, the dynamical

equations of the RMS (exists) and the flexible panel are formulated. Next, compatibility equations are established at the interface of the RMS and the panel. Interface accelerations are then determined using the predicted value of its time derivative. Interface accelerations are used to obtain interface forces. Finally interface forces are substituted into both RMS dynamical equations and panel dynamical equations to obtain the dynamic response of the entire system. This method is suitable for obtaining the coupling dynamics of any multi-body system such as Remote Manipulator System/Flight Telerobotic Servicer, Mobile Service Center/Space Station, and Mobile Service Center/Flight Telerobotic Servicer.

30. Vu, Bang Q.; and Kevin R. Kirkhoff (LESC): Systems Engineering Simulator Cupola Interactive Display Design Environment. Presented at the SES Cupola International Display Design Environment, April 12 - 14, 1989, Houston, Texas.

The Space Station Freedom cupola will serve as a secondary control center for on-orbit activities such as Mobile Service Center and Orbital Maneuvering Vehicle operations. One of the Systems Engineering Simulator's responsibilities is to provide a man-in-the-loop cupola simulator which will be used for engineering analysis of displays and controls, and an out-the-window MultiPurpose Applications Console which will be simulated on a Silicon Graphics IRIS 4D/70 GT workstation. As an engineering tool, the cupola simulator has to be greatly flexible to allow for continual upgrades during the design phase of the actual vehicle. We have developed a Display Builder in the SES lab which allows for rapid prototyping of displays consisting of 2D and 3D images. This paper will focus on the features of the Display Builder's User Interface and the detailed process of building and modifying a display.

31. Walter, Larry M. (JSC): Expectations for Non-Real-Time and Real-Time Simulations for the Engineering of Space Robotics and Other Flight Systems. Presented at the Workshop on Real-time Simulation Design, June 13, 1989, Houston, Texas.

"As space mission goals go, so go the sim requirements." The ever increasing sophistication and scope of the nation's (and world community's) space endeavors are bringing the requirements and implementation of simulation to levels of sophistication hardly envisioned a decade ago. Multiple, interactive spacecraft, extended on-orbit staytime, international joint ventures, on-orbit assembly, long-term servicing, and aggressive expansion of specific mission objectives are challenging the program managers and engineers as never before. These challenges can only be met through a wide use of simulation, both nonreal-time and real-time. Simulation itself becomes a challenge in that the complexity of these simulators can approach and exceed that of the actual spacecraft. As always, to have influence on the design of spacecraft, the simulators must precede the fabrication phase and accommodate design variations.

32. Yuen, Vincent K. (LESC): Issues in Visual Support to Real Time Space System Simulation Solved in the Systems Engineering Simulator. Presented at the Visual Support to R/T Space System Symposium, April 12-14, 1989, Houston, Texas.

State-of-the-art in visual systems can currently provide up to six simultaneous viewpoints for use by crewmen in real time simulators. Issues arise when it becomes necessary to support many views (out-the-window and closed-circuit TV) in order to sufficiently cover the viewing capabilities of the real world. A design to allocate three different scene generators to support one or two full scale simulations is presented in this paper. A modular approach is employed in the Systems Engineering Simulator (SES) at JSC. The problems encountered and solved in driving three different scene generators by one simulator are also discussed.

The hardware elements are the three scene generators (Evans & Sutherland's CT3, CT6, and a POLY 2000) and the graphics monitors in the two cockpit mock-ups (Shuttle Aft Cockpit and Space Station Cupola).  The software elements are the math models that derive visual objects position vectors (Scene Drive), format the data for the particular scene generator to use (Scene Interface), and the logic that determines what scene is to be generated by which scene generator and displayed on which monitor (Scene Select).

A total of eleven channels (two from CT3, six from CT6, and three from POLY 2000) are available for distribution, so mix and match of the scene generator outputs can be achieved to support various simulation study objectives.

1.    AliAhmad, S. G. (LESC); and J. R. Thibodeau, III (JSC):  Three Axis Attitude Proces-
      sor System for NASA's Space Station.  Presented at the JAIPCC Technical Sym-
      posium, March 23, 1989, Houston, Texas;  and at the 14th Annual AIAA Technical
      Symposium, May 18, 1989, Houston, Texas.

          This paper presents a prototype real-time Three Axis Attitude Processor System
      (TAAPS) for the Space Station Freedom.  This software system was designed,
      implemented, and verified in the Avionics Systems Division at the Johnson Space
      Center.  This report describes the system design rationale, structure, validation
      process and results, and the proposed scheme of application.

          The TAAPS design strategy emphasizes complete automation for star tracking,
      star identification, star verification, and optimal attitude alignments.  Redundancy
      management, fault tolerance, and system reconfiguration were also implemented,
      with a provision for graceful single/multiple star tracker failures.  FORTRAN 77
      software language was used for development in order to gain system portability.
      The system modules are the EXECUTIVE, the ALINE, the CIRAREA, the ACCESS,
      the STMASK, the DQMAT, the DMATQ, the QNORM, and the RECOVERY.

2.    Becker, Fred J. (LESC):  Space Station Freedom Integrated Fault Model.  *NASA
      Conference Publication 3045*, pp. 155-163, March 1989.  Presented at the 14th
      Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas and Graphics
      Technology in Space Applications, April 12-14, 1989, Houston, Texas.

          This paper describes a demonstration of an integrated fault propagation model
      for Space Station Freedom.  The demonstration uses a HyperCard graphical inter-
      face to show how failures can propagate from one component to another, both
      within a system and between systems.  It also shows how hardware failures can
      impact certain defined functions like reboost, atmosphere maintenance, or col-
      lision avoidance.  The demonstrations, which use an overview screen, enable the
      user to view block diagrams for various Space Station systems and to interac-
      tively choose a component and see what single or dual failure combinations can
      cause it to fail.  It also allows the user to directly view the fault model, which is a
      collection of drawings and text listings accessible from a guide screen.

          Fault modeling provides a useful technique for analyzing individual systems and
      also interactions between systems in the presence of multiple failures so that a
      complete picture of failure tolerance and component criticality can be achieved.

3.    Boelitz, Frederick W. (CSDL):  *Guidance, Steering, Load Relief, and Control of an
      Asymmetric Launch Vehicle*, NASA CR 185598, 1989.

4.    Brown, H. D.; J. B. Scarlett; J. A. Skweres (KRUG); R. L. Fortune;  J. L. Staples
      (MDSSC); and D. L. Pierson (JSC):  Microbial Identification System for Space
      Station Freedom.  Presented at the Interscience Conference on Environmental
      Systems.

          The Environmental Health System and Health Maintenance Facility on Space
      Station Freedom (SSF) will require a comprehensive microbiology capability.  This
      study reports progress in the development and testing of automated equipment for
      performing microbial identifications and antimicrobial sensitivity testing on the
      SSF.  The unit currently undergoing testing at JSC, the Automated Microbiology
      System-II (AMS-II), is downsized to fit an Orbiter middeck locker while utilizing the
      existing technology found in commercially available Vitek equipment.  Testing on
      the AMS-II indicates it is a promising technology for use on SSF.  The system
      handles both clinical and environmental microorganisms and can be further
      downsized to accommodate SSF requirements.

5. Chlouber, Dean (MDSSC): Plasma Impedance Calculations for Tether and Space Station. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

In this presentation we review the power loss mechanism associated with the interaction of a conducting satellite with the Earth's magnetic field and the ionosphere. For typical orbital speeds of 8 kilometers per second and a magnetic flux of 0.33 gauss, an electric field of approximately $\frac{1}{4}$ volt per meter is developed. The voltage developed across the structure constitutes a battery which drives current through the structure and surrounding plasma. A net amount of energy is radiated away resulting in a magnetic drag effect and electromagnetic noise in the plasma. For the Space Shuttle, where at most a potential difference of a volt or two is developed, the effect is negligible, however, for the Space Station and tether structures, whose dimensions range from 100 meters to 20 kilometers, the effect requires consideration. We present the results of plasma impedance and power loss computations for a conducting tether and model Space Station structure.

6. Conroy. W. T.; and W. F. Michaux (LESC): Mars Rover Sample Return (MRSR) GN&C Subsystem Design. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

A conceptual design study of the guidance, navigation, and control (GN&C) subsystem has been performed in support of the MRSR mission. The GN&C subsystem is required to perform all of the tasks necessary to successfully deliver and return the vehicles comprising the MRSR mission. The design study began by identifying the tasks that the GN&C subsystem must monitor and control. The trade studies that have been completed include; vehicle responsibility for each segment of the mission, avionics sharing between mated vehicles to save mass, and specific hardware implementations. A qualitative design was undertaken that created GN&C subsystems of low, medium, and high levels of complexity and redundancy. The completed designs consist of conceptual block diagrams and mass, power, and volume estimates for the avionics utilized.

7. Cunningham, H. H. (LESC): The Role of Software Simulators and Models in Space Station Freedom Development and Operations. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Unique aspects of the Space Station Freedom (SSF) that demand new and innovative approaches to ground-based and operational testing are first identified and briefly discussed. This is followed by a descriptive overview of the methodology for SSF ground-based developmental testing and subsequent integration, test, and verification. The concept of geographically distributed development and testing is presented. The roles played by software simulators and models in that ground-based program are explained. The ground-based growth to full maturity of the simulator/model assisted testing capability is next described. The presentation concludes with a description and discussion of onorbit applications of the model/simulator testing capability for the mandatory onboard checkout of the operational SSF.

8. Demeo, Martha E. (CSDL): *Remote Manipulator Systems (RMS) Based Control Structures Interaction (CSI) Flight Feasibility Study*, NASA CR 185600, 1989.

9. DiBattista, John (NASA HQ); Stephen L. Lamkin; and Ken Baker (JSC): Autonomous Systems Control for Solar System Exploration Spacecraft Presented at the AIAA/JPL 2nd International Conference on Solar System Exploration, August 22-24, 1989, Pasadena, California.

Currently the most complex autonomous procedure carried out by interplanetary spacecraft is the reestablishment of the spacecraft antenna boresight with Earth to maintain the all important communications link. In recent case studies the NASA Hqs. Office of Exploration (Code Z) has identified two system applications for additional autonomous behavior that have not been developed for previous interplanetary missions. A requirement has been identified for an autonomous rendezvous and docking capability and an autonomous precision landing and hazard avoidance capability. Because of large time delays and orbit obscuration, the control from Earth of rendezvous and docking about a distant planet is impractical. To enable this capability, new and potentially more efficient orbital rendezvous approaches are being developed and technology programs established for meeting new sensor requirements. In the terminal docking phase both fuzzy logic and neural net technology approaches are being pursued at this time. Both these approaches show promise in being able to accommodate the missed approach problems.

10. Gluck, R. (TRW); A. L. Hale (SSI); and J. W. Sunkel (JSC): Concurrent Processing Simulation of the Space Station. *Third Annual Conference on Aerospace Control Proceedings*, December 15, 1989.

This report describes the development of a new capability for the time-domain simulation of multibody dynamic systems and its application to the study of large-angle rotational maneuvers of the Space Station. The effort was divided into three sequential tasks: (1) the development of an explicit mathematical model via symbol manipulation of a flexible, multibody dynamic system; (2) the development of a methodology for balancing the computational load of an explicit mathematical model for concurrent processing, and (3) the implementation and successful simulation of the above on a prototype Custom Architectured Parallel Processing System (CAPPS) containing eight processors. The throughput rate achieved by the CAPPS operating at only 70 percent efficiency, was 3.9 times greater than that obtained sequentially by the IBM 3090 supercomputer simulating the same problem. More significantly, an analysis of the results leads to the conclusion that the relative cost-effectiveness of concurrent vs sequential digital computation will grow substantially as the computational load is increased.

11. Harmon, Gilbert D. (JSC): STS-26 Stand-Alone Pressure Measurement Device. *Sensors, the Journal of Machine Perception*, Vol. 6, No. 3, pp. 24-27, March 1989.

The Stand-Alone Pressure Measurement Device (SAPMD) is a self-contained instrumentation device capable of autonomous data and time recording for measurements of pressure at various points on the shuttle orbiter vehicle. The measurements begin at solid rocket booster ignition as detected by an appropriate vibration sensing element on the SAPMD. Pressure and corresponding time data are recorded every 0.1 s for 140 s. At the end of the recording period the operation discontinues, with the data preserved for interrogation subsequent to orbiter entry and landing.

The SAPMD can be mounted in a specific location under tiles of the Orbiter's thermal protection system. However, for this engineering test the devices were mounted in the payload bay on a longeron bridge attach-panel fitting.

The SAPMD precludes false starting of data recording by performing reasonableness checks on pressure gradients. Powered by a lithium thionyl chloride battery pack, the SAPMD measures 6.0 in. long by 1.5 in. wide by 0.4 in. high.

12. Hoelscher, Brian R. (LESC): Effects of a Control Reel Lock Jam on the TSS-1 Mission with Special Concern Toward the Slack Tether Issue. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

A locked or jammed tether control reel is a known cause of a slack tether. In the study, a reel lock is induced during all phases of the Tethered Satellite System Mission (TSS-1) profile to study and quantify when the reel lock results in slack tether. The Shuttle tethered object control simulation simulates the effects of a reel lock on the tethered system (Orbiter-tether-satellite), with considerable detail afforded to the study of slack tether dynamics. When the tether length is under 15 km, the tether is observed to oscillate between slackness and tautness following reel lock. This activity typically causes a loss of satellite attitude control and produces large amplitude oscillations in libration and satellite positioning. Also, the disrupted satellite attitude dynamics render the satellite thrusters ineffective for libration control purposes. It is shown that in most cases satellite thrusts must be disabled after a reel lock and other libration control techniques must be pursued until the reel action can be resumed. Controlling libration with Orbiter maneuvers is one alternate technique that is investigated.

13. Jenson, Dale (MDSSC): Concepts for Implementation of Fault Detection and Redundancy Management On Board Space Station. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

This paper presents some concepts and considerations for diagnostic testing to detect malfunctioning of inoperative systems and elements aboard the Space Station. This topic is termed Fault Detection and Isolation (FDI). A further purpose is to provide some operational and procedural concepts for management of failures by replacing or by-passing malfunctioning units so as to maintain functionality of the operating system and to ensure, particularly, that system critical functions are maintained. This topic is termed Redundancy Management (RM).

Due to the complexity and expense of Space Station logistics, it is important to give special consideration to efficient means of detecting malfunctioning equipment, and to the repair or replacement of system elements and components. Orbital logistics also preclude the employment of bulky, complex, and specialized test units or equipment. Similar consideration of built-in test equipment is appropriate for the Space Station application. Similarly, optimal management of multiple redundant system elements and the use of exceptionally reliable components will minimize the number of spares required to maintain functionally operating elements and systems. This presentation introduces concepts for implementation of FDI and RM in conjunction with built-in tests which are consistent with safety of operations, maintaining Space Station operations and functions, and orbital logistics. In addition, the procedures must be readily managed by the Space Station crew members. Consonant with the above, some fundamental concepts for FDI and RM are presented.

14. Kelly, C.; C. Marsh; J. Lewis; C. Partin; A. Sylvester; M. Wade; and B. Walker (MITRE): Space Station Freedom Operations Management System. Presented at the 11th International Joint Conference on Artificial Intelligence, August 20-25, 1989, Detroit, Michigan.

NASA is currently exploring the potential uses of expert system technology for Space Station Freedom. Two prototypes have been integrated demonstrating expert system capabilities for the control, monitor, and fault management functions of Freedom. These two prototypes, the Procedures Interpreter or PI, and the Integrated Status Assessment or ISA, will be shown functioning in this role. The PI prototype implements the functions of commanding the Space Station, monitoring operations, and enforcing general and context-sensitive flight rules. The crew procedures are supplied to the Procedure Execution Engine as data. Included in the procedure data are the commands that are to be issued, operating constraints, and rules that apply for the duration of the nominally

performed operation. The ISA prototype performs fault detection, isolation, and reconfiguration. It was designed as a hybrid expert system using different methodologies: (1) object oriented programming to describe the different parts of Space Station Freedom, (2) rule based reasoning to encode the knowledge on how to perform the failure diagnosis, and (3) qualitative modeling to describe the state of the various components.

15.  Lehman, Richard A. (LESC):  Space Station Communication Services for Heterogenous Computer Systems.  Presented at the JAIPCC Symposium, March 23, 1989, Houston, Texas.

   The Space Station Freedom will include a Data Management System (DMS) which will provide a broad set of communications services. Several of these services will consist of exchanging data among different types of computer systems. This paper describes the work which is currently being performed in the Space Station DMS Test Bed for exchanging data over a variety of different types of computers and operating systems. A method of exchanging data structures in the form of Ada record among distributed nodes will be discussed.

16.  McClain, Wayne D. (CSDL):  The Space Station Reboost Problem:  Motion of an Orbiting Spacecraft Under Constant Thrust.  Presented at the American Astrometrical Society, August 7-10, 1989, Stowe, Vermont.

   Two analytical models are developed for the motion of an orbiting spacecraft under the influence of continuous low level thrust in the transverse direction. The models are developed in orbit elements using a perturbation method with the magnitude of normalized trust acceleration as the small parameter. Formulations are presented for the equinoctial elements and for the classical elements. The equinoctial element formulation is closed form in the eccentricity at first order and a small eccentricity approximation is used at second order. The formal development of the classical element model is similar to the equinoctial model at first and second orders, however, due to the singularity in the equations of motion caused by a vanishing eccentricity the formalism breaks down for small eccentricity cases. Consequently, it is not possible to obtain a complete zeroth order model for the argument of perigee and mean anomaly or a complete first order model for the eccentricity. The performance of each model is evaluated by comparison with numerical integration.

17.  Michaux, W. F. (LESC):  Mars Rover Sample Return (MRSR) Mars Lander Dynamic Model.  Presented at the 14th Annual AIAATechnical Symposium, May 18, 1989, Houston, Texas.

   A one-third scale, dynamic model of a Mars lander was designed, constructed, and tested to obtain a qualitative feel of the Mars lander problem. The model was built of composite materials to minimize weight and used a Helium balloon to simulate Mars acceleration. Shock attenuation similar to the Viking landers was attained using a spring and ratchet system. This system allowed unlimited repetition of tests. The effectiveness of the model was demonstrated by a series of test drops conducted at LESC facilities. From this series of tests, it was concluded that dynamic testing can be used to verify computer models, and to simulate a variety of extreme landing conditions and unconventional lander concepts.

18.  Polutchko, Robert J. (CSDL):  *Cooperative Control of Two Active Spacecraft During Proximity Operations*, NASA CR 185596, 1989.

19. Sunkel, John W. (JSC); and L. S. Shieh (UH): An Optimal Momentum Management Controller for the Space Station. Presented at the AIAA Guidance, Navigation, and Control Conference, August 14-16, 1989, Boston, Massachusettes.

This paper repesents a new sequential design procedure for determining an optimal control moment gyro (CMG) momentum management and attitude control system for the Space Station Freedom. First, the Space Station equations of motion are linearized and uncoupled, and the associated state space equations are defined. Next, a new sequential procedure is used for the development of a continuous quadratic regulator with eigen value placement in a specified region of the complex plane. The regional pole assignment method is utilized since it is best suited for tradeoffs between eigenvalue locations and robustness with respect to parameter variations, sensor failures, implementation accuracies, and gain reduction. The matrix sign function is used for solving the Ricccati equations which appear in the design procedure. Simulation results are given which show that the resultant design provides excellent system performance.

20. Sunkel, John W. (JSC); and L. S. Shieh (UH): Digital Redesign of an Optimal Momentum Management Controller for the Space Station. Presented at the AIAA Guidance, Navigation, and Control Conference, August 14-16, 1989, Boston, Massachusettes.

A new digital redesign technique is developed for determining the digital version of an optimal momentum management controller previously designed by the authors for the Space Station Freedom. The technique matches all the states at all sampling instances to find a pseudocontinuous time quadratic regulator. It is shown that the redesigned digital states closely match the continuous time optimal states. It is also shown how the redesign technique can be applied to a state estimator.

21. Termini, James A. (LESC): Microgravity Regions of the Space Station. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Experiments planned aboard the Space Station, that will require an acceleration environment limited to a few micro-g's, have prompted an examination of a variety of minute operational disturbances and their contributory accelerations.

In this presentation the equations for the microgravity envelopes resulting solely from gravity gradient and rotation relate accelerations will be derived. Complex effects generated by crew motion, Mobile Remote Manipulator System (MRMS) motion, variations in aerodynamic drag, and other sources are left for an alternate study.

Special cases to be examined will include Local Vertical-Local Horizontal (LVLH) hold and inertial hold. It will be shown, for example, that the microgravity envelope of the LVLH hold case is an elliptical cylinder that is open-ended in the direction of motion, whereas in the inertial hold case the envelope is an ellipsoid of revolution. Agreement with Hill's equations will be noted for a special condition of the LVLH hold case.

22. Tomlinson, Bill (SRI): *Stand Alone Pressure Measurement Device (SAPMD) for the Space Shuttle Orbiter*, NASA CR 172119, 1989.

23. Wade, M. C. (LESC): Required Attributes of a Computer-Aided Software Engineering (CASE) Tool for Use in the Onboard Checkout (OBCO) System Design Environment. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

As systems and procedures on a space station increase in complexity, so does

the software used to control these systems. The costs and difficulties in managing a software project increase exponentially with the size and/or complexity of the software. Computer-Aided Software Engineering (CASE) tools help to make these projects more manageable and increase the reliability and verifiability of the software product. The required attributes of a CASE tool identified for the Onboard Checkout system design environment are presented here as well as some general observations about the use of CASE tools and their contributions to productivity.

24. Woosley, E. W.; J. T. Nishimi; V. H. Nguyen; and Thomas H. Payne (RIC): Space Shuttle Descent Flight Verification by Simulation: A Challenge in Flight Control System Robustness. Presented at the AGARD Space Vehicle Flight Mechanics Symposium, November 13, 1989, Luxembourg.

The Space Shuttle Flight Control System (FCS) is an all-digital fly-by-wire system that provides vehicle stability, response, and handling qualities necessary for a safe return from orbit which ends with a pinpoint landing on a 300- by 15,000-foot runway. Furthermore, it has to successfully fly the entire never-before-flown envelope on its first manned flight. Thus, the FCS was subjected to one of the most extensive certification-by-analysis-and-simulation ever conducted.

1.  Boyd, William C.; and Warren L. Brasher (JSC): A Perspective on the Use of Storable Propellants for Future Propulsion. Presented at the JANNAF Propulsion Conference, May 23-25, 1989, Cleveland, Ohio.

    Propulsion system configurations for future NASA and DOD space initiatives are driven by the continually emerging new mission requirements. These initiatives cover an extremely wide range of mission scenarios, from unmanned planetary programs, to manned lunar and planetary programs, to Earth-oriented ("Mission to Planet Earth") programs, and existing and future requirements for near Earth missions, such as to geosynchronous Earth orbit (GEO). The increasing space transportation costs and the anticipated high costs of future vehicles necessitates consideration of easily maintainable, cost-effective configurations which maximize the use of existing technologies and assets, and the use of budgetary resources. System design considerations associated with the use of storable propellants to fill these needs are presented. Comparisons in areas such as safety, complexity, performance, flexibility, cost, maintainability, and growth potential are made for the Earth-storable combination nitrogen tetroxide/monomehtylhydrazine and the space-storable combination liquid oxygen/monomethylhydrazine. Assessments are also made of the technology status of storable propellants, and the planned studies of storable system concepts and how they fit in with studies of the overall space transportation infrastructure.

2.  Boyd, William C. (JSC): Overview of the Superfluid Helium Tanker Program. Presented at the Cryogenic Engineering Conference, July 24-28, 1989, Los Angeles, California.

    The on-orbit resupply of superfluid helium (He II) will enable complex and costly scientific satellites to remain operational for longer time periods. Candidate spacecraft for He II resupply include Space Station modules, Space Station attached payloads such as ASTROMAG, and orbiting observatories such as the Advanced X-ray Astrophysics Facility (AXAF) and the Space Infrared Telescope Facility (SIRTF). The JSC has embarked on a program to develop the capability of replenishing He II by the mid-to-late 1990's. The superfluid helium tanker (SFHT) would provide a means for resupply of He II to a variety of users from the Space Shuttle Orbiter, Space Station, and the Orbital Maneuvering Vehicle (OMV). Conceptual design studies have been completed and many of the critical component technology areas are to be addressed in the Superfluid Helium On-Orbit Transfer (SHOOT) Shuttle flight experiment. Plans are being formulated at JSC for future preliminary design studies and critical subassembly validation efforts supporting eventual full-scale development and flight operation activities.

3.  Cardin, Joseph M. (MOOG); William C. Boyd; and Mark S. Falls (JSC): Development of a Fully Automated Fluid Resupply Interface System. Presented at the European In-Orbit Operations Technology Symposium, September 12-14, 1989, Toulouse, France.

    The international trend toward large, complex, expensive spacecraft has created an emerging requirement for on-orbit logistical support. The ability to resupply consumables on orbit is a key servicing capability that promises to extend the usable life, thereby, reducing life cycle costs of these valuable assets. Automation of fluid resupply is critical to achieve the level of safety, reliability, flexibility, and cost effectiveness necessary to make on-orbit servicing a reality. This paper describes a cooperative effort between NASA and Moog Inc. to develop an automated resupply interface system. Several coordinated efforts were undertaken to develop various elements, including an automated connector carrier, a storable propellant coupling, and a superfluid helium resupply coupling.

4. Darcy, Eric C.; and Tom Barrera (JSC): Crew Emergency Return Vehicle: Electrical Power System Design Study. *Proceedings of the 24th Intersociety Energy Conversion Engineering Conference*, Vol. 6, p. 2641, 1989. Presented at the 24th Intersociety Energy Conversion Engineering Conference, August 9, 1989, Crystal City, Virginia.

The United States is committed to building the permanently manned Space Station Freedom, located in low Earth orbit. Within the five yearly planned Space Shuttle support flights to Freedom, it is postulated that an emergency could require the immediate evacuation of a crew member or the entire crew when the Shuttle is unavailable. To cover this contingency, a Crew Emergency Return Vehicle (CERV) is proposed to perform this lifeboat function. This escape module will be permanently docked to Freedom and, on demand, will be capable of safely returning the crew to Earth. The objective of this work is to gather the unique requirements that the CERV, designed by NASA JSC, presents to its power source and to select a baseline system.

5. Delventhal, Rex; and Nanette Faget (JSC): Space Shuttle RCS Oxidizer Leak Repair for STS-26. Presented at the JANNAF Propulsion Conference, May 23-25, 1989, Cleveland, Ohio.

Following propellant loading of the Space Shuttle's Reaction Control System (RCS) for mission STS-26, an oxidizer leak was detected in the left Orbital Maneuvering System (OMS) pod, where the RCS is located. Subsequent investigation determined that the leak was isolated at a mechanical "Dynatube" fitting near the RCS nitrogen tetroxide tank. An intense effort was initiated to design, fabricate, and qualify a sealing device to externally stop the oxidizer leak so that the Shuttle launch could proceed. It was discovered that sealing devices called "clamshells" were widely used throughout the petrochemical and power generation industries to stop leaks developed in large diameter pipes which carry steam or other hazardous fluids. These clamshells are available in different diameters and strengths and are placed around the pipe in the location of the leak. A sealing compound is then injected into the clamshell under high pressure to stop the leak. This technology was scaled down and applied to the problem of stopping the leak on the Orbiter which was on a half-inch diameter line in a nearly inaccessible location. Many obstacles had to be overcome such as determining that the sealing material would be compatible with the nitrogen tetroxide and that the clamshell would actually fit around the Dynatube fitting without interfering with other lines which were in close proximity.

6. Downey, Michael G.; and Joseph R. Trevathan (JSC): Zero Gravity Vortex Vent and PVT Gaging System. Presented at the JANNAF Propulsion Conference, May 23-25, 1989, Cleveland, Ohio.

Space Station and satellite reservicing will require the ability to vent gas on orbit from liquid supply or storage tanks and to gage liquid quantity under microgravity conditions. In zero-gravity, the Vortex Vent is capable of venting gas from a tank of liquid containing gas randomly distributed as bubbles. The concept uses a spinning impeller to create centrifugal force inside a vortex tube within a tank which creates a gas pocket and forces the liquid through a venturi and back into the tank. Gas is then vented from the gas pocket through a liquid detector and then out through an exhaust port. If the liquid detector senses liquid in the vent line, the fluid is directed to the low pressure port on the venturi and is returned to the tank. The advantages of this system is that it has no rotating seals and is compatible with most corrosive and cryogenic fluids. A prototype was designed

and built at the NASA JSC and flown on the KC-135 zero-gravity aircraft. During these test flights, where microgravity conditions are obtained for up to 30 seconds, the prototype demonstrated that less than 0.10 percent of the volume of fluid vented was liquid when the tank was half full.

7.  Eberhardt, Ralph N.; and John P. Gille (MMSS): Superfluid Helium On-Orbit Resupply. Presented at the Cryogenic Engineering Conference, July 24-28, 1989, Los Angeles, California.

Replenishment of superfluid helium (SFHe) offers the potential to extend the on-orbit life of observatories, satellite instruments, sensors, and laboratories which operate in the 2K temperature regime. A reference set of resupply customers was identified as representing realistic helium servicing requirements and interfaces for the first 10 years of superfluid helium tanker (SFHT) operations. These include the Space Infrared Telescope Facility (SIRTF), the Advanced X-ray Astrophysics Facility (AXAF), the Particle Astrophysics Magnet Facility (Astromag), and the Microgravity and Materials Processing Sciences Facility (MMPS)/Critical Point Phenomena Facility (CPPF). A mixed-fleet approach to SFHT utilization was considered, whereby our 6000 liter tanker concept is compatible with launch on the STS as well as the Delta, Atlas, Titan III, or Titan IV expendable launch vehicles. The tanker permits servicing from the Shuttle cargo bay, in-situ when attached to the Orbital Maneuvering Vehicle (OMV) and carried to the user spacecraft, and as a depot at Space Station.

8.  Faget, Nanette M. (JSC): Shuttle RCS Line Leak Repair for STS-26. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The nitrogen tetroxide tank overflow line of the left pod Reaction Control System (RCS) on Shuttle Orbiter Vehicle 103 developed an overboard leak prior to flight STS-26. The leak was detected by tank pressure decay tests indicating a loss rate of 800 standard cubic centimeters per hour of pressurant. Subsequent investigations determined that the leak was at a mechanical "Dyantube" fitting near the tank. On July 22, 1988, efforts were initiated towards stopping the leak by encapsulation of the exterior of the fitting. This approach enclosed the fitting with a clamshell-like jacket so that a material could be injected as a sealant inside the clamshell to stop the leak. This approach was successfully developed at the JSC and tested at the Thermochemical Test Area. On August 19, 1988, Rockwell technicians at the KSC installed a Rockwell designed clamshell-like jacket, similar in design to the clamshell developed at the JSC, around the leaking fitting on OV-103. A silicon material (Furmanite FSC-6B) was injected into the clamshell and the leak was stopped, allowing launch preparations to proceed as planned. This presentation will focus on the specialized hardware developed, the test program used to evaluate the candidate clamshells and sealants, and the successful teamwork which prevented the nitrogen tetroxide leak from becoming an impact to the launch of STS-26.

9.  Iacabucci, R.; S. Evans; G. Briley (Rocketdyne); and R. Delventhal (JSC): Space Station Technology Development Summary. Presented at the JANNAF Propulsion Conference, May 23-25, 1989, Cleveland, Ohio.

With the completion of the Space Station Advanced Technology Programs in the area of propulsion, the baseline oxygen/hydrogen and waste gas resistojet systems were brought to an acceptable level of readiness. This level included testing of a full end-to-end system in which oxygen and hydrogen were generated electrolytically at 1000 psia, stored and fired through the prototype thruster. Since then, additional testing has been ongoing. This testing includes resistojet life testing, resistojet plume testing, resistojet EMI testing, testing of additional models of

the thruster which involved producibility investigations, and further thruster tests in full end-to-end systems including the 3000 psia Integrated Propulsion Test Article at NASA JSC. This paper will present the results of the testing conducted on the thrusters and resistojet both separately and on the various system test articles subsequent to the completion of the advanced technology programs. A total of five oxygen/hydrogen thrusters have been fabricated to the same basic design and tested to show life and reproducibility. Five resistojets have also been fabricated and tested, with modifications made to improve producibility. The lessons learned in the area of producibility for both the oxygen/hydrogen thrusters and for the resistojet will also be summarized.

10. Johnson, Paul R. (JSC): SPF Fuel Cell Off-Nominal Testing. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Ergenics Power System's, Inc. is currently developing an advanced Fuel Cell Energy Storage System (FCESS) which is under consideration as a power source for the Space Station Extravehicular Mobility Unit (EMU). It consists of a 32 cell stack with passive conduction heat transfer, passive water removal, and metal hydride hydrogen storage. This fuel cell utilizes a Solid Polymer Electrolyte (SPE) proton exchange membrane. SPE fuel cells offer many advantages, including increased cell performance, lower mass, greater tolerance to reactant pressure differentials, and elimination of problems related to toxic electrolytes.

At the NASA JSC the Propulsion and Power Division is performing off-nominal tests on all 18 cell, air-cooled SPE demonstrator fuel cell manufactured by Ergenics Power Systems, Inc. in order to expand the database on the SPE fuel cell and provide data which will help support the operation of the Space Station EMU FCESS. The tests were chosen to evaluate areas of the demonstrator fuel cell that are the most similar to the EMU FCESS. These areas are the cell membrane and cell assembly and the water removal system. The objectives of the testing are to investigate the effects of reactant impurities on the stack performance and purge requirements and to investigate the effects of reduced reactant inlet pressures on the stack performance and water removal system. The results and implications of the tests will be presented.

11. Jones, Donald L. (JSC); and Phillip E. Cota (RIC): Space Shuttle Orbiter Main Propulsion System Flight Safety Enhancement. Presented at the AIAA/ ASME/ SAE/ ASEE Joint Propulsion Conference, July 10-12, 1989, Monterey, California.

The Space Shuttle main propulsion system, like other major vehicle elements, has been the subject of an ongoing program to enhance the flight safety of the Space Transportation System. This activity, inherent in the basic program since its inception, has been the subject of a renewed review of failure modes and effects pertinent to flight critical functions. Select components were further evaluated, their potential for impacting flight safety defined, and then the necessity for change in design and/or operational practices determined. Major examples of such components are the 17-inch disconnect and the gaseous oxygen flow control valve. This paper presents a summary of that activity and provides examples of critical processes and components that have been or are being modified to enhance flight safety.

12. Kandula, Max; and Daniel Pearce (LESC): Computational Fluid Dynamics Analysis of Space Shuttle Main Propulsion Feed Line. *Proceedings of NASA Computational Fluid Dynamics Conference*, pp. 133-148, 1989. Presented at the NASA Computational Fluid Dynamics Conference, March 7-9, 1989, Moffett Field, California.

A steady incompressible three-dimensional (3-D) viscous flow analysis has

been conducted for the Space Shuttle Main Propulsion External Tank (ET)/Orbiter (ORB) propellant feed line quick separable 17-inch disconnect flapper valves for liquid oxygen ($LO_2$) and liquid hydrogen ($LH_2$). The main objectives of the analysis were to predict and correlate the hydrodynamic stability of the flappers and pressure drop with available water test data.

Computational Fluid Dynamics (CFD) computer codes were procured at no cost from the public domain and were modified and extended to carry out the disconnect flow analysis. The grid generator codes SVTGD3D and INGRID, developed by Sverdrup Technology Inc., were obtained from Arnold Air Force Station, Tennessee. NASA Ames Research Center supplied the flow solution code INS3D and the color graphics code PLOT3D. A driver routine was developed to automate the grid generation process. Components such as pipes, elbows, and floppers can be generated with simple commands, and flapper angles can be varied easily. The flow solver INS3D code was modified to treat interior flappers. Other interfacing routines were developed which include a turbulence model and a force/moment routine. In particular, an under-relaxation scheme was implemented to enhance the solution stability. Results of the analysis are presented for $LO_2$ and $LH_2$ disconnects. The predicted stop loads, hydrodynamics stability boundaries of the ET and orbiter flappers, and pressure drop across the valve compare well with the water test data, covering a tube Reynolds number of 3.5E06 for $LO_2$ unit and 2.4E06 for $LH_2$ unit.

13. Karakulko, Witalij (JSC), and Scott Frazier (MDSSC): Optimized Space Shuttle Aft Propulsion Subsystem. Presented at the 1989 AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 10-12, 1989, Monterey, California.

Several proposals for improving the Space Shuttle orbital maneuvering system (OMS) are presently being evaluated by the NASA Office of Space Flight. One of the principal concepts is a pump-fed orbital maneuvering engine, under development by Aerojet Techsystems Company, which provides higher specific impulse, thereby reducing the propellant required for a given mission, or allowing greater velocity change (altitude) for the same propellant quantity. Another proposal integrates the OMS and the aft reaction control system (RCS) together, thereby reducing Orbiter weight, propellant residuals and dispersions, and permitting the RCS propellant to be loaded to meet specific mission requirements. This paper analyzes the performance improvements to the Space Shuttle for a typical manifest in the 1990s and Shuttle high-altitude delivery/reboost missions for several improved OMS configurations.

14. Karakulko, Witalij (JSC); and Scott Frazier (MDSSC): Shuttle Evolution: Improved Aft Propulsion System . Presented at the 1989 AIAA/ASME/SAE/ ASEE Joint Propulsion Conference, July 10-12, 1989, Monterey, California.

Several proposals for improving the Space Shuttle Orbital Maneuvering Subsystem (OMS) are presently being evaluated by the NASA Office of Space Flight. One of the principal concepts is a pump-fed Orbital Maneuvering Engine (OME), under development by Aerojet Techsystems Company. The higher performance of this engine reduces the propellant requirements or allows higher Shuttle altitudes. Another concept integrates the OMS and the aft Reaction Control Subsystem (RCS). This reduces Orbiter weight, propellant residuals and dispersions, and allows the RCS propellant to be loaded to meet specific mission requirements.

15. Kroll, Kenneth R; Nancy E. Munoz; and R. Scott Baird (JSC): An Overview of Zero Gravity Fluid Quantity Gaging. Presented at the 25th Joint Propulsion Conference, July 10-14, 1989, Monterrey, California.

This paper provides an overview of the problems and current activity with zero gravity quantity gaging of two phase fluids. The fundamental purpose of fluid quantity gaging is to prevent inadequate or excessive fluid for the safe and efficient performance of operations. Currently, the direct determination of fluid quantity is conducted by measuring the position of the liquid/ gas interface, requiring an acceleration environment to insure the interface is flat. Since the position of multiple, curved liquid/gas interfaces in zero gravity can not be determined by a single measurement, the existing direct determination methods are incapable of working on a non-accelerating spacecraft. Indirect methods use an inventory of either the liquid or gas flows across a tank interface, requiring a known initial condition. Ground based or non-recovered vehicles use the ground loading quantity as the initial condition. Space based fluid systems will accumulate error using indirect methods, due to repeated usage. Therefore, new methods of gaging two phase fluids are required. This paper assess the current position of gaging technology. In particular, the gaging concepts are identified which are considered ready for flight hardware development and recommend additional testing for other concepts.

16. Le, Michael (JSC): Water Electrolysis Technology for Space Station Propulsion. Presented at the 1989 Spring National Meeting of the American Institute of Chemical Engineers, April 2-6, 1989, Houston, Texas.

The Space Station propulsion system will utilize a water electrolysis system for providing gaseous hydrogen and oxygen propellants at 3000 psi. The water electrolyzer uses primary electrical power from a solar source for converting water into chemical energy. In this capacity, it is intended for the electrolyzer to consume on-board waste water, thus minimizing the expensive resupply of propellants. The electrolyzer will be operated in a sunlit portion of the low Earth orbit (LEO) cycle and idled in the eclipse portion of the orbit. Its use will be required for the 30-year duration of the Station life. Not only does the device have to be power and weight efficient, it must be reliable and require minimal maintenance by the crew. While the electrolysis technology is a mature electrochemical science, development of a safe and reliable flight qualified electrolysis system presents many unique challenges. At JSC two methods of electrolyzing water are being developed, the acid system built by Hamilton Standard and the alkaline system built by Life System, Inc. The basic characteristics of each technology were presented in this paper as well as development issues with material compatibility, water purity, zero-g components, product gas purity, and dew point control. The results of in-house testing of a 3000 psi acid electrolysis unit used in a fully integrated propulsion breadboard system were also discussed and the status of these programs and its future use were presented.

17. Le, Michael (JSC): Space Station Propulsion Electrolysis System -- A Technology Challenge. Presented at the AIAA/ASME/SAE/ASEE 25th Joint Propulsion Conference, July 10-14, 1989, Monterrey, California.

The Space Station propulsion system will utilize a water electrolysis system for producing the required 8 to 1 ratio of gaseous hydrogen and oxygen propellants. The baseline station reboost and contingency strategy requires a significant quantity of propellants stored at extremely low dew point. A water electrolysis system which operates at gas storage pressure of 3000 psi to reduce weight and volume of the storage tanks is preferred. The use of high pressure eliminates the need for separate H2 and O2 gas compressors and produces the electrolysis product gas free of liquid water to minimize the weight of the dessicant dryer.

The water electrolyzer uses primary electrical power from a solar source to

convert water into chemical energy. In this capacity, it is intended that the electrolyzer consume on-board waste water, thus minimizing the expensive resupply of propellants. The electrolyzer will be operated in a sunlit portion of the low Earth orbit (LEO) cycle and idled in the eclipse portion of the orbit. Its use will be required for the 30-year life of the Station.

18. Masetta, John P. (JSC); Richard Gerlach; and Ed Schroeder (SRI): Small Displacement, Long Life On-Orbit Compressor Design and Fabrication. Presented at the JANNAF Propulsion Conference, May 23-25, 1989, Cleveland, Ohio.

    The requirements for a wide range of gases, gas mixtures, and operating conditions have been identified for various Space Station and related on-orbit fluid transfer operations. The practical use of these systems for fluid storage and transfer operations will require compressors capable of long term on-orbit operations over this entire range of requirements.

    The objective of this project is the exploration of compressor technology applicable for use by the Space Station Fluid Management System, Space Station Propulsion System, and the Orbital Spacecraft Consumables Resupply System. The approach is to develop a conceptual design for a compressor that can be adapted to meet the requirements for each of the applications and to fabricate a prototype for one specific application. The prototype development will include a detailed design for the prototype conditions, fabrication of the prototype compressor, and verification testing. Subassembly fabrication and testing will be performed as necessary to support the prototype development.

    The primary emphasis is to develop basic compressor technology (designs, materials, manufacturing techniques) in a time frame consistent with the support of the Space Station fluids sytems development. Design considerations will include: (1) commonality; i.e., interchangeability of common hardware assemblies, (2) maximization of service life, and (3) ease of maintenance.

19. Pham, Michael (JSC): Space Station Utility Distribution System. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

20. Rosenbaum, Bernard J. (JSC): Space Shuttle Hydraulic Subsystem. Presented at the Racine Fluid Power Panel, May 2, 1989, Gurnee, Illinois.

    This presentation discusses the Hydraulic Subsystem on the Space Shuttle. Included are the basic system architecture, general requirements, and how the system is used in the various mission phases. Particular emphasis is placed on the special design considerations that are unique to the Shuttle environment, including zero gravity and the hard vacuum of space. Also discussed are some of the special design issues, how they were resolved, and how the system was tested and certified for flight.

21. Rousar, D. C.; R. D. Harris; and J. L. Pieper (GenCorp Aerojet Tech Systems): Presented at the JANNAF Propulsion Conference, May 23-25, 1989, Cleveland, Ohio.

    Aerojet experience with oxygen/hydrocarbon combustion devices during the 1956-1988 time period is surveyed. Main injectors, gas generators, and igniters which burn either kerosene (RP-1), methane ($CH_4$), propane ($C_3H_8$), or ethanol ($C_2H_5OH$) with liquid or gaseous oxygen are discussed. Experimental performance, combusion stability, heat transfer, and carbon deposition characteristics are presented.

22. Ryder, M. O.; and D. H. Morash (MOOG): Superfluid Helium Orbital Resupply Coupling. Presented at the JANNAF Propulsion Conference, May 23-25, 1989, Cleveland, Ohio.

The resupply of superfluid helium to satellites and other space-based experiment packages can increase the useful longevity of these devices far beyond their present life expectancies. The transfer of superfluid helium to spacecraft in space will require a reusable coupling that functions at 1.8 ° Kelvin with little heat leak and low pressure drop. Moog has designed the helium II resupply coupling to meet these operational requirements. Initially, the coupling manual mode operation will be demonstrated on orbit by an EVA crewmember during the Space Shuttle borne Superfluid Helium On-Orbit Transfer (SHOOT) experiment. The ultimate application will use a robotic (automatic) coupling operation to which the present design rapidly adapts.

This paper describes the utilization of Moog's exclusive rotary shut-off (RSO) technology in the development of the superfluid helium resupply coupling. The coupling not only performs the function of a flow control valve and disconnect, but it also provides adequate safety features for a Shuttle launched man-rated payload. In addition, the coupling incorporates the necessary features to provide the high thermal isolation of the internal flow path from the external environment.

23. Scott, Walter (JSC); Doug Meyer; and Kent Weber (SATG): Electric Auxiliary Power Unit for Shuttle Evolution. Presented at the 25th AIAA/ASME Joint Propulsion Conference, July 10-12, 1989, Monterey, California.

The Space Shuttle Orbiter currently uses three hydrazine-fueled auxiliary power units (APUs) to provide hydraulic power for the vehicle aerodynamic surface controls, main engine thrust vector control, landing gear, steering, and brakes. Electric APUs have been proposed as possible replacements for the hydrazine APUs. Along with the potential advantages, this paper describes an electric APU configuration and addresses the technical issues and risks associated with the subsystem components. Additionally, characteristics of an electric APU compared to the existing APU and the direction of future study with respect to the electric APU are suggested.

24. Van Leuvan, K. (BASG): RF Modal Quantity Gaging. *The Chemical Propulsion Information Agency (CPIA) Publication 515*, Vol. 1, pp. 471-478. Presented at the JANNAF Propulsion Conference, May 23-25, 1989, Cleveland, Ohio.

The primary objective of this paper is to provide a concept exposition of a radio frequency modal resonance technique that is being investigated as a method for gaging the quantities of subcritical cryogenic propellants in metallic tanks. Of special interest are the potential applications of the technique to microgravity propellant gaging situations. The results of concept testing using cryogenic oxygen, hydrogen, and nitrogen as well as paraffin simulations of microgravity fluid orientations are reported.

1.  Arepalli, Sivaram (LESC):  Demonstration of the Feasibility of Laser-induced Fluorescence for Arc Jet Flow Diagnostics, NASA CR 185595, October 1989.
    Laser-induced fluorescence (LIF) studies are carried out on nitric oxide and oxygen molecules in the arc jet flows at the JSC Reentry Testing Facility.  Measurements are taken in the free stream and from a blunt body shock layer.  Tests are performed under different flow conditions to determine the feasibility and sensitivity of the LIF technique for various species.  The LIF technique is developed as part of high enthalpy flow diagnostics and will be useful to elucidate the rotational and vibrational temperatures.  Adequate sensitivity for the detection of O2 and NO is demonstrated and proposed improvements of the current system are presented.

2.  Arepalli, Sivaram (LESC); H. Blackwell (BSA); R. Willey (NU); Eric Yuen (JSC); and C. D. Scott (JSC):  Plasma Diagnostics for the Arc Jet Facility.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    Progress made in the diagnostics program at the Atmospheric Reentry Testing Facility at JSC is detailed.  Optical emission and mass spectrometric studies have been used for identifying the different atomic and molecular species in the arc jet plasma as well as for some qualitative mapping of the free stream and the shock layer.  These studies will allow the determination of temperature gradients across the shock layer and an attempt to understand the transition from non-equilibrium to equilibrium across the shock.  The preliminary results of a feasibility study on the proposed doppler measurements will also be discussed using a ring dye laser and present details of current and future laser-based diagnostics program.

3.  Babel, H.W.; Brian D. Vickers (MDSSC); and Donald A Thomas (JSC):  Sustained Load Behavior of Graphite/Epoxy Metal-lined Tanks for Long Life Space Applications.  Presented at the AIAA 25th Joint Propulsion Conference, July 10-14, 1989, Monterey, California.
    Large lightweight pressure vessels operating at high pressures are required for manned space structures.  The most weight efficient vessels under consideration use high strength graphite/epoxy (Gr/Ep) overwrapped on a metal liner.  These vessels must resist failures under sustained pressure loads as their explosive potential is a threat to both the space structure and the crew safety.  However, long term data for Gr/Ep pressure vessels subjected to sustained loads are limited.  The McDonnell Douglas Space Systems Company has recently completed sustained load tests and analysis on 3.75-inch diameter composite pressure vessels overwrapped with high strength 38-45 Msi modulus PAN based graphite fibers.  Sustained load tests were conducted at 97% of the average vessel burst strength.  Various graphite fibers were evaluated based on their time-to-failure using Weibull statistical methods.  Analysis of the results together with published Gr/Ep composite data indicate that sustained load effects may not be a design driver for composite tanks used in long duration space missions.  As an example, a conservative analysis predicts that the probability of surviving stress rupture for 30 years is 99.99% at sustained pressure levels of 63% of the average burst strength.

4.  Bilardo, Vincent J. (NASA Hqs.); and William Van Dusen (RIC):  Development of an Operational Helium Leak Detection Program for the Space Shuttle Program.  Presented at the Materials Evaluation Conference, American Society for Nondestructive Testing, November 1989, Columbus, Ohio.
    This paper outlines the development of an operational mass spectrometer helium leak detection program for the Space Shuttle Program at KSC and Vandenberg launch site.  Leak detection is the primary nondestructive test

technique used to revalidate Space Shuttle Orbiter fluid systems during ground turnaround operations between flights. Of the various techniques available, helium mass spectrometry is the most challenging due to the relatively complex equipment, field environment, and operator training required for consistent performance.

5.  Blackwell, Harvel E. (BSA); Eric Yuen (JSC); Sivaram Arepalli (LESC); Carl D. Scott (JSC): Nonequilibrium Shock Layer Temperature Profiles from ARC Jet Radiation Measurements. Presented at the AIAA 24th Thermophysics Conference, June 12-14, 1989, Buffalo, New York.

Shock layer temperature profiles are obtained through analysis of radiation from shock layers produced by a blunt body inserted in arc jet flow. Spectral measurements have been made in a nitrogen flow of 54.4 gm/s at an enthalpy of 8.72 MJ/kg. Vibrational temperatures for $N2+$ are obtained by matching spectral regions from arc jet spectra with spectra generated using the NEQAIR code. Temperature profiles obtained from the radiation layers show a vibrational temperature higher than the rotational temperature near the front of the shock and both temperatures decrease as the flow approaches the body. The spectral measurements are made and analysis completed for four distances from the surface of the blunt body. The corresponding shock layer thickness is approximately 3.6 cm. Although nonequilibrium, the measured rotational temperature approaches the single temperature results of viscous shock layer calculations at this test condition.

6.  Blackwell, Harvel E. (BSA); Frederic A. Wierum (Rice); Sivaram Arepalli (LESC); and Carl D. Scott (JSC): Vibrational Temperature from Measurements of N2 and $N2+$ Shock Layer Radiation. Presented at the AIAA 27th Aerospace Sciences Meeting, January 9-12, 1989, Reno, Nevada.

Measurements of the vibrational temperature in the shock layer produced by a cylindrical blunt body in an arc jet flow are made for both the neutral molecule and the molecular ion. Shocks produced under two arc flow conditions are investigated: a high enthalpy case, 31.784 MJ/kg with a mass flow of 0.0227 kg/s, and a lower enthalpy case, 22.864 MJ/kg with a mass flow of 0.0454 kg/s. Spectra were obtained from the air shock layer of a 20-cm long cylindrical blunt body inserted in the arc jet conical flow. The technique used for determining temperatures from the spectral radiation involves obtaining ratios of integrated intensities for certain spectral regions of the measured spectrum and making a comparison with ratios computed as a function of temperature for the same regions.

7.  Ehlers, H. K. F. (JSC): Spacecraft External Molecular Contamination Analysis. Presented at the Space Operations, Autonomy, and Robotics (SOAR) Conference, July 25-27, 1989, Houston, Texas

Control of contamination on and around spacecraft is required to avoid adverse effects on the performance of instruments and spacecraft systems. Several tasks are necessary to successfully control contamination: development of a contamination control plan, definition of requirements, prediction of contamination levels based on spacecraft parameters by means of "modeling", measurement and analysis of processes which lead to excessive contamination levels, and verification/monitoring of contamination levels during spacecraft missions. Recent work in some of these areas is discussed. Specific issues and limitations to be considered as part of the effort to predict contamination effects using modeling techniques are addressed. Significant results of Space Shuttle missions in the field of molecule/surface interactions as well as their implications for Space Station design and operation are reviewed.

8.  Fowler, M.; L. Leger; M. Donohoo (JSC); and P. Maley (RI): Contamination of
    Spacecraft by Recontact of Dumped Liquids. Presented at the SOAR Confer-
    ence, July 25-27, 1989, Houston, Texas.

    Liquids partially freeze when dumped from spacecraft producing particles
    which are ejected into free space at various velocities. Recontact of these
    ejected particles with the spacecraft is possible for specific particle sizes and
    velocities and, therefore, can become contaminated for experiments within the
    spacecraft or experiments released from the spacecraft. Since such contamina-
    tion can be produced from waste and potable water dumped from space shuttle,
    an examination of dump characteristics was conducted on STS-29 using both on-
    board video records and ground based measurements. A preliminary analysis of
    data from this flight was presented.

9.  Hong, Sun I. (RIC): Automation Techniques for Thermal Analysis of Spacecraft Sys-
    tems. Presented at the 24th AIAA Thermophysics Conference, June 12-15, 1989,
    Buffalo, New York.

    Design and performance evaluation of current and future hypersonic flight
    vehicles including Shuttle Orbiter, National Aerospace Plane (NASP), and Crew
    Escape Reentry Vehicle (CERV) require rigorous and very extensive thermal
    analyses. These analyses are imperative to ensure adequate design and proper
    safety margins of the spacecraft systems for given mission requirements. Ther-
    mal analyses have been performed without aids from the integrated automatic
    procedures for construction of nodalized thermal models, incorporation of initial
    and boundary conditions, and other necessary modifications. These manual pro-
    cesses mandate consumption of considerable manpower which could otherwise
    be utilized for other tasks. In order to improve these time consuming and tedious
    analysis procedures, an engineering concept and methodology for thermal anal-
    ysis automation has been developed and implemented in Space Shuttle Orbiter
    thermal analysis areas. This paper presents and discusses this automated ther-
    mal analysis methodology.

10. King, Guy L.; and Ted Tsai (JSC): The Design and Analysis of a Double Swivel Tog-
    gle Release Mechanism for the Orbiter Stabilized Payload Deployment System.
    Presented at the 23rd Aerospace Mechanisms Symposium, May 3-5, 1989,
    Huntsville, Alabama.

    A new NASA deployment system called the Stabilized Payload Deployment
    System (SPDS) will soon be operational. The lightweight and heavy-duty system
    rolls payloads over the orbiter's side rather than ejecting them upward. The sys-
    tem will enhance the orbiter capability of carrying larger and heavier payloads.
    This paper describes the design, the function, and the analysis of a new 3-pin
    "double" swivel toggle release mechanism which is crucial to the successful
    development of the SPDS.

11. Larsen, Curtis E. (JSC); and Loren D. Lutes (AMU): An Improved Spectral Method
    for Variable Amplitude Fatigue Prediction. Presented at the Energy-Sources
    Technology Conference and Exhibition, January 22-26, 1989, Houston, Texas.

    The dependence of fatigue damage accumulation on power spectral density
    (PSD) is investigated for several types of random processes relevant to the stres-
    ses in offshore structures. Representative data have been obtained from rainflow
    analysis of time histories simulated from both unimodal and bimodal pad func-
    tions. These data are used to test the accuracy of spectral approximation meth-
    ods in which the damage predictions are made from fairly simple calculational
    operations on the PSD function. Primary emphasis is placed on the commonly

used Rayleigh approximation method and a new method which involves calculation of only one spectral moment (i.e., one integral of the PSD). The new method is shown to be substantially more accurate than the Rayleigh approximation for some bimodal PSDs. In some other situations the results of these two methods are very similar. No situation is found in which the new method is significantly less accurate than the Rayleigh method.

The spectral methods are also shown to be useful for determining the consequences of truncation of a given PSD. That is, one can estimate the effect of a high frequency component or a low frequency component on the rate of damage accumulation in order to determine whether that component could reasonably be ignored. This question of truncation effects is very common since it is always present in simulation studies for realistic PSDs.

12. Larsen, Curtis E.; and Timothy T. Cao (JSC): Feasibility of Treadmill Isolation for the Space Station Freedom Microgravity Environment. Presented at the 60th Shock and Vibration Symposium, November 14-16, 1989, Virginia Beach and Norfolk Naval Shipyard, Norfolk, Virginia.

In this study the crewperson/treadmill is modeled as a six degree-of-freedom mass-sprint-damper system which is coupled to a detailed NASTRAN finite element model of the assembly complete stage of the Space Station Freedom (SSF). To perform transient response analyses, the combined system of equations of motion is transformed into modal coordinates containing a truncated number of modes. The retained number of modes depend on the desired accuracy and the evolution characteristics of the forcing function. This technique requires the solution of a large dimension eigenvalue problem to obtain system modes and, if there is a change in the treadmill model or the attachment location, the modal coupling and subsequent transient analyses must be repeated. As an alternative, the crewperson/treadmill and SSF models are represented separately in a hybrid form with the attachment interface DOF retained as physical. The size of the mass and stiffness matrices associated with this degree of freedom is usually much smaller than the size of the free-free crewperson/treadmill/SSF model. Accelerations at the interface DOF are used as excitation to the SSF and treadmill equations of motion. These equations are integrated separately by utilizing a Newmark scheme. Forcing functions approximating crewperson walking and jogging are applied to the crewperson/treadmill model and the resultant acceleration levels are compared to the currently defined requirements for the microgravity environment. Relative displacements are also reported between the crewperson and the treadmill, and between the treadmill and the mounting location to assess the required volume for the treadmill exercise area. The proposed isolation scheme requires soft mounting of the treadmill, in combination with some form of ballasting, to lower the first natural frequency of the crewperson/treadmill system below that of any other vibration modes of the SSF. Further reduction of the microgravity environment experienced within the LAB is proposed by rigid mounting of the experiments to the equipment racks and the module structure. The proposed isolation scheme thus provides the widest possible frequency separation between the vibration source and the sensitive experiments.

13. Larsen, Curtis E. (JSC); and Loren D. Lutes (AMU): An Improved Spectral Method for Variable Amplitude Fatigue Prediction. Presented at the Energy-Sources Technology Conference and Exhibition, January 22-26, 1989, Houston, Texas.

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14. Lawson, Mike (JSC); and Norm Allen (LESC): Development of a Preprototype Advanced Extravehicular Mobility Unit Regenerable Life Support Subsystem. Presented at the 19th Intersociety Conference on Environmental Systems, July 24-26, 1989, San Diego, California.

Regenerable life support technologies are being developed by JSC's Crew and Thermal Systems Division for use in the advanced extravehicular mobility unit onboard Space Station Freedom. Steady progress has occurred in vital technology areas in the NASA supporting development program over the past few years, but some design options must still be evaluated before the final selections are made for the flight hardware. A "preprototype" hardware program has been initiated to define further options. "Preprototype" is used to designate hardware that performs like flight hardware but may have a different form and fit. LESC, under an Engineering Support Contract with JSC, has been asked to support this program by designing, procuring, integrating, and testing this hardware. This paper describes the actions to date and those planned for the next 3 years to perform this interim technology readiness demonstration.

15. Mackey, Alden C.; Curtis E. Larsen (JSC): Space Station Freedom Requirements for Structural Safety, Reliability and Verification. Presented at the 5th International Conference on Structural Safety and Reliability, August 8-11, 1989, San Francisco, California.

The Space Station Freedom (SSF) Program has established extensive safety, reliability, and verification requirements to ensure the integrity of the SSF structure during its projected 30-year lifetime. All primary, secondary, and support equipment structure must be designed to safe life requirements, and all Truss members and interface structure except the Truss modes must be designed to meet fail-safe requirements. Protection from micro-meteoroids and debris will be accomplished by shields or design of the structure to accept the particle impact. Pressure vessels must be designed to leak before rupture, and overall station design must consider the effects of a failed or burst pressure vessel. Reliability requirements are for fault tolerance of all systems during assembly and long-term operation, structural design to properly provide for effects of failures, and allowance for Truss replacement. Verification requirements include dynamic math model verification of components and assemblies, stress models to be verified by comparison of predictions to ground static test results, and ground simulations to verify the on-orbit assembly process.

16.  Mackey, P. C.; and M. A. Kneeland (LESC):  Orbiter TPS/TCS Instrumentation Drawings/Heater.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

An Obiter Thermal Protection System (TPS)/Thermal Control System (TCS) Instrumentation Drawings/Heater computer Aided Design (CAD) Relational Data Base program is being written to relate thermocouples to locations on the vehicle, plus references to instrumentation drawings and schematics.  It will provide the ability for quick access to data during mission support.  The data base will be menu driven, taking advantage of the X-Windows package, the standard windowing package for Space Station efforts.  Compression and decompression routines will be written to provide minimum storage requirements without losing needed data.  A raster editing capability will allow the user to cleanup the image, apply colors, add and delete thermocouple identifiers, and group portions of the schematic together as single objects.  For example, a schematic containing hydraulic, freon, water and fuel lines could be modified to apply a particular color to each line.  Each line could be treated as an overlay, allowing the user to view any combination of the lines by placing one on top of the other and building the desired picture from the individual objects.  The overall package will reside on an Apollo 4500 workstation, making it compatible with the Thermal Synthesizer System's Apollo network.

17.  Monteleone, Frank J. (LESC):  Johnson Space Center Materials and Processes Requirement Experiment.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The development of the current Materials and Processes requirements used on the Space Shuttle and now adopted by the operational National Space Transportation System (NSTS) are traced from NASA's Mercury Program of the early 1960's.

The intent and the primary objectives of the Materials and Processes requirements from inception to present will be discussed.  In particular, the important lessons learned from NASA problems and solutions will be addressed in view of the development of safety and functionality in the Materials and Processes Requirements Evolution to Space Station Freedom.

18.  Panczak, T. D. (LESC):  A Fast, Linear Time, Monte Carlo Radiation Interchange Program Utilizing Adaptive Spatially Coherent Subdivision. *Sixth International Conference on Numerical Methods in Thermal Problems Proceedings*, Vol. VI, Part 1, pp. 702-712, July 1989.  Presented at the 6th International Conference on Numerical Methods in Thermal Problems, July 3-7, 1989, Swansea, U.K.

A Monte Carlo raytracing radiation interchange analysis program that utilizes an adaptive, spatially coherent datastructure to reduce the number of ray/object intersection calculations is presented.  The program is a part of an advanced integrated computer aided thermodynamics design and analysis system developed for JSC.  The advantages of analyzing radiation interchange using Monte Carlo techniques have long been known.  The most important advantages are the ability to analyze models with directional and spectral surface property variations, and the simple and direct implementation of the algorithm in a massively parallel computational environment.  Proper application of the algorithm also leads to a simpler user interface as compared with present grey body analysis codes.  The raytracing algorithm also has advantages over view factor matrix methods even when the model consists of only grey surfaces.  The method is not widely used because of the extensive computational resources required by the algorithm.  The complexity of the basic algorithm severely limits the size of problems.  However, the desire to generate photo-realistic graphics images for advertising and special

effects has motivated a great deal of research in the graphics industry to improve the efficiency of the raytracing algorithm. The methods for improving raytracing for image generation are directly applicable to improving raytracing for radiation interchange and orbital heating.

Two popular classes of algorithms were reviewed: hiearchical bounding volume schemes and spatially coherent subdivision. An adaptive method utilizing a spatially coherent oct-cell datastructure was chosen because of its ease of implementation into the basic raytrace algorithm, the consistent performance of the algorithm for a wide variety of geometric configurations, and the transparency of the algorithm to the end user. Results are presented that demonstrate a time complexity that is linear with problem size.

19. Pedley, Michael D. (LESC): Materials for Pressurized Oxygen Systems. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Ideal materials for use in pressurized oxygen systems should have the mechanical properties required to function effectively and should also be nonflammable in oxygen at all use pressures. In reality, this combination of properties is almost impossible to find. All known polymeric materials are flammable in oxygen at ambient pressure (14.7 psia or 101.3 kPa). Metallic materials are generally more resistant to ignition than polymers, but Monel alloys are the only common structural materials that are nonflammable at pressures above 7 MPa (1000 psia). Because all pressurized oxygen systems require some polymeric materials and Monel alloys are generally unsuitable for spacecraft hardware (poor strength-to-weight ratio and fatigue resistance combined with high cost), we accept that flammable materials must be used in spacecraft oxygen systems. However, fires in oxygen systems can cause extensive damage to spacecraft before they self extinguish.

20. Sarkani, S. (GWU); and Curtis E. Larsen (JSC): Extrema Simulation by First Order Auto-Regressive Models. Presented at the IASTD International Conference, Applied Simulation and Modeling, November 13-15, 1989, Santa Barbara, California.

To determine the reliability of a structural component, designers often simulate the loadings that the component is expected to carry during its service life. For structural members that are subjected to time dependent loads (which are generally of random nature as well) fatigue failure is often the dominant failure mode. Example of such structures include aircrafts, highway bridges, and offshore structures. The usual method of simulating a stochastic time history for fatigue analysis is the Gaussian simulation technique. An improved version (in terms of computation time) of this technique utilizes the so-called Fast Fourier Transform (FFT). This method may not be desirable for fatigue studies since the entire time history is simulated while only the extrema are needed for the analysis. This shortcoming has prompted a number of investigators to examine other methods of simulating stochastic time histories. One such method is the so-called auto-regressive technique, in which the current value of time history is computed as the linear combination of its previous values plus an independent random increment. This idea can be used to either simulate the entire time history at discrete intervals or to simulate the extrema of the time history. For the purpose of reliability analysis against fatigue failure, the auto-regressive technique can be used directly to generate the extrema of the time history. Several different auto-regressive models useful for fatigue studies are discussed. Results of both simulation and experimental studies are presented to establish the validity of the auto-regressive models. Short-comings of the auto-regressive models and modifications for future improvements are also discussed.

21. Shivakumar, V.; and J. M. Beek (LESC): Solutions for Through Crack Geometries Using the Boundary Element Method in Combination with the Fracture Analog of Love's Nuclei of Strain. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The analysis of fatigue crack propagation in metal components, essential to fracture control analysis of space systems and structures, is performed using computer programs like NASA/FLAGRO. This program contains around 25 models in its library of crack geometries which include many of the common fracture configurations encountered in practice. However, geometries which do not fall within the available set are frequently encountered and the only resource until now has been to choose a solution that models the actual component conservatively, even at the expense of similitude. The Boundary Force Program, written to form a companion package with NASA/FLAGRO, is capable of obtaining stress intensity solutions for through-the-thickness cracks as well as performing regular stress analysis for any two-dimensional geometry in a state of plane stress or strain.

22. Thomas, Donald A. (JSC): Future Microgravity Materials Processing Programs for the United States. Presented at the AIAA 14th Annual Technical Symposium, May 18, 1989, Houston, Texas.

The 1980's have seen the lead in microgravity materials processing, established by the U.S. during the Apollo, Skylab, and Apollo-Soyuz Test Project Programs of the 1970's, shift to the Soviet Union and Western European countries. Significant strides and aggressive microgravity programs in Europe and Japan also threaten domination of the commercialization of materials processing in space. A number of new U.S. microgravity materials processing initiatives have been approved for the 1990's. These include both dedicated Spacelab missions (e.g., U.S. Microgravity Lab and U.S. Microgravity Pallet series) and initial studies of the Space Station Furnace Facility (SSFF). The future NASA microgravity materials processing programs and facilities development for Space Station Freedom will be reviewed together with a forecast of the commercialization opportunities anticipated for the 1990's and beyond.

22. Thomas, Donald A. (JSC): Technique for Assessing 30 Year Lifetime Capabilities of Graphite/Epoxy Materials for Space Station Freedom Pressure Vessels. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The current baseline design for Space Station Freedom requires many pressure vessels for liquids and gases to operate propulsion systems, fluid management and distribution systems, and miscellaneous gases for Space Station operation. Graphite/epoxy (Gr/Ep) composite overwrapped pressure vessels are being considered for use on Space Station because of their light weight and high efficiency. These vessels must resist failures under sustained pressure loads for crew safety considerations and adequate protection of the space structure during their 30-year life. However, extremely limited data are available on the stress rupture behavior of these materials over the 30-year time period of interest. Weibull statistics have been applied to the times-to-fail under sustained load for graphite/epoxy composite materials. Use of this methodology permits an assessment to be made of the 30-year stress rupture survival probability of these pressure vessels under various levels of sustained load. Both the technique and the lifetime predictions made for Space Station pressure vessels will be discussed.

23. Visentine, J. T.; and A. E. Potter, Jr. (JSC): *In-Space Technology Development: Atomic Oxygen and Orbital Debris Effects.* NASA TM 102154, May 1989.

   Earlier Shuttle flight experiments have shown atomic oxygen within the orbital environment can interact with many materials to produce surface recession and mass loss and combine catalytically with other constituents to generate visible and infrared glows. In addition to these effects, examinations of returned satellite hardware have shown many spacecraft materials are also susceptible to damage from high velocity impacts with orbital space debris. These effects are of particular concern for large, multi-mission spacecraft, such as Space Station and SDI operational satellites, that will operate in low-Earth orbit (LEO) during the late 1990's. Not only must these spacecraft include new materials and exterior coatings that are resistant to atomic oxygen surface interactions, but these materials must also provide adequate protection against erosion and pitting that could result from numerous impacts with small particles (less than 100 microns) of orbital space debris. This report will present an overview of these concerns and outline activities now underway to develop materials and coatings that will provide adequate atomic protection for future spacecraft. It will also discuss atomic oxygen and orbital debris flight experiments now under development to expand our limited data base, correlate ground-based measurements with flight results, and develop an orbital debris collision warning system for use by future spacecraft.

24. Wade, Donald C. (JSC): Systems Interoperability Approach: Apollo-Soyuz Test Project. Presented at the Crew Safety and Rescue in Space Workshop, June 7, 1989, Le Bourget, France.

   The performance of routine joint flights and/or rescue missions requires the capability to rendezvous, dock, and transfer the crew members from one spacecraft to the other. The first international demonstration of these capabilities was the United States' and Soviet Union's Apollo/Soyuz Test Project mission 1975. This mission used slightly modified Apollo and Soyuz Spacecraft, a new jointly designed docking system, a new docking module (used as an airlock), and many existing flight and ground systems. This highly successful joint flight was the culmination of 5 years of unprecedented cooperation between the two countries on a space project. Many logistics, communications and technical problems had to be overcome along the way. Communication was more of a problem than technology in developing the joint program. While language and distance contributed to the communication problem, the major difficulty was the diverse philosophies for spacecraft design, development, and operations which were so widely separated that a great chasm of differences had to be bridged before the technical work could be completed. Five joint Soviet-American working groups spent long hours, over many months, negotiating and reconciling the differences to produce a successful mission. This presentation describes the joint approaches used to design and develop the new hardware and to insure the compatibility of existing systems used for this mission.

25. West, M. P. (LESC): Rigid Body Mode Condensation for Dynamic Transient Response Analysis of Free-Free Structures. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

   In transient structural dynamic analysis by direct time integration. free-free structures present numerical difficulties due to the presence of rigid body motion. While use of modal superposition for transient analysis effectively eliminates this problem, other difficulties may arise in the reduction of large problems to normal modes, especially if the loading is impulsive, or if many modes exist in the frequency range of interest for vibration response. In the present paper, a

procedure for condensation of rigid body modes of free-free structures is presented. The method is based on the orthogonality between rigid body modes and elastic modes. This orthogonality constraint leads to a reduction in the degrees of freedom of the system equal to the number of rigid body modes. Direct time integration of the equations of motion then gives the elastic motion only. Implementation of the method using NASTRAN is illustrated for several example problems.

26.  Xu, Gene (LESC); and Michael West (LESC): An Iterative Algorithm for Correlation of Strain Gage Data with Aerodynamic Load. Presented at the 14th Annual Technical Symposium, May 18, 1989, Houston, Texas.

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 in the following that iteration of this scheme can improve the accuracy of the computed pressure distribution.

27.  Yin, Dah N. (RI): Local Stiffener and Skin Pocket Buckling Prediction by Special PASCO Modeling Technique: Correlation to Test Data. *NASA Conference Publication 10024*, pp. 13-21, 1989. Presented at the AIAA/ASME/ ASCE/ AHS/ ASC 30th Structures, Structural Dynamics and Materials Conference, April 3-5, 1989, Mobile, Alabama.

Two analysis techniques are briefly described for computing buckling allowable of waffle type panels. Experimental testing was performed on the blade stiffened panel subject to pure compressive load. The PASCO model with five small elements simulating the fillet radius yielded the most accurate result when compared with the result of the experiment. The prediction from WAFFLE, a Rockwell developed program, was conservative. It is suggested that WAFFLE be used for calculating general instability, and PASCO for stiffener and skin pocket buckling.

28.  Yin, Dah N. (RI): Space Shuttle Commit-To-Flight Thermal Assessment. *A Collection of Technical Papers*, Paper No. 89-1229, Part 2, pp. 640-644, 1989. Presented at the AIAA/ASME/ASCE/AHS/ASC 30th Structures, Structural Dynamics and Materials Conference, April 3-5, 1989, Mobile, Alabama.

Commit-to-flight activity for the Space Shuttle orbiter requires that temperature distribution predictions be used to predict thermal stresses in the orbiter shell and frame structure. A new method of analysis based on finite sum modeling and a three dimensional temperature distribution is used to take into account all available temperature data on a cross section. This method was developed specifically for commit-to-flight activity and is a unique synthesis of a known finite sum algorythm, utilizing a least square optimization technique. In conjunction with the finite sum method, a method based on the temperature distribution on several discreet nodes is also developed. This simpler method is neither as accurate nor as dependable as the finite sum method but is useful when applied in conjunction with the finite sum method.

29.  Zipay, John J. (JSC):  Should the U. S. Participate in Future Manned Space Missions with the Soviets.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

On April 10, 1989, a seminar was held in the Bldg. 2 auditorium to address this question.  James Oberg presented some of the latest information on the Soviet Space Program and Vance Brand related his experiences with the Soviets on Apollo-Soyuz.  The audience was made up of NASA technical employees with under ten years experience.  The audience was pre-polled prior to the event and re-polled after the event to determine how they felt about possible missions with the Soviets.  The results of the poll and the issues raised during the seminar are presented.

1. Hare, Richard K. (MITRE): Independent Security Assessments at Johnson Space Center. Presented at the Fifth Annual Computer Security Applications Conference, December 7, 1989, Tucson, Arizona.

2. Krishen, Kumar (JSC): Technology Development at NASA/Johnson Space Center. Presented at the NASA Science and Technology Council Meeting, November 2-3, 1989, Jet Propulsion Laboratory, Pasadena, California.

   NASA/Johnson Space Center (JSC) is pursuing technology development in both critical and enabling categories for future space programs. The anticipated benefits of this advanced technology also include safety, reliability, and enhanced projectivity for both space and ground operations. These technology areas support future NASA programs which include Shuttle, Space Station Freedom, Earth Observation, Lunar Outpost, and Mars Missions. This lecture will cover specific technology pursued currently at JSC will be discussed. Progress made and anticipated results in each technology area will also be reviewed.

1.  Ferry, Dennis L.; and Fred M. Richards (MITRE):  What Makes a Good Benchmark?
    Presented at the International Conference on Management and Performance
    Evaluation of Computer Systems, December 11-15, 1989, Reno, Nevada.
         The purpose of this paper is to address the development of performance
    benchmarks used in the computer acquisition process.  In this context a good
    benchmark is one reasonably representative of the workload intended for the
    system being acquired as well as one which can be developed in a cost-effective
    and timely manner.  The intention is not to discuss the hows of benchmarking, but
    rather some of the whats and whys, thereby helping to shape a practical and
    effective benchmarking philosophy.  The perspective of the paper is that of the
    performance analyst and as such is concerned with what can affect system per-
    formance, including hardware architecture, operating system, runtime environ-
    ment, language translators, and workload.

1.  Baffes, Paul (JSC): NETS: A Tool for the Development and Evaluation of Neural Networks. Presented at the JAIPCC Technical Symposium, March 23, 1989, Houston, Texas.

    A description of a software package called NETS is discussed. NETS is a neural network simulator produced by the Artificial Intelligence Section of the Mission Planning and Analysis Division at NASA/Johnson Space Center. NETS allows a user to create arbitrary networks of nodes and connections which can be trained to "learn" a set of data pairs via the "back propagation" algorithm. The simulator requires no special hardware, and will run on a variety of machines. To date, NETS has been supplemented on the following machines: IBM personal computers, Apple Macintosh, VAX, Sun, and the HP 9000. NETS is free to NASA and NASA contractors and comes with full documentation of its features provided in the NETS User's Guide.

2.  Benson, S. A.; and N. W. Parrott (MDSSC): EPSYS - A Script-Based Planning Architecture for Coordinated Expert System. Presented at the JAIPCC Technical Symposium, March 23, 1989, Houston, Texas.

    The Electrical Power System Expert System (EPSYS) is a prototype of an architecture which hierarchically distributes anomaly evaluation and response generation responsibilities among a group of subsystem manager expert systems and a subsystem coordinator. The EPSYS architecture supports a script-based planning system for response generation through its integration of rules and procedures. The architecture is implemented using a modified version of CLIPS known as SCLIPS. SCLIPS utilizes a declarative construct known as a script for the expression and evaluation of plans and algorithms.

3.  Bowling, Alan (MDSSC): Space Station Freedom Core Resupply Optimization. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    Station Integrated Core Logistics Optimizing Processor (SICLOP) is currently being designed to optimize delivery strategies for Space Station Freedom core resupply items. Core resupply is defined as all items, fluids, and gasses required to keep Freedom operational. Resuppling delivery strategies currently involve replacing the exact amount of material used since the last delivery without consideration for future resupply requirements. This results in poor utilizaton of the delivery system resources. Many times carriers (used to hold the resupply items in the STS payload bay) are sent up as much as 80% empty. One way to optimize th delivery system resources is to "backmanifest," that is, to deliver resupply items before they are needed. However, to find the "best" solution is a very complex problem since many permutations are possible. SICLOP is being designed to find the "best" solutions.

    A prototype has been developed in order to answer two basic questions: can the resupply problem be analytically modelled, and will optimized resupply scenarios be generated? The optimizer used was a commercially available package called SUPER GINO, a nonlinear optimizer which can handle models with up to 50 equations and 100 variables.

4.  Cernosek, Gary J. (MDSSC): An Analysis of Strategies for Integrating Non-Ada Software Into an Ada Environment. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    Initiatives for inserting the Ada language and its related technologies into NASA's new programs are conceptually sound. However, there are many challenges facing the engineers responsible for actually making Ada development a part of the mainstream workplace. Possibly the most difficult problems stem from

the fact that NASA has a tremendous investment in their existing non-Ada software base and desires to recover as much of its functionality as possible. Since Ada cannot implicitly add quality to existing software, care must be taken to ensure that existing code recovery efforts are practical and appropriate to the software engineering principles that Ada is designed to support. This paper presents five strategies for integrating non-Ada software into an Ada environment. The techniques are then analyzed for their support in producing well-engineered Ada products. Each method is cited for its advantages, limitations, and recommended usages.

5. Cernosek, Gary J. (MDSSC): Strategies Toward a Comprehensive Reusable Parts Engineering Environment. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

A requirements framework is presented for addressing the impact of a reuse-oriented approach to software development. The requirements areas for a parts engineering subdiscipline of software engineering are structured in response to the following questions:

- What is a "part" and how does one build "reusable" parts? These are concerns for the *Parts Definition* activity (the <u>construction</u> aspects).
- How are parts going to be stored, retrieved, and managed? These are concerns for the *Parts Library and Change Management* function (the <u>organization</u> aspects).
- How can an application developer efficiently incorporate existing parts into the application development process? These are concerns for the *Parts-Based Application Development Methodology* studies (the <u>incorporation</u> aspects).
- How can one assess the potential benefits (e.g., return on investment) in building and reusing parts? This question directs us to the need for *Reuse-Oriented Cost / Benefit Analysis and Modeling* (the <u>amortization</u> aspects)

Past efforts are identified that support these activities. Current efforts are then presented that build on these existing efforts to extend and integrate them into a comprehensive reuse-oriented environment.

6. Chu, Wen-Ho (MDSSC): Balance Spreadsheet Method for Analysis of the Space Station IWS Water and RCS Propellant Requirements. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

By treating sources and sinks of fluids in a system as the debits and credits of assets in an account, the complexity of fluid systems analysis can be reduced. By treating sources as assets, sinks as liabilities, and the unused sources or tank fluid levels as owner's equity, fluid changes as a function of time can be programmed using Lotus 1-2-3. The Lotus spreadsheet may be easily changed to perform trade studies or to investigate different system design requirements. This analysis method is illustrated by using information from the Space Station Integrated Water System (IWS) Architectural Control Document (ACD) and the Reaction Control System (RCS) specifications to analyze the IWS water and the RCS propellant requirements for a given Space Station assembly sequence. The balance spreadsheet method may also be applied to other subsystems of the Fluid Management Systems and to other Space Station systems, especially the Environmental Control and Life Support System, and the United States Logistics System.

7. Chu, Wen-Ho (MDSSC): Mass Analysis for the Space Station ECLSS Using the Balance Spreadsheet Method. Presented at the SAE 19th Annual Intersociety Conference on Environmental System (ICES), July 24-26, 1989, San Diego, California.

The balance spreadsheet method, introduced by the author for the analysis of the Space Station Integrated Water System (IWS) water and Reaction Control System (RCS) propellant requirements, is applied to mass analysis of the Environmental Control and Life Support System (ECLSS). This method is used to analyze the requirements for ECLSS carbon dioxide, latent water, crew potable water, crew waste water, animal potable water, animal hygiene water, hydrogen, oxygen, nitrogen, and various solid wastes. The spreadsheet layout, developed under the Lotus 1-2-3 environment, reduces the complexity of the ECLSS analysis by concisely defining the sources, sinks, and net changes in mass for each fluid. This approach also builds the database by assigning an area for time-independent data and another one so that layout modifications and formula implementations can be easily accomplished. The analysis method is illustrated by using information from the latest Space Station ECLSS Architectural Control Documents and a given Space Station assembly sequence. The analysis results are tabulated, plotted, and discussed. Trade studies for some ECLSS processing equipment and other kinds of ECLSS mass analysis are also discussed.

8.  Cleghorn, Timothy F.; Paul T. Baffes; and Lui Wang (JSC): Robot Path Planning Using a Genetic Algorithm. Presented at the Robotics in Aerospace Conference, Society of Manufacturing Engineers, February 1989, Anaheim, California.

Robot path planning can refer either to a mobile vehicle such as a Mars Rover, or to an end effector on an arm moving through a cluttered workspace. In both instances there may exist many solutions, some of which are better than others, either in terms of distance traversed, energy expended, or joint angle or reach capabilities. A path planning program has been developed based upon a genetic algorithm. This program assumes global knowledge of the terrain or workspace, and provides a family of "good" paths between the initial and final points. Details of the algorithm will be discussed.

9.  DeFelice, Dane M. (MDSSC): A Quantitative Method of Determining Delivery Requirements for Space Station Freedom Orbital Replaceable Units (ORUs). Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

An efficient ORU delivery strategy must solve two problems: the replacement of failed ORUs, and the delivery of an optimal set of ORUs to be stowed and used as spares on-board the Space Station Freedom. An optimal spares for delivery set can be defined as those stowed ORUs which would most effectively reduce the risk of danger to the crew and mission in the event of an on-line component failure. Therefore, the quantitative determination of delivery requirements necessitates the capabilities of anticipating ORU failures and formulating an optimal spares set for the prescribed planning period.

To develop failed ORU replacement models and optimal spares sets, a priority scheme based on the risk associated with the failure of each operational ORU must be developed. Such a scheme would utilize a quantitative risk factor based on the probability of failure and criticality of each on-line ORU. After determining which ORUs must be supplied to the Space Station Freedom, delivery requirements based on the physical characteristics, transportation constraints, and stowage limitations of the selected ORUs can be developed and integrated into a total system resupply strategy.

10.  Everett, Shonn F. (MDSSC): Real Time Determination of Desired Shuttle Attitude. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The flight officers with mission control would like to have a method of determining what the current shuttle attitude should be at any time during second stage flight. In the event the shuttle is not flying at the currently desired attitude due to some failure or error, the crew could be told what attitude to fly manually. The desired attitude should be provided for the nominal mission or any currently selected abort mode. The calculation of the desired attitude is provided by a Fortran subroutine which can be added to the existing MCC Abort Region Determinator (ARD), which predicts the current abort capability in real-time throughout shuttle ascent. The desired attitude can be with given the following information; initial mass properties, desired target, desired thrust parameters calculated by the powered explicit guidance routine, current throttle settings (or burn rates), and current position and velocity (provided by telemetry). The method of solution was presented at this symposium.

11.  Funk, Matthew S. (MDSSC): STS Guidance Flight Software Upgrade: The Universal Pointing Enhancement. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

A future Space Shuttle flight software release (OI-20) will include an enhanced On-Orbit Guidance Universal Pointing (UP) processor. The UP Processor allows attitude maneuvers to be executed automatically during on-orbit coasting flight. Presently, only one current and one future automatic maneuver can be loaded by the crew, and maneuvers may be performed and displayed only in inertial coordinates. The crew must manually enter each maneuver and change the Digital Autopilot (DAP) load and jet configurations. The UP enhancement allows up to 25 future maneuvers, which can be uplinked or crew entered. A summarized format is used to display basic information (start time, option, and DAP load/jet configuration selections) about the current and future automatic maneuvers without the need to edit the maneuvers. Either inertial or local vertical, local horizontal reference frames are permitted for executing maneuvers and displaying attitude data. The enhancement will automatically select DAP load and jet configuration when attitude or tracking orientation is achieved. In addition, greater flexibility in creating maneuvers is possible with the addition of a new option (track/rotate) and clockwise/counter-clockwise rotation directions. The UP display is easier to use since targets and body vectors have individual item numbers and only required data is displayed when editing a maneuver. The UP enhancement frees the crew from monitoring maneuver execution, allows more flexibility in creating and executing maneuvers, and displays maneuver and attitude data in an easier to understand format.

12.  Gottlieb, Robert G. (MDSSC): Eccentricity-Intercept Targeting and Guidance (EITAG). Presented at the AIAA Computer & Software Systems Technical Exchange Meeting, May 24, 1989, Houston, Texas.

The phrase "Eccentricity-Intercept" is meant to convey the notion that two different curves of eccentricity, e, vs semi-major-axis, a, have hit or intersected. The targeting and guidance strategy herein derives from the observed empirical fact that low thrust along the horizontal velocity vector causes the semi-major axis to increase linearly and the eccentricity to change cyclically. A typical example of eccentricity vs semi-major axis is shown in Fig 3. Since a is essentially constant, a is linearly related to time, and using a as independent variable is equivalent to using time as independent variable with one exception. When thrust is terminated time increases, but 3 and a do not change. This fact makes the e-a plane the preferred plane for viewing the reboost process since no motion occurs when there is no thrust.

Every point in the e-a plane represents an orbit. If no thrusting occurs, the point

will stay fixed. If thrusting starts, the point will move because the orbit will be altered. However, it is a fact that the direction of the resulting motion in the e-a plane depends entirely on the position in the orbit where thrusting is initiated. It is also true that no matter where in the orbit thrusting is initiated, a plot of e vs a will be cyclical.

These observed facts can be used to develop a simple reboost targeting and guidance strategy.

13. Griffin, Sandy (JSC): *Graphics Technology in Space Applications Proceedings.* CP 3045,July 1989.

Papers presented at the Graphics Technology in Space Applications hosted by University of Houston, Clear Lake at Johnson Space Center on April 12, 13, and 14, 1989 are documented herein. During the three days, approximately 35 papers were presented. Technical topics addressed included Graphics Standards, Graphics Applications, and Tools, Merging of Graphics and Video Display Technology, Partial Task and Stand Alone Simulations, Space Station Freedom Graphics and Large Scale Simulations.

14. Jack, Linda S. (JSC): Space Station Freedom Onboard Navigation. Presented at the National Technical Association Meeting, April 8, 1989, Houston, Texas.

The baselined navigation system onboard the Space Station Freedom will utilize the Navigation Timing and Ranging Global Positioning System (NAVSTAR GPS). NAVSTAR GPS is at the forefront in navigation technology. This navigation system is a very accurate and highly reliable worldwide positioning tool developed by the Department of Defense. It can provide navigation information via radio signals transmitted from space-based satellites. The navigation system onboard Freedom will receive the GPS transmitted signals and process the data with a very sophisticated Kalman filter. The output of this filter will be accurate state vectors to all users.

15. Kilgore, M. V.; R. J. Zahorchak; and W. F. Arendale (UA): Definition of a Near Real-Time Microbiological Monitor for Space Vehicles, NASA CR 185599, 1989.

16. Kullman, Annette;  Grayum Watts; Kurt Schmeckpeper; Barry Fox; David Roman (MDSSC); Dan Bochesler; and Yashvant Jani (LinCom): Demonstrations of Expert Systems. Presented at the SOAR '89 Conference, July 25-27, 1989, Houston, Texas.

In the course of development of a test bed for analysis and demonstration of space vehicle operations autonomy (AUTOPS), we have developed several expert systems to perform vehicle fault detection, isolation, and recovery and to provide rudimentary mission planning for proximity operations, mission monitoring, and replanning to accommodate anomalous events. We intend to present these results at SOAR '89 by providing demonstrations on SUN computers and via videotape presentations, as appropriate. We also would like to demonstrate planning and scheduling tools developed under NASA contracts and at McDonnell Douglas Research Lab that would find potential use in NASA programs and activities.

17. Kullman, Annette; and Grayum Watts (MDSSC): A Shuttle-Like Fault Diagnostic Propulsion Expert System. Presented at the JAIPCC Technical Symposium, March 23, 1989, Houston, Texas.

The Propulsion Expert System (PROPSYS) is a prototype for a fault management system. It is a rule-based system written in CLIPS and the user interface

was developed using TAEPLUS and Xwindows. PROPSYS will be a part of a distributed network of cooperating expert systems which will manage and monitor the performance of an automonous vehicle's subsystems. PROPSYS will assess the health of the propulsion subsystem and cooperate with the vehicle system monitoring during fault analysis and recovery. PROPSYS fault detection consists of four main modules: tank faults, manifold faults, heater faults, and jet faults.

18. Lardas, Mark N. (MDSSC): The Effects of Tethered Operations on the Orbiter's Inertial Trajectory. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The most ambitious Shuttle missions ever planned, the first full-scale test of a large tethered satellite system, will take place in 1991. The Orbiter will be linked to a 500 kg payload by a 20-km tether, an action with a profound effect on the trajectory of the Orbiter. For the first time in the history of the Shuttle Program, the vehicle will conduct prolonged operations with the orbiting system's center of mass a significant distance from the Space Shuttle Orbiter's center of mass, a violation of a fundamental assumption made in both the Orbiter ground-based and on-board navigation software.

Inertial navigation of tethered operations with the Shuttle is further complicated by the presence of nonconservative forces, electrodynamics and RCS effects, due to different RCS control modes, commanded attitudes, and attitude deadbands.

19. Lea, Robert N. (JSC): Applications of Fuzzy Sets to Rule-Based Expert System Development. *Telematics and Informatics*, Vol. 6, No 3-4, pp. 403-406, 1989. *NASA CP-3033*, pp. 385-388, 1989. Presented at the 1989 Goddard Conference on Space Applications of Artificial Intelligence, May 16-17, 1989, Greenbelt, Maryland.

In this paper problems of implementing rule-based expert systems using fuzzy sets are considered. A fuzzy logic software development shell is used that allows inclusion of both crisp and fuzzy rules in decision making and process control problems.

Results are given that compare this type of expert system to a human expert in some specific applications. Advantages and disadvantages of such systems are discussed.

20. Lea, Robert N. (JSC); Yashvant Jani (LinCom); and Annette Kullman (MDSSC): Future Spacecraft Operations with Fuzzy Logic Hardware. *Proceedings of Satellite Services Workshop IV*, Vol. 2, pp. 215-231, June 1989. Presented at the Satellite Services Workshop IV, June 21-23, 1989, Houston, Texas.

Novel fuzzy microprocessors being developed by Yamakawa in Japan and by Togai InfraLogic in California process more than 30,000 fuzzy inferences per second in hardware. The microprocessors can be used in a stand-alone mode or as a coprocessor. Potential applications in spacecraft operations include management of redundant sensor data, control of relative motion, attitude control, and robotic arm control (motion of end-effector as well as the grapple mechanism).

Autonomous spacecraft operations with knowledge-based expert systems can also greatly benefit from these speed and performance capabilities (e.g., fault detection and isolation). This paper discusses the advantages of these microprocessors and a few highly innovative applications related to satellite servicing.

21. Lea, Robert N. (JSC); Yashvant Jani (LinCom); Jon Teichrow; and Masaki Togai (TIL): Fuzzy Logic Approach to Combined Translational and Rotational Control of

a Spacecraft in Proximity of the Space Station. *Proceedings of the Space Artificial Intelligence, Robotics, and Automation Symposium*, pp. 126-131, October 1989. *Proceedings of the Third International Congress of the Fuzzy Systems Association*, pp. 23-29, August 1989. Presented at the Space Artificial Intelligence, Robotics, and Automation Symposium, October 18-19, 1989, Tokyo, Japan. Presented at the Third International Congress of the Fuzzy Systems Association, August 6-11, 1989, Seattle, Washington.

Relative trajectory control of a spacecraft using fuzzy membership functions and fuzzy rules has been demonstrated using a simulation of the Space Shuttle and solar max satellite. A fuzzy logic attitude control system for three axes rotational control is being developed using Togai's Fuzzy-C Development System. This attitude control will be combined with relative trajectory control to form a six-degree-of-freedom controller for proximity operations around another spacecraft. A methodology to combine these two control systems will be presented. A high fidelity spacecraft simulation with graphics will be used for detailed testing and checkout of this controller and its performance will be compared with conventional control systems.

22. Lea, Robert N. (JSC); and Yashvant Jani (LinCom): Spacecraft Attitude Control System Based on Fuzzy Logic Principles. Presented at the Robotics and Expert Systems Workshop 1989, August 2-4, 1989, Palo Alto, California.

A spacecraft attitude control system is designed using the fuzzy logic principles. A typical phase plane was used to derive the fuzzy rules for generating correction torques. The membership function definitions were based on the performance requirements of the spacecraft. A preliminary version of the control system for single axis was implemented using Togai's fuzzy-C compiler and fuzzy chip emulator.

23. Lee, Kevin A. (MDSSC): Relative Navigation of a Tethered Satellite Mission. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

A Shuttle mission planned in 1991 will test the feasibility of tethers in space. This mission, a joint effort between Italy and the United States, will connect a satellite (built by the Italians) to the Shuttle with a 20-km-long tether. This mission poses unique navigation problems. The flight software on the Shuttle was never designed to account for the low level acceleration generated by the gravity gradient. IMU's on the Shuttle will sense the acceleration of the tether, but the accelerometer noise generates greater errors than the unmolded acceleration. Relative navigation is another important issue since the majority of the mission will be conducted while the satellite's motion is desirable. Feedback of the satellite motion can be generated by using the rendezvous radar. To process the radar measurements, the flight software uses a 13 state kalman filter, but unfortunately with the filter as it is currently tuned, valid measurements tend to be ignored. Performance analysis shows that this mission can be safely navigated and the results of this analysis, as well as the trade-offs, will be presented.

24. Lee-Taylor, Karen E. (MDSSC): An OMS for a Software Development and Operational Environment. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

At the heart of any software system is the data management capabilities. Many believe that some data, like commonly shared information, is best managed by a database management system (DBMS) and some data, like source code, is best managed by a file management system (FMS). Combining the DBMS and FMS capabilities relieves the user concern about physical representations and

storage information which frees the user to concentrate on solving the "real" problem.

In support of an environment for the development and operation of engineering analysis software, the Object Management System (OMS) provides this combination of DBMS and FMS services creating a single access point for all data in the system. The OMS also overcomes some of the problems inherent in the relational data model. For example, the relational model is often inadequate for the management of engineering data especially in the area of the limited available data types . The OMS provides a core set of object classes tailorable to provide the exact data typing needs of the user. This presentation will discuss many of the concepts behind the OMS in general and the Knowledge Based Executive (KBE) OMS in particular including the KBE OMS object model and the support of an Ada interface for programmatic access to objects.

25. Lowenthal, Richard J. (MDSSC): A New Variable Altitude Strategy for the Space Station Freedom. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Successful completion of the Space Station Freedom's projected 30-year goals necessitates a careful analysis of the environment in which it will exist. The newly proposed altitude strategy accommodates the variations in solar flux over this long duration. The strategy is designed to take advantage of solar flux minimums as well as to reduce the danger of an unplanned reentry during periods of greater solar energy output.

Previous altitude studies have concentrated on such operational issues as microgravitational effects, with its inherent emphasis on payloads, while others sought a constant altitude, with its apparent advantage of reducing planning complexity. The overall importance of these issues has not diminished, but their priorities with respect to altitude planning have changed to some degree. The latest area of primary concern is the orbital lifetime of the Station.

26. McCormick, Bernell (MDSSC): Collision Probabilities in Geosynchronous Orbit and Techniques to Control the Environment. *Orbital Debris From Upper-Stage Breakup*, Vol. 121, 1989.

This paper addresses the physical crowding problem of geosynchronous satellites by summarizing two independent analyses. The first analysis included developing a new technique for predicting the expected time between collisions of active geosynchronous satellites with expired geosynchronous satellites. The unique feature of this new technique is that deterministic methods are used to model the motion of satellites and statistical techniques are employed to estimate collision probability. This allows realistic distributions of active and expired satellites to be used in the prediction process. The results of this new technique compare very closely to the results of previously used techniques. The second analysis addresses disposal options for spent upper stages (PAM-D, KUS, etc.) that are currently left in stable elliptical orbits. These spent upper stages are a hazard to the geosynchronous region as well as low earth orbits. Two propulsive techniques are presented that will reduce the orbit life time of the spent upper stages.

27. McNenny, Robert W. (JSC); and Roger A. Burke (MDSSC): VV&T Advantages Provided by the ID3 Algorithm. Presented at the IJCAI-89 Workshop: Verification, Validation, and Testing of Knowledge Base Systems, August 19, 1989, Detroit, Michigan.

The VV&T benefits obtained by using an ID3-based tool to create expert systems (also known as knowledge based systems (KBS)) to implement heuristic classification reasoning (including the implementation of Rushby's minimal

competency concept) are described and illustrated. Representative aerospace KBS applications using heuristic classification reasoning are identified to illustrate the range and depth of the applications to which the ID3 algorithm is suited. Particular attention is devoted to describing how ID3 facilitates domain expert and domain referee participation in code walk-throughs, peer reviews, and design reviews; code susceptibility to test inspections is also addressed. ID3's automatic detection of conflicting, subsumed, and missing rules are illustrated, as is the suitability of its output to structural testing using conventional software test methods.

28.  Mendoza, Frank Adam (LinCom); and David Roman (MDSSC): Mixed Language Simulations - A Path To Ada. Presented at the Fall '89 Southwest Simulation Conference, September 27-28, 1989, Houston, Texas.

In constructing a test bed for autonomous space vehicles, there is a need to integrate C-language and Fortran simulations with control programs written in Ada to maximize the reuse of existing code. In this paper the design and implementation of Ada programs which serve as interfaces to the simulations and as a clearing house for data produced by one or more of the simulations are discussed. The simulations currently in use are written in C, but the techniques employed are generally applicable to other languages. Specific development areas include developing a mechanism to identify simulation output variables, acquiring and storing values of these variables from the simulations, and providing a means of retrieval of data for single variables or blocks of variables from any source simulation.

29.  Paddock, Eddie J.; Anthony S. Pocklington; Frank P. Kittle, Jr.; and Lui Wang (MDSSC): An Approach to a Real-Time Distribution System. Presented at the SOAR '89, Third Annual Workshop on Automation and Robotics, July 25-27, 1989, Houston, Texas.

The requirements of a real-time data distribution system are to provide fast, reliable delivery of data from source to destination with little or no impact to the data source. In this particular case the data sources are inside an operational environment, the Mission Control Center (MCC), and any workstation receiving data directly from the operational computer must conform to the software standards of the MCC. In order to supply data to development workstations, it is, therefore, necessary to use gateways that prevent unauthorized data transfer back to the operational computers.

Many software programs produced on the development workstations are targeted for real-time operation. Therefore, these programs must migrate from the development workstation to the operational workstation. It is another requirement for the Data Distribution System to ensure smooth transition of the data interfaces for the application developers. A standard data interface model has already been set up for the operational environment, so the interface between the distribution system and the application software was developed to match that model as closely as possible. The system, as a whole, allows the rapid development of real-time applications without impacting the data sources.

30.  Pierce, C. J.; and R. G. Coleman (MDSSC): Logistics and Operations Integration Requirements to Support Station-Based Servicing of Free Flyer Satellites. Presented at the Satellite Services Workshop IV, June 21-23, 1989, Houston, Texas.

The servicing of free flyer satellites at an orbital base will require a unique set of logistics and operations integration requirements. The planning process must be modeled so that the required operations and associated integration

activities, products, schedules, and interfaces can be identified and merged with those of other operations support elements. If the servicing concept is to become a reality, the development and operational deployment of servicing vehicles, such as the Orbital Maneuvering Vehicle (OMV), and of growth concepts, including OMV-derivative and other orbital/space transfer vehicles, is essential. The planned family of satellites designed for on-orbit servicing in the early 21st century presents a formidable challenge to logistics and operations planning. The performance capabilities of the servicing vehicles, orbital base altitude profile strategy, trajectory predictions, available orbital servicing resources, and lift capability and frequency of the Earth-to-LEO space transportation vehicles all place restrictive limitations on a comprehensive servicing plan for free flyer spacecraft. Traffic models for a representative time period, following an assumed initial orbital servicing operations capability, will be developed in order to assess and define the attendant logistical and operational requirements. This presentation will describe ongoing studies, the anticipated form and character of an integrated set of servicing operations planning guidelines and requirements, and various related issues.

31.  Pirker, Dana M. (MDSSC):  Onboard Navigational State Degradation During the Tethered Satellite System Mission - 1.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The degradation of the navigational state accuracy as modeled by Shuttle onboard navigation system is examined. Responses to the loss of communications scenario are proposed for three cases. The first two cases examine navigational performance during a "nominal" attitude profile, the first controlled by the Vernier Reaction Control System, the second controlled by the Primary Reaction Control System. The third case is identical to the first, with the inclusion of modeled tether electrodynamical forces. Comparisons of trajectories propagated from the onboard navigational state-vector and a reference ephemeris state-vector were performed, with the tether cut simulated at various points during the mission. Additionally, updates to the onboard navigational state via ground uplinks were provided prior to the assumed loss of communication. Through these comparisons, the onboard navigation state error was determined. Alternative responses result from efforts to minimize this error during the various phases of TSS-1 deployment. These results demonstrated existing NASA flight rules were not violated by cutting the tether, but that doing so greatly degraded navigation performance, particularly during the end of the reel-out phase of deployment.

32.  Schemeckpeper, K.; J. P. Aldridge; S. Benson; S. Horner; A. Kullman; T. Mulder; W. Parrott; D. Roman; G. Watts (MDSSC); and Daniel C. Bochsler (LinCom): Applications of Graphics to Support a Testbed for Autonomous Space Vehicle Presented at the Graphics Technology in Space Applications Conference, April 12-14, 1989, Houston, Texas.

We describe our experience using graphics tools and utilities while building an application, AUTOPS, that uses a graphical Macintosh (TM)-like interface for the input and display of data, and animation graphics to enhance the presentation of results of autonomous space vehicle operations simulations. AUTOPS is a test bed for evaluating decisions for intelligent control systems for autonomous vehicles. Decisions made by an intelligent control system, e.g., a revised mission plan, might be displayed to the user in textual format or he can witness the effects of those decisions via "out of the window" graphics animations. Although a textual description conveys essentials, a graphics animation conveys the replanning results in a more convincing way. Similarily, iconic and menu-driven screen interfaces provide the user with more meaningful options and

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displays. We present our experiences with the SunView and TAE Plus graphics tools that we used for interface design, and the JSC Interactive Graphics Laboratory animation graphics tools that we used for generating our "out of the window" graphics.

33. Shelton, Robert O. (JSC): An Application of the Fuzzy Ring Network to Machine Vision. Presented at the JAIPCC Technical Symposium, March 23, 1989, Houston, Texas.

A fundamental problem in machine vision is to perform object identification in the presence of translation, rotation, and scale distortion. This problem is addressed by a prototype system which uses a fuzzy ring neural network to determine the class and orientation of three-dimensional images. The fuzzy ring network, developed by Taber for identification of underwater acoustic signals, incorporates fuzzy logic into a neural network which is very similar to the spatiotemporal pattern recognition network of Hecht-Nielsen. A modified Hough transform is used to preprocess the raw images. The transform converts rotation into a phase shift which the network is designed to recognize. The network output is decoded by a very simple fuzzy classifier.

34. Shelton, Robert (JSC): NETS: A Tool for the Development and Evaluation of Neural Networks. Presented at the JAIPCC Technical Symposium, March 23, 1989, Houston, Texas.

A description of a software package called NETS is discussed. NETS is a neural network simulator produced by the Artificial Intelligence Section of the Mission Planning and Analysis Division at NASA JSC. NETS allows a user to create arbitrary networks of nodes and connections which can be trained to "learn" a set of data pairs via the "back propagation" algorithm. The simulator requires no special hardware, and will run on a variety of machines. NETS has been supplemented on the following machines: IBM personal computers, Apple Macintosh, VAX, Sun, and the HP 9000. NETS is free to NASA and NASA contractors and comes with full documentation of its features provided with the NETS User's Guide.

35. Sponaugle, Steven J.; and Stanley T. Fernandes (MDSSC): Space Shuttle Guidance for Multiple Main Engine Failures During First Stage. *AIAA Journal of Guidance, Control, and Dynamics*, Vol 12, No. 6, November - December, 1989.

This paper presents contingency abort guidance schemes recently developed for multiple Space Shuttle main engine failures during the first two minutes of flight (first stage). The ascent and entry guidance schemes significantly improve the probability of the crew and the orbiter surviving a first stage contingency abort. Both guidance schemes meet specified structural and controllability constraints. In addition, flexibility was designed into both systems to allow for seasonal variations in the atmosphere and wind. The ascent scheme guides the vehicle to a lofted state at solid rocket booster burnout while reducing the structural loads on the vehicle. After orbiter separation from the solid rockets and the external tank, the entry scheme guides the orbiter through one of two possible entries. If the proper altitude, range and velocity conditions have been met, a return-to-launch-site maneuver can be attempted. Otherwise, a downrange abort to a controlled glide and subsequent crew bailout are performed.

36. Tabor, Jill (MDSSC): Graphical Perspectives on the Orbital Debris Environment. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Currently, the trackable orbital debris population is cataloged in the U.S. Space Command database and defined by each object's specific orbital elements. In an attempt to generate a more illustrative representation of the debris population, an investigation of the statistical characteristics of the debris population as a function of such parameters as altitude and inclination has been done. The effect which these parameters and others, such as the relative collision velocity, have upon collision probability estimates has also been examined.

By calculating the points at which the orbit of each debris object intersect an earth-centered spherical shell of a given radius, it is possible to graphically repre-sent the spatial distribution of all the debris objects which pass through a speci-fied altitude region. Such a depiction of the trackable orbital debris population provides a lucid, more comprehensible perspective of the debris environment. It affords insight into observed trends in estimates, previously obtained for the prob-ability of collision between debris objects and a target object as the altitude and inclination of the target is varied, and has the potential for other applications as well.

37.  Vedder, John D.; and Jill L. Tabor (MDSSC):  Quantifying the Inevitable:  The Grow-ing Peril of Orbital Collisions.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

An unconventional but general method for estimating the probability of collision between an earth orbiting spacecraft and orbital debris is described. This method uses a Monte Carlo simulation of the orbital motion of the target spacecraft and each discrete debris object to generate an empirical set of distances, with each distance representing the separation between the spacecraft and the nearest debris object at random times. Using concepts from the asymptotic theory of extreme order statistics, an analytical density function is fitted to this set of mini-mum distances. From this function it is possible to generate realistic collision estimates for the spacecraft.

The method described has a number of distinct advantages. For a known or hypothetical debris population and a known target orbit, it enables a rather direct, intuitive, and flexible approach to estimating the probability of collisions. This approach can cope easily with an arbitrary target orbit and an inhomogeneous debris distribution. The method also lends itself well to scaling for a debris popu-lation which may either change in size in the future, or which may be under-estimated because of current observability limitations.

Although the emphasis in this paper is to describe the method, some represent-ative numerical results are included as well. These results are of interest to the Space Station and Shuttle Programs and are also useful for comparison with those previously reported in the literature.

38.  Vedder, John D. (MDSSC):  Statistical Characterization of the Tracked Orbital Debris Population.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Several methods of characterizing the tracked orbital debris population have been devised for the purpose of evaluating the collision hazard which it poses to the Shuttle and Space Station. Analogies to other dynamic particle populations have been exploited to formulate collision probability models for orbital debris using the methods developed for these other particle ensembles.

Although some such analogies do exist, the orbital debris problem is essentially sui generis. A population, whose kinematics are governed by the laws of orbital motion in a central force field with perturbations, is not characterized well by the same statistics as prevail for such particle ensembles as in kinetic gas theory,

particle beams, etc. It is, therefore, worth exploring other statistical approaches to the orbital debris problem.

One such approach which will be discussed is the application of the asymptotic theory of extreme order statistics to the distribution of minimum distances between a potential target and the nearest debris object at any given time. Pertinent data for this approach can be readily generated by a Monte Carlo simulation using actual ephemerides of the tracked debris population and an arbitrary target orbit. Because this data can be generated from such specific information and because of the consequent realism inherent in the data, analysis of the data should lead to useful conclusions about the collision hazard of specific concern.

39. Villarreal, James; and Paul Baffes (JSC): Sunspot Prediction using Neural Networks. Presented at SOAR 89, July 25-27, 1989, Houston, Texas.

The earliest systematic observance of sunspot activity is known to have been discovered by the Chinese in 1382 during the Ming Dynasty (1368 - 1644) when spots on the sun were noticed by looking at it through thick, forest fire smoke. Not until after the 18th century did sunspot levels become more than a source of wonderment and curiosity. Since 1834 reliable sunspot data has been collected by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Naval Observatory. Recently, considerable effort has been placed upon the study of the effects of sunspots on the ecosystem and the space environment. This chapter describes the efforts of the Artificial Intelligence Section of the Mission Planning and Analysis Division of the JSC involving the prediction of sunspot activity using neural network technologies.

40. Warren, Wayne; Bong Wie (UTA); and David Geller (JSC): Periodic-Disturbance Accommodating Control of Space Station for Asymptotic Momentum Management. *Journal of Guidance, Control, and Dynamics*, 1989. Presented at the AIAA GN&C Conference, August 1989, Boston, Massachusetts.

Periodic maneuvering control is developed for asymptotic momentum management of control moment gyros used as primary actuating devices for the Space Station. The proposed controller utilizes the concepts of quaternion feedback control and periodic-disturbance accommodation to achieve oscillations about the constant torque equilibrium attitude, while minimizing the control effort required. Three-axis couple equations of motion, written in terms of quaternions, are derived for roll/yaw controller design and stability analysis. It is shown that the quaternion feedback controller is very robust for a wide range of pitch angles. It is also shown that the proposed controller tunes the open-loop unstable vehicle to a stable oscillatory motion which minimizes the control effort needed for steady-state operations.

41. Weed, Daniel (MDSSC): Minimum Droop Guidance Algorithm. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Early loss of more than one Space Shuttle Main Engine during second stage powered flight can result in the altitude of the vehicle drooping below a minimum altitude of 265,000 feet. This altitude is the minimum safe altitude defined by aerodynamic heating constraints on the External Tank. If the vehicle can remain above this altitude, it may be possible to reach a TAL landing site. If the vehicle cannot remain above this altitude, the crew must be warned far enough in advance to begin contingency abort procedures leading to a bailout and loss of the Shuttle and payload. Therefore, a guidance algorithm would be desirable which will predict if the vehicle will descend below the minimum safe altitude and also determine the vertical thrust elevation necessary to remain above the minimum altitude. The algorithm presented explicitly solves the equations of motion

for the vertical thrust elevation and the time to the minimum droop altitude for any given initial conditions. This desired elevation then becomes a new thrust elevation limit imposed on the Powered Explicit Guidance (PEG) solution.

Results from using this algorithm as an adjunct to PEG show MECO velocities can be improved on the order of 1000 ft/sec in some cases, while remaining above the minimum altitude where PEG alone would not. The algorithm also gives as much as 400 seconds of warning if the vehicle cannot remain above 265,000 feet.

42. Williams, Linda J. F. (MDSSC): Reducing Brittleness in Expert Systems. Presented at the JAIPCC Technical Symposium, March 23, 1989, Houston, Texas.

The majority of expert systems being deployed today use heuristics as the major source of knowledge. This type of expertise, in the form of associational information, is often a short cut to solving problems. However, most expert systems using only heuristics will eventually be faced with a problem that cannot be matched to one of the associational rules in the knowledge base (i.e., a novel situation) and the expert system will fail. Not that the code will break, but the expert system will be hard pressed to even suggest an adequate path of reasoning to follow. The movement toward more complete system autonomy has suggested environments where the expert system will be required to understand and deal with novel situations.

43. Wood, Ron (MDSSC): A Banking Torque Prediction/Correction Technique for the Aeroassist Flight Experiment (AFE) (& Other Fixed-Geometry Aerobraking Vehicles). Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

This paper develops a method for the atmospheric guidance of fixed-geometry aerobraking vehicles (such as the AFE) to predict and subsequently correct for the effects of banking torques caused by offsets in the center of gravity. The banking torque has been seen in Monte Carlo analyses (dispersion analyses) of AFE aeropass trajectories to seriously impact vehicle performance due to the fact that the AFE mission includes a planned period of approximately 30 seconds in which no jet activity will take place. Aside from minimal jet firings (i.e., minimal fuel consumption) always being desirable, on-board experiments will sample the flow and take measurements during this time. Jet firings would contaminate the flow and the readings. The 30-second interval is referred to as the "quiescent period" (QP) and is initiated at a specific point in the trajectory. It will be terminated prematurely only if mission success comes into jeopardy. Monte Carlo results have revealed difficulties in the ability of the atmospheric guidance algorithms to obtain 30 continuous seconds of QP. This is because the banking torque can sometimes cause the lift vector to sufficiently deviate from the nominal that premature skip-out can occur. Therefore, guidance would terminate the QP early, fire the jets, and force the lift vector to a commanded position. To alleviate the problem, the guidance must be given the ability to predict the torque the vehicle will experience in the QP and in some way correct for it prior to QP start.

44. Wood, Ron (MDSSC): The Controllability of the Aeroassist Flight Experiment Atmospheric Skip Trajectory. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The Aeroassist Flight Experiment (AFE) will be the first vehicle to simulate a return from geosynchronous orbit, deplete energy during an aerobraking maneuver, and navigate back out of the atmosphere to a low Earth orbit. It will gather scientific data necessary for future Aeroassisted Orbital Transfer Vehicles (AOTVs). Critical to mission success is the ability of the atmospheric guidance to

accurately attain a targeted postaeropass orbital apogee while nulling inclination errors and compensating for dispersions in state, aerodynamic, and atmospheric parameters. In trying to satisfy mission constraints, atmospheric entry-interface (EI) conditions, guidance gains, vehicle weight, and Earth-atmosphere modeling were investigated for effects on the trajectory. This paper presents the results of the investigation, emphasizing the adverse effects of dispersed atmospheres on trajectory controllability.

1. Griffin, Sandra (JSC): Graphics Technology in Space Applications Proceedings. NASA CP 3045, July 1989.

    Papers presented at the Graphics Technology in Space Applications hosted by University of Houston, Clear Lake at Johnson Space Center on April 12, 13, and 14, 1989 are documented herein. During the three days, approximately 35 papers were presented. Technical topics addressed included Graphics Standards, Graphics Applications, and Tools, Merging of Graphics and Video Display Technology, Partial Task and Stand Alone Simulations, Space Station Freedom Graphics and Large Scale Simulations.

2. Griffin, Sandra (JSC): Third Annual Workshop on Space Operations Automation and Robotics (SOAR '89). NASA CP 3059, December 1989.

    Papers presented at the Third Annual Workshop on Space Operations Automation and Robotics (SOAR '89), hosted by the NASA Lyndon B. Johnson Space Center at Houston, Texas, on July 25-27, 1989, are documented herein. During the 3 days, approximately 100 technical papers were presented by experts from NASA, the USAF, universities, and technical companies. Also held were panel discussions on Air Force/NASA AI Overview and Expert System Verification and Validation. Tutorial sessions included Neural Networks: Theory and Application of Back Propagation; Verification and Validation of Expert Systems; Evaluation of Expert System Tools; and Technical Environment for Modular Architectures for Robotic in Space; and are not documented herein. Technical topics addressed included intelligent systems, robotics, human factors, and environment.

3. Healer, Garlan (LESC): Case for Simulation Requirements Development. Presented at the JAIPCC Symposium, March 23, 1989, Houston, Texas.

    The development of requirements for simulation of the Space Station Freedom environment called for the support of an appropriate Computer Aided Software Engineering (CASE) tool. The methodology is iterative so that the final requirements specification document includes all primitive subprocesses and data flow diagrams for each subprocess. This methodology allows for easy transition to the system design process. A CASE tool would integrate the capabilities of word processing, structured analysis, and object-oriented design, allow for automated generation of the requirements specification document which includes traceability for the requirements, and generate DFD's corresponding to the sections in the document.

4. Keller, T. W. (IBM): The Development Process for the Space Shuttle Primary Avionics Software System. Presented at the 1989 Share Conference, August 21, 1989, Orlando, Florida.

5. Keller, T. W. (IBM): Space Shuttle Primary Onboard Software Reliability Approach. Presented at the AIAA Software Reliability Conference, August 23-25, 1989, Colorado Springs, Colorado.

6. Kolkhorst, Barbara G.; A. J. Macina (IBM): Developing Error-Free Software. Presented at the Juran Institute, Inc., Impro 89, November 1-3, 1989, Atlanta, Georgia.

    The software development techniques employed include process definition, state-of-the-art software engineering principles, rigorous inspection of work products across the process, independent software verification, sophisticated defect cause analysis and use of specialized tools to enhance development and testing. While a percentage of software developed today is done using methods inferior to those taught in the nation's institutes of higher learning, the on-board Shuttle Software is developed with a unique blend of state-of-the-art software

engineering, practical configuration management and process automation. To meet the increased need for software of the highest quality, knowledge engineering, expert systems, and value gained from "lessons learned" were applied.

7.  Kolkhorst, Barbara G.; Barry Ogletree (IBM):  Onboard Shuttle On-Line Software Requirements Prototype Electronic Storage, Access, and Retrieval.  Presented at the Graphics Technology in Space Applications Conference, April 12-14, 1989, Houston, Texas.

8.  Kolkhorst, Barbara (JSC):  Software Testing and Validation -- Real-Time Testing.  Presented at Portland State University, June 14, 1989, Portland, Oregon.

9.  Satterwhite, Scott R. (IBM):  ACES - Space Shuttle Flight Software Analysis Expert System.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    Analysis Criteria Evaluation System (ACES) is a knowledge based expert system created to capture the analysts' expertise and automate the analysis of Shuttle GN&C flight software.  Knowledge acquisition was performed by the domain experts themselves.  Concurrently, automation techniques were evaluated and prototyped.  The knowledge base began as set of pass/fail criteria which grew as methods for analysis of the criteria violations were developed.  Three pre-processors were created to evaluate the pass/fail criteria while the methodology for analyzing the criteria violations was implemented in a rule based expert system shell, Knowledge Tool (KT).  KT uses conventional expert system constructs and compiles the Knowledge Base into PL/I modules for efficiency and modularity.  Overall ACES reduces the manpower and increases the quality in the certification of the Space Shuttle flight software.

1.  Flackbert, A. Clyde; and Jim L. Allison (MDSSC):  McDonnell Douglas Helicopter
    Advanced Simulation Group Aids NASA in Defining Space Station Visuals.
    *IMAGES - The Image Society Newsletter*, Vol. 3, No. 2,  p. 12, 1989.
        Paper summarizes study conducted by McDonnell Douglas to define require-
    ments for a real-time simulator visual system used to train astronauts to perform
    proximity operations from the Space Station cupola.  The study includes require-
    ments analysis for projection systems, computer image generators, and visual
    database applications.

2.  Gorski, Arthur M. (MITRE):  A Simulation Model of the Shuttle Mission Simulator
    Task Dispatcher.  *Summer Computer Simulation Conference (SCSC)
    Proceedings*, pp. 133-138, 1989.  Presented at the 1989 SCSC, July 24-27, 1989,
    Austin, Texas.
        The JSC operates the Shuttle Mission Training Facility, which is responsible for
    flight and mission-specific training of Shuttle crews.  Much of this training is per-
    formed with the Shuttle Mission Simulator (SMS), an integrated complex of com-
    puters and simulated crew stations capable of realistic real-time simulation of the
    Shuttle environment.  An upgrade of these simulators has replaced the original
    Univac 1100/44 host mainframe computers with compatible machines and
    rehosted the existing application software.  The development contractor has also
    replaced the Frame Time Dispatcher, used to schedule real-time application pro-
    grams for execution on the host computer, with an improved Task Dispatcher.
    This paper describes a performance model of the Task Dispatcher written in the
    Performance Analyst's Workbench System simulation language.  It starts with an
    overview of the major elements of the Task Dispatcher and how the interaction of
    these elements schedule the real-time applications.  It then describes how these
    elements are modeled and concludes with a discussion of the proposed usage of
    the model to support future upgrade options for the SMS.

3.  Hajare, Ankur R.; and Patrick M. Brown (MITRE):  Payloads Simulation In the Shuttle
    Mission Training Facility.  Presented at the AIAA Flight Simulation Technologies
    Conference, August 1989, Boston, Massachusetts.
        The Shuttle Mission Training Facility (SMTF) at the NASA JSC is the primary
    facility for full mission training of astronauts.  The training provided in the SMTF
    includes payload operations that are performed by the astronauts while the Space
    Shuttle is in orbit.  This training requires real-time simulation of the operational
    aspects of Shuttle payloads as well as simulation of the interaction between pay-
    loads and the Orbiter.  For this purpose the SMTF contains Payloads Simulators
    (PLS) that are coupled to and operated in synchronization with the Shuttle Vehicle
    Simulators.  The PLS are used for simulating all payloads with the exception of the
    European Space Agency's Spacelab.  The SMTF contains a separate Spacelab
    Simulator for training Spacelab astronauts.

4.  Hammen, David G.; Daniel L. LaBasse; and Robert M. Myers (MITRE):  Process
    and Information Integration via Hypermedia.  Presented at the SOAR Conference,
    July 25, 1989, Houston, Texas.
        This paper explores the use of hypermedia as an integrating platform for data,
    conventional software, and advanced automation software in the ground control
    centers that support Shuttle and space station operations.  Hypermedia enables
    data integration through the display of diverse types of information and through the
    creation of associative links between chunks of information.  Further, hypermedia
    enables process integration through graphical invoking of system functions.
    Through analysis and examples we are able to illustrate how diverse information
    and processing paradigms can be integrated into a single software platform.

5.  McMahon, Robert A. (IBM): Implementation of ISO/OSI Protocols on a Masscomp 6600. Presented at the Masscomp Users' Society Conference, May 10, 1989, Danvers, Massachusetts.

    This paper describes a prototype design and implementation of International Standards Organization/Open System Interconnect (ISO/OSI) protocols on the Masscomp 6600 workstation. The Masscomp 6600 has been selected as part of the Mission Control Center (MCC) upgrade project at NASA JSC. The paper provides a brief overview of the MCC network environment and the requirements for ISO/OSI protocols in the MCC. The prototype implementation (OSI layers 1 - 7) is described along with results and future plans.

6.  Miller, David N. (JSC): Systems Engineering and Integration of Control Centers in Support of Multiple Programs. International Telemetering Conference (ITC) Proceedings, Vol. XXV. Presented at the ITC, October 30 - November 2, 1989, San Diego, California.

    With the increasing complexity encountered in space vehicles and missions, control centers can no longer support new vehicles with generic capabilities derived from old programs. This deficiency appears to drive requirements for new, specialized control centers. However, budget constraints and the mushrooming of new vehicle requirements suggest the need for a new type of control center which is both generic and flexible.

    From a budgetary perspective, this new control center must employ modular designs for expandability, be easily reconfigurable to support various programs, take advantage of existing control and data processing technology, and in many cases, utilize existing system resources. From an operational perspective, the control center must satisfy numerous distinct requirements and support future advances in control and data processing technology. Thus, an effective control center must combine elements of economy, capability, and flexibility.

    JSC personnel are developing a Multiprogram Control Center (MPCC) for support of Tethered Satellite System, Orbital Maneuvering Vehicle, Aeroassist Flight Experiment, and numerous less complicated vehicles and payloads. This paper will describe the architecture of the MPCC and how it satisfies both generic and program-specific requirements.

7.  Schmidt, James R.; and Ankur R. Hajare (MITRE): Concept of Operations for the Space Station Training Facility. Presented at the Summer Computer Simulation Conference, July 24-26, 1989, Austin, Texas.

    The Space Station Training Facility (SSTF) will be the primary facility for training the Space Station Freedom astronauts and the Space Station Control Center (SSCC) ground support personnel. Conceptually, the SSTF will consist of: a student environment and an author environment. The student environment will contain trainers, instructor stations, computers, and other equipment necessary for training. The author environment will contain the systems that will be used to manage, develop, integrate, test and verify, and operate and maintain the equipment and software in the student environment.

8.  Skudlarek, Martin J. (Ford): Large Screen Display for the Mission Control Center. Presented at the SPIE/SPSE Symposium on Electronic Imaging, January 15-20, 1989, Los Angeles, California.

    At JSC the flights of the National Space Transportation System (NSTS or Space Shuttle) are monitored and controlled from the Mission Control Center (MCC). In support of this effort, Flight Control management utilizes several large screen display systems in each of two Flight Control Rooms (FCR) for group information dissemination. The centerpiece of these systems is the Projection Plotting Dis-

play (PPD). As most have observed from television coverage of NSTS missions, the PPD is the large display screen (10 feet by 20 feet) flanked by four smaller screens (10x10) and usually displays a two-dimensional representation of a world map with spacecraft tracking/planning data overlaid. Ford Aerospace, the systems development contractor for the MCC, has been tasked by NASA to develop a replacement system for the PPD and investigate its utilization for other subsystems and programs.

9.  Williams, Keith (LFSD): The Orbital Maneuvering Vehicle Training Facility Visual System Concept. Presented at the Graphic Technology in Space Application Conference, April 12-14, 1989, Houston, Texas.

To provide training for OMV missions, a training facility is being developed to simulate the real-world interactions of the OMV with the pilot console. The OMV has two redundant camera systems that will send images to Mission Control Center via telemetry. The OMV Visual System will provide the capability to simulate the video scenes that would be produced by the OMV camera system. The simulation shall include all the camera eye points, dynamic models, moving appendages, and scene degradation due to the compression/decompression of video telemetry. Video system malfunctions shall also be provided to ensure the pilot is ready to meet all challenges the real-world system could provide.

10. Wilson, Thomas L. (JSC): The Superconducting Super Collider, Proposed Experiments. Presented at the Convocation of Scholars, January 18, 1989, Houston, Texas.

Grand unified theories in physics and cosmology were reviewed and related to new frontiers in particle physics and space physics. The search for supersymmetric particles, proposed for the Superconducting Super Collider (SSC) or hadron supercollider in Texas, was related to possible experiments from a NASA lunar base. A neutrino detector on the farside of the Moon was proposed to conduct long-baseline particle beam experiments between the SSC and the Moon. Neutrino oscillation experiments through the Earth and Moon were discussed, dubbing this configuration the Earth-Moon laboratory for fundamental physics and astrophysics.

11. Wilson, Thomas L. (JSC): Physics from a Lunar Base: New Experiments In an Earth-Moon Laboratory. *Proceedings of the Symposium on the Next Supernova: Astrophysics, Particle Physics and Detectors*, p. 115, February 1989. Presented at the Symposium on the Next Supernova: Astrophysics, Particle Physics, and Detectors, February 21-22, 1989, Santa Monica, California.

Neutrino physics and astrophysics from a lunar base were discussed, while proposing that the entire Moon could be used as a neutrino detector. It was announced that JSC would hold a workshop on physics experiments from a lunar base at Stanford University, May 19-20, 1989. [See A. E. Potter and T. L. Wilson, eds., *NASA Workshop on Physics and Astrophysics from a Lunar Base, AIP Conference Proceedings*, vol. 202 (American Institute of Physics, New York, 1990).] This work contributed to the presidential decision that a return to the Moon, not a Mars initiative, would be the next major goal in the United States manned space program.

1.  Armstrong, Gloria D. (RSOC):  Computerized Electronic Library.  Presented at the National Technical Symposium, April 7-8, 1989, Houston, Texas.
    This paper will cover the different definitions of Computer-Aided Systems/ Software Engineering (CASE) and how it could be integrated into the data processing functions of an organization.
    CASE is one of the latest industry-wide buzzwords; and very few organizations have implemented a CASE environment.  This paper will include the different kinds of CASE tools, the variety of CASE products, principles of software/systems engineering, methods of prototyping applications, and diagramming techniques used in a CASE environment.

2.  Bauch, Garland T. (JSC):  Chinese Aerospace Management Systems/Program Observations.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    This presentation will cover my personal observations of the Chinese (PRC) Aerospace program, facilities, and management.  These observations were obtained during facility visits and technical discussions as a delegate during the 1988 AIAA- Houston Section trip to China in September 1988.  The visits included the Institute of Space Medico Engineering, Chinese Academy of Space Technology (CAST), Landsat Ground Station, Beijing University of Aeronautics and Astronautics, and Institute of Radio Technology at Beijing; Satellite Control Center and Llshan Micro-electronics in Xian; and Xin Zhong Hua Machinery (Long March) Factory in Shanghai.  Technical discussions were held in each of the facilities visited and a special technical discussion was held at the Peace Hotel in Shanghai.  My observations will include the Chinese approach to space planning, management systems, launch hardware design, aerospace academic training, contract management, and advanced technology development.

1.  Bell, Jerome A. (JSC); and Michael A. Culp (LESC):  Site Selection Support Strategy for Human Exploration.  Presented at the AIAA 6th Annual Technical and Business Exhibition and Symposium (TABES), May 15-16, 1989, Huntsville, Alabama.

    The primary method for the conduct of exploration of the Moon and Mars will utilize humans living and working from bases on the planetary surfaces.  The need to implace the supporting systems and to land humans on the surface will require the selection of places to "land," set up shop, and operate facilities.  Valid location options must accommodate, in order of priority:  (1) the operations aspect associated with safe launch/landing and habitation, (2) the conduct of long-term and wide-range scientific investigations, and (3) in situ resource production.

    In general the required steps leading to site selection are initialized by establishing potential sites of interest from a prior knowledge about the planetary body on a global scale, followed by the gathering of data that characterize each specific candidate site.

    The Lunar Orbiter mission will provide imaging and resource mapping information which will build on the Apollo knowledge base to permit the initial selection of lunar outpost candidates.  A rover mission will then certify the selected outpost location through on-site analysis of terrain (accessibility and geologically interesting topography), soil characteristics, and surface composition.

2.  Moore, James S. (JSC):  Satellite Servicer System Flight Demonstration Program.  Presented at SOAR 89, July 25-27, 1989, Houston, Texas.

    The NASA and SDI, in a program to develop the capability of servicing satellites in remote locations, has planned a series of flights that will demonstrate:  (1) autonomous rendezvous and docking, (2) supervised autonomous orbital replacement unit (ORU) exchange, (3) supervised autonomous fluid transfer, and (4) Space Station Freedom proximity operations.  The flight demonstrations are the result of several mission scenarios with complex technical objectives.  Three Shuttle flights are required to complete the multi-objective program.  The major hardware elements of the program are described and discussed.  Demonstration objectives and technical approaches to the flight demonstrations are discussed.  Existing and developing technologies are assessed for applicability to the Satellite Servicer System (SSSFD) program.

3.  Morrey, A. E. (JSC):  Research and Technology Annual Report - 1988.  NASA TM 100473, February 1989.

    Johnson Space Center accomplishments in new and advanced concepts during 1988 are highlighted.  This year, reports are grouped in section Space System Technology, Solar System Sciences, Space Transportation Technology, and Medical Sciences.  Summary sections describing the role of Johnson Space Center in each program are followed by descriptions of significant tasks.  Descriptions are suitable for external consumption, free of technical jargon, and illustrated to increase ease of comprehension.

4.  Selepack, Joe (GE):  NASA RRS Lifesat Science Working Group Briefing.  Presented at the Lifesat Science Working Group meeting, July 12, 1989, Washington D.C.

5.  Sepahban, Sonya (JSC):  Advanced EVA Portable Life Support System Technologies and Issues.  Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    The NASA/Office of EXPloration (OEXP) has defined four principal lunar and Mars mission case studies to extend human activity in space to permanent presence on the Moon and exploration of Mars.  A study was conducted to

assess the available and potential technologies and the related issues regarding advanced ExtraVehicular Activity (EVA) life support for OEXP cases 3 and 4. These cases refer to the "Lunar observatories on the Far Side of the Moon," and the "Lunar Outpost to Early Mars Evolution," respectively.

The relatively long mission durations, large crew sizes, long time lags in earth-based resupplies, and the potentially long mission abort times associated with these missions dictate a set of unique requirements compared to the Shuttle Orbiter and the Space Station Freedom (SSF) Life Support Systems (LSS). A survey of the available and potential technologies and subsystems, together with results of quantitative analyses and qualitative data will be presented.

1.  Jenkins, Lyle M. (JSC): Construction of Large Space Power Facilities. Presented at the IAF International Conference on Space Power, June 5-7, 1989, Cleveland, Ohio.

    Construction was an important facet of the Satellite Power System studies in the late 1970's. Satellite servicing and assembly of the Space Station Freedom are addressing many of the critical issues in construction of large space systems. Design for assembly, capability of construction equipment and interaction with the launch system influence configuration development. The extravehicular capabilities of space-suited crew and remote operating systems like the Flight Telerobotic Servicer will provide an operational experience base for development of future large space power facilities. Economic success may well depend on early consideration of construction requirements and capabilities.

2.  Jenkins, Lyle M. (JSC): Demonstrating a System for Servicing Satellites. Presented at the 12th Annual AAS Guidance and Control Conference, February 4-8, 1989, Keystone, Colorado.

    NASA has initiated a program to demonstrate a Satellite Servicer System prototype in a series of flight tests with the Space Shuttle. When the commitment to an operational system has been demonstrated, it is anticipated that a variety of missions will develop that can productively use the servicing capability. Rendezvous and proximity operations contain key enabling technologies needed for an effective operational system. Guidance, navigation and control hardware, and operational techniques must be integrated into the program. Supporting sensor technology may limit or enhance the capability of the system depending on its readiness. Requirements for docking the spacecraft will interact with the G,N,&C implementation. Issues in the system concept development and technology requirements will be reviewed. Examples of the initial assessment of technology readiness and applications opportunities will be discussed. The degree of autonomy is of particular interest. Necessary elements for an effective servicing system can be combined in a worthwhile system flight demonstration that is the basis for an operational system.

3.  Jenkins. Lyle M. (JSC): Evaluating the Potential of Large Space Systems in Global Change Mitigation. Presented at the Earth Observations and Global Change Decision Making: A National Partnership Meeting, September 18-19, 1989, Washington, D. C.

    Alternative courses of action are an important aspect of reacting to climate change with the greenhouse effect and other environmental issues such as depletion of the ozone layer. Earth orbit represents a vantage point to overview the global environment. This capability is being used to develop a scientific understanding of Earth system processes and their interactions. As this understanding is incorporated into computer models with the proficiency to predict the course of global change, deliberate action may be needed to prevent or mitigate the effects of change. An activity is proposed that defines and evaluates very large space systems concepts for feasibility in actively reducing or averting the effects of deviations in the environment. Such a study analyzes alternative modes of intervention in critical cases of global change. This effort must build on the Earth system research objectives to be valid and to result in feasible concepts that are well understood and where benefits overwhelm risks in implementation.

4.  Jenkins, Lyle M. (JSC): Flight Experiments in Telerobotics-Orbiter Mid-Deck Concept. Presented at the NASA Conference on Space Telerobotics, January 31 - February 2, 1989, Pasadena, California.

    Most uncertainties of operation of a telerobot in the space environment

relate to the absence of gravity effects and not to vacuum. A flight experiment concept is proposed for the mid-deck of the Space Shuttle that provides direct access by the crew. Telerobot dexterous manipulation issues in task performance, mechanism response, system duty cycles, and operator interface can be effectively addressed. A pair of replica type master controllers would be adapted for slave manipulator functions. A variety of test setups and control modes can obtain data on zero g operation of a telerobot.

1.  Monford, Leo G. (JSC); and Ed Carter (LESC):  Dexterous Manipulator Flight
    Demonstration.  Presented at the NASA Conference on Space Telerobotics,
    January 31 - February 2, 1989, Pasadena, California.

    The Dexterous Manipulator Flight Demonstration or DMD is a flight experiment
    scheduled to fly on the Space Shuttle near the end of 1990 to demonstrate the use
    of a dexterous manipulator which features force and torque feedback from a six-
    degree-of-freedom force torque sensor (FTS).  The demonstration will consist of
    several tasks which require a high level of dexterity, and which could probably not
    be accomplished by a manipulator without force and torque feedback.  The
    demonstration will include several other components developed at JSC to
    increase the facility for robotic movement of equipment, assembly, and repair of
    satellites in space.

    The paper presents an overview, including background, operating experience,
    and future plans.  The characteristics, principles of operation, and an interface of
    the FTS are described.  The magnetic end effector's performance and physical
    specifications are discussed, as is an alignment concept called TRAC, which has
    been used to provide precise alignment without a three dimensional target.
    Results of development testing at the Manipulator Development Facility at JSC are
    presented, and a detailed description of the flight experiment objectives and flight
    scenario is given.

1. Lance, Nick (JSC): Mars Rover Sample Return Ascent, Rendezvous, and Return to Earth. Presented at the AIAA - 27th Aerospace Sciences Meeting, January 9-12, 1989, Reno, Nevada.

    Ascent, rendezvous, and Earth return are three operational mission sequences in the sample return phase of the Mars Rover Sample Return (MRSR) mission. In conducting the current study, several vehicles were identified which would enable the sample return phase of the mission. These elements are the Mars Ascent Vehicle (MAV), the Earth Return Vehicle (ERV), the rendezvous and docking module (RDM), and the sample return capsule (SRC). The sample return elements, when combined with other elements performing the launch and delivery functions, form the basis of the MRSR system. This paper summarizes the significant mission aspects of the sample return phase, describes the Mars ascent and Earth return scenario, illustrates the conceptual designs developed for the MAV, ERV, RDM, and SRC, and discusses the results of significant trade studies conducted.

2. Office of Exploration (JSC): *OEXP Exploration Studies Technical Report, FY89 Status.* NASA TM 4170, August 1989.

    The Office of Exploration (OEXP) at NASA Headquarters has been tasked with defining and recommending alternatives for an early 1990's national decision on a focused program of human exploration of the solar system. The Mission Analysis and System Engineering (MASE) group, which is managed by the Exploration Studies Office at the Lyndon B. Johnson Space Center, is responsible for coordinating the technical studies necessary for accomplishing such a task. This technical report, produced by the MASE, describes the process that has been developed in a "case study" approach. The three case studies that were developed in FY 1989 include: (1) Lunar Evolution Case Study, (2) Mars Evolution Case Study, and (3) Mars Expedition Case Study. The final outcome of this effort is a set of programmatic and technical conclusions and recommendations for the following year's work.

3. Roberts, Barney B. (JSC): Lunar Base and Need for Lunar Analog. Presented at the Seminar on Engineering and Sciences in Space, November 1989, Fort Collins, Colorado.

    NASA is in the process of preparing a response to the Vice-President's request for a program plan for the exploration of the solar system. This program plan will include science and operations facilities on the surface of the Moon and Mars, the construction and operation of which will require skills that are foreign to NASA's experience base. To develop these skills, verify operational techniques, and certify surface systems, NASA will need one or more Earth-based "planetary analogs" for research and development.

1. Gieck, William C. (JSC): An Overview of Computer Power for JSC Facilities. Presented at the Industrial Energy Technology Conference, September 12-14, 1989, Houston, Texas.

   Techniques and devices used by NASA at JSC to provide and maintain a quality power distribution system are discussed. Quality power is essential to support the array of facilities and functions involved in planning, developing, testing, and controlling a major portion of this Nation's space exploration program. An overview is provided of the distribution system and components. Discussions address the criticality of the complex and computers in particular, the disturbance immunity of the hardware, and the redundancy of the systems.

   No attempt is made to draw absolute comparisons between the various types of power conditioners and their derivatives on the market today. Rather, an explanation is given of the rationale used at JSC to select the equipment and the circuit configurations that have proven to provide the required power quality and reliability. Because that level of power quality is sustained only through well planned and executed operation and maintenance activities, a description of JSC's program is also given.

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1. Brand, Vance D. (JSC): The Challenge of Assembling Space Station Freedom in Orbit. Presented at the Space Vehicle Flight Mechanics Symposium, November 13-16, 1989, Luxembourg.

    Assembly of the Space Station Freedom is one of the more complicated and challenging tasks ever faced by America's space program. Freedom has evolved from a linear truss design, to a dual keel, and finally to the current architecture in which assembly will be accomplished in two phases. The completed first phase of assembly in 1998 will consist of a large 5 by 5 meter truss over 135 meters long, outfitted with two U.S. modules (connected by four nodes), a European module, a Japanese module, and numerous other systems. Assembly will require at least 20 Space Shuttle flights and will be performed by space-walking astronauts, remote manipulators, and telerobotic devices. Interesting technical challenges are Shuttle approach and departure operations in close proximity to the Freedom, Shuttle berthing or docking, attitude control and reboost of the Freedom as required at each stage of assembly, and station construction from a work platform in the Shuttle's payload bay. Other challenges include development of a new spacesuit and astronaut mobility aids, planning a forgiving assembly process, man-in-the-loop simulations of assembly operations, and verification of Freedom's hardware/software prior to the assembly flights. Assembly planning is focused on constructing the most capable station with the least number of Shuttle assembly flights and utilizing the Freedom to provide scientific returns long before the assembly is completed. These planning goals, which complicate the construction process, are discussed in this presentation.

2. Machell, Reginald M. (MDSSC): Manned Space Flight Considerations. *Space Mission Analysis and Design*, Chapter 22, 1989.

    Manned vehicles provide the capability to achieve certain types of space mission objectives which are virtually impossible without man's presence. At the same time additional resources and supporting functions are required beyond those for unmanned flight systems. Further, manned systems have unique limitations and constraints which must be recognized and accommodated. In order to determine the correct space system for accomplishing his objectives, the space mission designer must understand and consider both manned and unmanned space flight systems. For manned missions he must decide whether to make use of existing systems, the Space Transportation System and the Space Station Freedom, or to develop a new manned space system.

3. Omori, Erin Y. (MDSSC): An Approach to Data Security and Privacy for the Space Station Freedom Program. Presented at AIAA Computers in Aerospace VII, October 3, 1989, Monterey, California.

    Computer and information system security for the Space Station Freedom program (SSFP) protects valuable life, resources, and technology. Access to information will be permitted over an extensive geographic area, through space and ground communications, and by multiple users of varying disciplines. The SSFP data security and privacy approach is designed to prevent unauthorized attempts to access, alter, modify, or destroy data objects of varying sensitivity levels within the Space Station Information System (SSIS). The four types of SSFP security and privacy mechanisms (protection, detection, containment, and recovery) implemented at key SSIS locations provide a secure, cost-effective, and operationally supportive environment.

4. Paddock, Stephen G.; and Randy L. Farner (MDSSC): Space Station Freedom Manned Base Operations. Presented at the Space Communications Conference, March 5, 1989, Nashville, Texas.

The Space Station Manned Base (SSMB) will support a variety of users with payloads that will advance Earth and space sciences, service satellites, manufacture materials, advance technologies, and provide a commercial return on space investment. This paper illustrates how a typical payload will operate in the Freedom era by detailing a payload scenario for a representative user in 1999 assuming the dual keel configuration and a crew of eight. The payload has monitoring and control equipment in the pressurized volume and externally-mounted sensors. Station capabilities to support this representative user as well as environmental factors affecting design, such as altitude and attitude, Shuttle resupply frequency, and crew complement are described. Recommendations for user action to improve interfaces and smooth data flow are presented.

5.   Stolle, Michael; John Nagel; John Trowbridge; and Rick Smith (MDSSC): Outlining the Crew Health Care System for Space Station Freedom. Presented at the 19th Intersociety Conference on Environmental Systems, July 24, 1989, San Diego, California.

Engineering design challenges in the development of the Space Station Freedom's crew health care (CHeC) system, which is made up of over 80 individual components/instruments, are highlighted. Certain instruments have been selected as representative of these design challenges. The paper discusses the overall CHeC system, gives a detailed description of the selected components, and identifies various design concerns. There is also a discussion of issues and constraints associated with integrating the individual components to operate as a functional subsystem.

1. Kramer, Cathy D. (JSC): Evolution of EVA Capabilities for Space Station Construction and Maintenance: Soviet and American Experience. Presented at the Second European In-Orbit Operations Technology Symposium, September 12-14, 1989, Toulouse, France.

   This study discusses the evolution of both Soviet and American extravehicular activity (EVA). A qualitative review evaluates each EVA with respect to risk, criticality, complexity, and duration. The assessment factors used and the EVA total assessments are summarized in table format. Examined in detail are the primary EVA mission objectives: ensuring safety of the station/vehicle or crews servicing and repairing of the spacecraft and various assembly tasks. Analyzed further, evolutions of tools, tasks, and lessons learned are stated for each EVA. Graphics emphasize the related advancements in the spacesuits, EVA tools, and equipment technology.

1.  Moore, Kevin-Duron (JSC):  Infrared Biotelemetry System.  Presented at the Annual
    National Technical Association Symposium, April 7-8, 1989, Houston, Texas.

    For man's long term goals in space exploration, his health is an overriding concern.  Care must be taken to assure that conditions in which an astronaut will be asked to perform and workloads under which an astronaut will be placed must not go beyond normal physical limits.  Nonintrusive monitoring of biomedical and physiological functions can serve as a tool to ascertain data which will assist in tailoring workloads to individual abilities and within accepted norms for continual activity in the microgravity of space.

    By means of sensors already developed for this purpose, a method was found to compress data from monitoring transducers into a format already used for commercial voice communications.  This format uses infrared as an alternative to the crowded radio bands available in space.  Also, because the infrared energy is enclosed in small spaces and dies off quickly, privacy from unauthorized parties listening is enhanced.  Infrared transmitters and receivers allow free-floating astronauts not encumbered by dangerous cords to float freely in the space environment.

    This paper is the result of a successful 6-month investigation into using existing technology to construct a working two- and three-channel device to collect EEG, EKG, EMP (muscle potential), and other physiological signals from sensors and transmit the signals to a remote infrared receiver inside the cabin.  Tests were conducted at the NASA Space Station Mock-up in a similar environment to that expected in space travel.

2.  Smith, Elizabeth S. S. (JSC):  The Space Station Freedom Configuration.  Presented
    at the National Technical Association Symposium, April 7-8, 1989, Houston,
    Texas.

    An overview of the current Space Station Freedom Configuration "Assembly Complete" Stage.  This discussion shall include the physical description of the elements and systems which comprise the Space Station Freedom.  The functionality and capabilities of the Space Station as well as probable futuristic applications will be reviewed.

    Descriptions of the interior of the habitation and laboratory modules and the cupola will be presented.  Robotics technology, which will be used on the Space Station, will be discussed.

1. Domingue, Steven (MDSSC): Test Methodologies for the Operations Management Application. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    The Operations Management Application (OMA) is the on-board command and control coordinator for the Space Station Freedom. Performing this task requires the ability to command, monitor, and react to systems physically and logically distributed throughout the station. A multitude of obstacles impede a traditional test and verification of the OMA: the complexity of interfaces among the systems and elements that make up the station, the relative immaturity of test strategies for expert systems, and the fact that the station is never assembled and tested as a complete unit before launch.

    Verification of design concepts will begin with software prototyping during the preliminary design stage. Portions of this prototyping will be performed on engineering test beds distributed throughout the JSC which simulate the various distributed systems.

    Preliminary test of the OMA software will be performed following the traditional software life-cycle testing phases. Integrated tests to maximize the confidence in the final OMA product prior to launch will be performed on a variety of test facilities: DMS kits, the JSC DMS test bed, and the Multi-System Integration Facility (MISF). Final checkout of the software is to be completed on-orbit as the station is assembled.

2. Easton, C.R. (MDSSC); Phil Cressy (NASA Hqs); Tom Ohnesorge; and Garland Hector (JSC): Approach to Transaction Management for Space Station Freedom. Presented at AIAA Computers in Aerospace VII, October 3, 1989, Monterey, California.

    The Space Station Freedom will consist of multiple systems providing support to many user payloads and other station systems. Some of the operations of the systems and payloads may be potentially hazardous; others will require resources and may require stringent environmental conditions for successful conduct. Some operations may disturb the operating environment for other systems and payloads, such that their environmental requirements are not met. Provision for any of these operating requirements is conditioned on other operations and the status of the space station and its systems. This paper describes an approach to managing the operations based on their external effects. The approach presumes that there is a conflict-free schedule that, if followed, will allow only appropriate operations to occur. The problem then reduces to assuring that operations initiated are within the latitude allowed by the schedule.

3. Easton, C.R.; and J.J.L. Dickinson (MDSSC): AI in Space Station Freedom Planning and Scheduling. Presented at AIAA Computers in Aerospace VII, October 3, 1989, Monterey, California.

    The Space Station Freedom Program will require a planning and scheduling process far more complex than any yet attempted. A changing complement of payloads will compete with each other and with the core systems for resources and potentially interfere with each other's rights to an operating environment free of disturbing influences. Many potential payload operators will insist on tele-science operation, i.e., with the freedom to exercise real time command and control of their payloads. Operators will also need to respond to targets of opportunity, such as supernovae and solar flares. Some responses will be programmed into onboard payload microprocessors and initiated without contact with ground operators. This paper suggests an artificial intelligence approach to planning and scheduling that will support the operators in establishing their schedules and in responding to schedule changes and targets of opportunity.

Although funding constraints and the newness of the technology require a more conventional approach for initial operation, these approaches are appropriate for potential inclusion in the program growth phase to ease scheduling problems, add flexibility, and reduce operating costs.

4.  Muhm, P. M. (MDSSC): The Onboard Short Term Plan and the Operations Management Application. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    At the conclusion of the ground planning flow, detailed descriptions of the activities to be performed aboard Space Station Freedom are assembled, expanded, formatted, combined with supporting data, and uplinked to Space Station Freedom as the Onboard Short Term Plan (OSTP). The onboard execution of this plan is then automated and coordinated by the Operations Management Application (OMA) software. Additionally, OMA provides a capability to edit and update the OSTP, and to look forward in the plan and identify conflicts and problems before they occur. The OSTP itself is organized as a multi-layer hierarchy of activity descriptions and contains supporting data such as resource requirements, chronological dependencies, fault recovery procedures, and Transaction Management data. This organization eases construction, certification, and modification of the OSTP.

5.  Raines, Gary K. (JSC): The NASA Approach to the Space Station Freedom Program and Ada. Presented at the Fourth Annual German Ada Users Conference, April 5-7, 1989, Munich, W. Germany.

    The NASA Space Station Freedom Program has officially declared that all operational software developed for the program will use the Ada programming language, developed under the U.S. Department of Defense. Offically accepted as a national and an international standard, it supports the solution to many of the current software engineering problems, especially those of very large software projects such as the Space Station Freedom Program. An overview is given of the Space Station Freedom, describing the extensive flight and ground data systems and facilities to the detail necessary to emphasize the software challenges that they present. The data systems architecture is described and the unique software problems that Ada addresses are outlined. Reports are given on test bed activities and prototyping efforts that have been completed, lessons learned so far, and perceived risks and how they will be managed.

6.  Sinclair, Susan; and Ken Haithcoat (MDSSC): OMGA as the Operations Director Tool. Presented at the 14th Annual AIAATechnical Symposium, May 18, 1989, Houston, Texas.

    As space operations become more complex and the corresponding ground support activities become more distributed, tools must be developed to facilitate safe, coordinated, and integrated operations. Accordingly, the Operations Management System (OMS) concept was developed to address this growing complexity and distribution. Onboard Space Station Freedom, the Operations Management Application (OMA) will serve as the commander's window into station operations. While on the ground, the Operations Management Ground Application (OMGA) will be the Operations Director's tool for coordinating all activities involved in conducting station operations. This paper addresses the OMGA in its role as the Operations Director's tool.

7.  Thompson, Nelson (MDSSC): Transaction Management Aboard Space Station Freedom. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

The concept of Transaction Management (T/M) as a solution to a set of apparently contradictory space station requirements is presented. The goals of T/M are to permit unchecked commanding of payloads from the ground, while simultaneously guaranteeing a safe and predictable operational environment aboard the station. The stringent requirements for autonomous ground control of onboard payloads are examined, as well as their apparent conflict with flight requirements for crew safety, station integrity, resource husbandry, and non-interference among the station's systems and payloads. T/M is proposed as a concept for handling these issues without real-time checking of commands issued from the ground. The feasibility of effective command checking is questioned.

8. Winkler, Jerry (CTA): A Report on the Proposed Naming Standards for Space Station Freedom Program Objects. Presented at the NIST Naming Convention Forum, November 16, 1989, Gaithersburg, Maryland.

This presentation gives an overview to the set of documents that are being produced in support of Space Station Freedom Program (SSFP) data and object standardization as well as discuss the requirements for naming standards and the different types of names that these standards are intended to support.

The presentation will focus on the unique approach to naming standards represented in the SSFP Data and Object Standards Document (as of October 23, 1989) which was jointly produced by MDSSC, IBM, and CTA. This approach has four primary features:

- It is object oriented.
- It incorporates an integrated view of naming as represented by standards for dictionary and directory services.
- It incorporates the concept of registration of terms used in naming objects.
- It provides a rigorous syntax for interpretation of names and their inherent semantics. (There are no other naming conventions that the author is aware of that are based on a rigorous syntax.)

This presentation will solicit comments from other developers and administrators of naming conventions. As a fringe benefit, it is expected that the presentation will influence the direction taken by the American National Standards Development Committee for Information Resource Dictionary Systems in their specification of a standard IRDS module for verifying naming conventions. A task group of the committee is cosponsoring this forum.

1. Drewry, J.D.; S. J. Pearson; and R. H. Anderson (MDSSC): On Orbit Deployment and Maintenance of the Utility Distribution System for Space Station Freedom. Presented at the AIAA 14th Annual Technical Symposium, May 18, 1989, Houston, Texas.

   The Utility Distribution System (UDS) for the Space Station Freedom includes thermal and hydraulic lines, valves, and couplings that support the propulsion, fluids, thermal, and life support activities of this 150-meter-long manned space base. This challenging undertaking is the first United States space structure to be assembled on orbit and requires a high degree of reliability to achieve its planned 30-year operation. Assembly and routine maintenance operations should strive for maximum use of robotic systems to reduce prohibitive crew workloads.

   Capabilities and limitations of crew Extra Vehicular Activity (EVA) and Robotics must be considered when developing and planning assembly operations. Ease of maintenance and repair (both EVA crew or robotically) as well as low cost over its 30-year operational life are design goals of the UDS.

   Operation of this low Earth orbiting, manned space structure will require provisions for on-orbit deployment, installation, maintenance, and repair of the components making up the UDS. The system will incorporate over 2500 couplings and fittings to join over 2 miles of flexible and rigid line.

2. Sirko, Robert; and Robert Wood (MDSSC): Space Station Freedom as a Bridge to Future Missions: Technology Benefits. Presented at the 26th Space Congress/ Canaveral Council of Technical Societies, April 25, 1989, Kennedy Space Center, Florida.

   The development and operation of Space Station Freedom provides an array of technology challenges and potential benefits that are unique in the history of the space programs. As the latest in a series of American and Soviet space stations, the baseline design of Freedom can be largely accomplished without overly relying on the development of new technologies; yet Freedom stands apart from every other spacecraft and space station built to date because of (1) the requirement for assembly on-orbit, and (2) its charter to serve a changing and growing user community over its extended lifetime, during which the capabilities and capacities of the station must adapt to evolving needs and technology possibilities. This paper presents a brief overview of some of the technological benefits that may be expected to derive from the development--and more significantly, the operation-- of Space Station Freedom. The first section provides a brief summary of some of the baseline characteristics and parameters of the phase-one version of Freedom. In Section 2 the process pushing the evolution and growth of Freedom is described. Section 3 then proposes a set of priorities for emphasis in the directed development of selected high-leverage and enabling technologies that can best be carried out by utilizing Freedom as on on-orbit national testbed.

1.  Buratti, Davey L. (BAO):  Automation for Performing Risk Analysis.  Presented at the System Safety Society, July 17 - 20, 1989, Long Beach, California.

    The NASA SR&QA Directorate at the JSC is working with NASA Headquarters to identify and develop computerized tools that will be used to assess the risk in NASA programs.  Specifically, the current program where risk assessment is being implemented involves the National Space Transportation System (NSTS) Space Shuttle.  One of the stated goals and objectives of JSC is to define and apply the new Mission Safety Assessment (MSA) process; a process that is completed prior to Space Shuttle Flight Readiness Firings and Flight Readiness Reviews.  The MSA is intended to identify and highlight those areas of significant NSTS program risk, identify the controls of these areas, and develop recommendations for improvements on future missions.  This paper addresses specific automation development work in support of risk analysis for NASA programs.

2.  Lempriere, B. M.; and J. E. Shrader (BAE):  Integrated Nondestructive Evaluation Data Reduction System (INDERS).  Presented at the JANNAF RNTS Meeting, October 17-19, 1989, Silver Springs, Maryland.

    INDERS is an ongoing program with NASA MSFC to develop NDE data fusion techniques for rocket motor evaluation.  These techniques are implemented in hardware (computer and calibration devices), software (data manipulation techniques), and procedures.  In the first two phases of this program completed in 1987, Boeing software was adapted and installed in the MSFC system, and training and documentation were provided.  Under Phase 3 completed in 1988, customized computer hardware was purchased for MSFC, and calibration procedures developed for x-radiography (RT), computed tomography (CT), ultrasonic (UT), eddy current (EC), and thermography (TG).  Phase 4 is currently in progress, and involves embedding the Phase 3 developed procedures in software, improving the existing software, and extending the ability of INDERS to fuse data from multiple NDE inputs into a common, part based coordinate system.  The results from Phases 1 and 2 were reported at the JANNAF Nozzle Technology Subcommittee meeting last year, so this year's update focusses on the recent results including reporting on the calibration procedures and a status on recent work.  By having INDERS installed at MSFC, NASA can efficiently handle large amounts of NDE data that previously were very difficult to manage.

1.    Huang, Hsien-Lu (RSOC):  Reliability Consideration of Thin-Film Temperature
       Sensors in New Era Space Shuttle Propulsion System.  Presented at the 14th
       Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
          The space shuttle main engine (SSME) is the most sophisticated reusable
       earth-to-orbit propulsion system in use today.  Recent NASA development
       programs for orderly evolution of future engines include structural integrity and
       durability effort for advanced high-pressure oxygen-hydrogen rocket-engine
       technology.  One of the major items is to develop thin-film thermocouple tempera-
       ture sensors for real-time condition monitoring of the turbine blade of the high-
       pressure fuel turbopump (HPFT), a critical space engine component.  Such thin-
       film temperature sensors will be used in next era SSME's to replace the existing
       resistance temperature devices (RTD) in detecting SSME turbine over tempera-
       tures.  Operation of SSME in the presence of possible turbine overtemperature
       events and temperature sensor failures entails a measurable risk.  Reliability
       enhancement of such sensors is essential in reducing risks of an erroneous
       engine shut-down and an undetected overtemperature event as a result of sensor
       failures.  Thus informed design and flight policy decisions concerning overtemp-
       erature can be made.
          This presentation highlights the recent technical accomplishments in thin-film
       temperature sensors for space propulsion technology.  Reliability enhancement of
       such thin-film sensors is considered.  A brief background of SSME engine failures
       caused by exceeding redline limits, sensor failures, or main engine controller
       failures is described.  All possible combinations of such thin-film temperature
       sensor failures, overtemperature events, etc., which may be present with the
       computer voting logic for reduced risks calculation, are investigated.  A model to
       describe such a computer voting logic for the above-mentioned risks' calculation
       is constructed.

1.  Fraley, Norman E.; and Eric Leroy Miller (LESC): Determination of Hydrazine, Monomethylhydrazine, and 1,1-Dimethylhydrazine in Aqueous Solutions by Ion Chromatography. Presented at the 1989 Conference on Analytical Chemistry and Applied Spectroscopy, March 6-10, 1989, Atlanta, Georgia.

    Waste water produced at rocket testing and launching facilities often contains low concentrations of propellant hydrazines. Current methods of analysis do not easily lend themselves to identification and determination of these compounds.

    A procedure was developed at the JSC WSTF which allows the accurate and rapid separation, identification, and quantification of hydrazine, monomethylhydrazine (MMH), and 1,1-dimethylhydrazine (UDMH) in waste water produced at rocket testing and launching facilities.

1.  Mulholland, John (JSC):  Instability Analysis of a Small Liquid Rocket Engine Using
    an ESPI.  Presented at the JANNAF Nondestructive Evaluation Subcommittee,
    May 2-4, 1989, Hampton, Virginia.

    Small flight-weight engine instability analysis is currently performed using close-
    coupled pressure transducers and accelerometers, which often provide incon-
    clusive results.  The device is mounted to the engine surface, limiting the resolu-
    tion to the transducer location and possibly disturbing the actual events.  Elec-
    tronic speckle pattern interferometry (ESPI) would improve the capability for
    engine instability analysis since it would yield full surface activity information
    without disturbing the surface or event.  This report details the progress on a
    current project to measure engine instability using ESPI.

2.  Smith, Irwin D. (JSC):  A Review of $N_2O_4$ Iron Nitrate.  Presented at the JANNAF
    Propellant Development & Characterization Subcommittee Meeting, November 28-
    December 1, 1989, Laurel, Maryland.

    A review of the $N_2O_4$ iron nitrate problems encountered in the Space Shuttle
    propulsion systems was presented.  These problems include the failure of quick
    disconnects (QDs) and primary reaction control system (RCS) oxidizer valves.
    The interrelationship between these failures, current iron nitrate technology and
    investigations, and proposed actions to better understand and solve the problems
    was discussed.

3.  Smith, Irwin D. (JSC); and Richard E. Agthe (LESC):  Vapor Phase Corrosion of
    Stainless Steel by Nitrogen Tetroxide.  Presented at the JANNAF Propellant
    Development & Characterization Subcommittee Meeting, November 28- December
    1, 1989, Laurel, Maryland.

    In late 1987, nitrogen tetroxide vapor phase corrosion of 304L or 15-5 PH
    stainless steel was suspected to have caused a WSTF Shuttle reaction control
    system helium regulator failure.  This study presents the results of a 14-, 27-, and
    100-day exposure test to investigate this problem.  Sample rods of 304L and 15-5
    PH stainless steel were given several different types of surface finishes to simu-
    late the materials in the helium regulator.  These rods were exposed to MON-3
    $N_2O_4$ vapor at its vapor pressure and isolated from contact with the stainless steel
    exposure fixture by a sheet of TFE Teflon.  After exposure, visual examination of
    the samples did not indicate any significant corrosion.  Analysis of the 304L and 5-
    15 PH rod water rinse samples for iron indicated the corrosion rate was similar to
    that observed for 304L stainless steel exposed to liquid phase MON-3 $N_2O_4$.  The
    surface finish of the rods did not significantly influence the results.

4.  Smith, Irwin D. (JSC); K.E. Burke; A.B. Swartz; and G.B. Bardwell (LEMSCO):  Pre-
    sented at the Third International Symposium on Protective Clothing, January 15-
    17, 1989, San Diego, California.

    Virtually no literature data exists on the decontamination of personal protective
    equipment (PPE).  Recent work presented at the 1987 ASTM meeting on PPE
    suggested that this area should be examined.  Five PPE suit materials and one
    glove material were tested for residual contamination by MMH and $N_2O_4$.  The
    specimens were subjected to either heavy vapor or liquid splash before decon-
    tamination with tap water.  The results indicate that this simple decontamination
    step may not be adequate.  Additional decontamination steps involving heat and
    vacuum indicate the residual propellant concentrations can be further reduced.
    Tests were also conducted to evaluate the effect of wearing an item of PPE that
    contains residual propellant within the material matrix.  These tests indicated that
    the wearer of PPE should not be subjected to toxic hypergolic propellant levels
    that approach the threshold limit value (TLV).

5. Smith, Irwin D. (JSC); and Patrick A. Tanner (LESC): Vapor Phase Reaction of Hydrazine or Monomethylhydrazine with MON-3 Nitrogen Tetroxide. Presented at the JANNAF Propellant Development & Characterization Subcommittee Meeting, November 28- December 1, 1989, Laurel, Maryland.

A series of tests was conducted to investigate the reaction that occurs when MON-3 nitrogen tetroxide and propellant hydrazines vapor (either hydrazine or monomethylhydrazine) mix in a helium pressurization system. The experiments simulated a bipropellant satellite propulsion system where both propellant vapors leaked through the isolation check valves into the helium system. The experiment was conducted at 250 psia helium pressure and produced no significant fluctuations of pressure or temperature under constant volume and temperature conditions. Qualitative analyses of the product gases revealed that reaction products were highly sensitive to test conditions and that cleaning solvents as well as the bipropellants were reactants. However, quantitative analyses revealed that the reaction products were highly sensitive to test conditions.

1.  Benz, Frank (JSC); Thomas A. Steinberg; and Dwight Janoff (LESC): Combustion of 316 Stainless Steel in High-Pressure Gaseous Oxygen. Presented at the Fourth International ASTM Symposium, April 11-13, 1989, Las Cruces, New Mexico.

    The design of high pressure oxygen systems requires a better understanding of the combustion properties of structural metals and alloys to make proper choices for any particular set of operating conditions. Upward combustion of 316 stainless steel (SS) rods is discussed and a combustion model is presented. The effects of varying oxygen pressure and rod diameter on the rate limiting processes for combustion of 316 SS are evaluated. The rate limiting steps for combustion up 316 SS rods are shown to be dependent on incorporation and mass transport of oxygen in the molten mass, and heat transfer between the molten mass and rod. Both of these rate limiting steps are shown to be dependent on rod diameter.

2.  Bunker, Radel L. (JSC); and David Baker (LESC); and John H.S. Lee (McGill University): Explosive Decomposition of Hydrazine by Rapid Compression of Gas Ullages. Presented at the 12th International Coll. on the Dynamics of Explosion & Reactive Systems, July 23-28, 1989, Ann Arbor, Michigan.

    The initiation mechanism and the explosion mode of hydrazine decomposition under rapid compression conditions were investigated. Experiments were performed in which a column of liquid hydrazine (20 cm in length) was accelerated into a column of gaseous nitrogen (38-102 cm in length) in a close-ended cylindrical chamber (1.3 cm in diam). The liquid hydrazine column was physically separated from the nitrogen by a thin Teflon diaphragm (0.05 mm thick) and was accelerated into the nitrogen column by activating a rapid opening solenoid valve, which connected the cylindrical chamber to an accumulator (14 liters) of high pressure. A pressure transducer was placed at the end of the bottom chamber to register the pressure-time history of the event. High-speed video data together with data obtained from nitromethane detonation studies indicate that under rapid compression conditions, the explosion mode of hydrazine decomposition is a confined thermal runaway reaction. Experiments conducted with water confirmed that the explosive events observed in hydrazine experiments were caused by chemical reactions of liquid hydrazine and not by water hammer effects.

3.  Christianson, Rollin C. (LESC); and Barry A. Plante (JSC): Design of an Ignition-Resistant, High-Pressure, High-Temperature Oxygen Valve. Presented at the Fourth International ASTM Symposium, April 11-13, 1989, Las Cruces, New Mexico.

    Components used in high-pressure, high-temperature, flowing oxygen can be susceptible to ignition and combustion when particles traveling with the gas stream impact surfaces. Such impact was responsible for the violent combustion of the original Space Shuttle Main Propulsion system oxygen flow control valves during qualification testing at the NASA WSTF. This provided the impetus to develop a new valve based on Shuttle operating specifications and on several criteria ensuring ignition resistance, proper performance, and fabrication economy. Several flow control devices and concepts were investigated, and the design incorporating a variable segmented orifice was considered most likely to meet the basic design parameters. This design was selected for further development, which resulted in a valve that met all design parameters.

4.  Gunaji, M.V. (LESC); D.L. Fenton (KSU); and L.J. Linley (JSC): An Experimental Investigation to Improve and Control the Repeatability of the Heat Source Used in the Aircraft and Ordnance Safety Program. *ASME Journal of Heat Transfer*, Vol, 106, p. 327.

The Naval Weapons Center (NWC) at China Lake subjects various ordnance devices, such as bombs and rockets, to conditions representative of a fire caused by an accidental fuel spill on an aircraft carrier deck. This paper describes the investigation of various techniques to improve the control and the repeatability of the heat source (pool fire) used in the aircraft and Ordnance Safety Program at China Lake. Only those techniques that would not alter the structure of the pool fire were considered. Using wind screens with a porosity of 37 percent outside the pool radius, appeared to be the most promising technique because the screens would reduce the wind velocity and still allow the fire to entrain air. Pool fire tests both inside and outside the wake of the screens to compare the repeatability of the pool fires.

5.  Gunaji, Mohan V. (LESC); Joel Stoltzfus (JSC); Leonard Schoenman (ATSC); and John Kazaroff (JSC): Surface Modification of Monel K-500 as a Means of Reducing Wear and Friction Heating in High-Pressure Oxygen. Presented at the Fourth International ASTM Symposium, April 11-13, 1989, Las Cruces, New Mexico.

A new generation of reusable hydrogen/oxygen powered space-based orbit vehicles are required for a more affordable space transportation system. Aerojet TechSystems Company, under contract from NASA, has been investigating the use of Monel K-500 as the primary material of construction of an advanced rocket engine oxygen turbopump. The turbopump is driven by heated high-pressure oxygen and is supported on oxygen-pressurized hydrostatic bearings. In this phase of the research at the White Sands Test Facility, surface modifications (such as ion implantations and hard chrome) and composite surfacing were investigated for their potential benefit in reducing wear of rubbing surfaces while maintaining the superior burn-resistant characteristics of Monel K-500. Data produced by this research indicate that some surface modifications can improve the tribological properties, while others should be avoided.

6.  Janoff, Dwight; Larry J. Bamford (LESC); Barry E. Newton; and Coleman J. Bryan (JSC): Ignition of PTFE-Lined Flexible Hoses by Rapid Pressurization with Gaseous Oxygen. Presented at the Fourth International ASTM Symposium, April 11-13, 1989, Las Cruces, New Mexico.

There has been increasing concern in recent years about the ignition sensitivity of polytetrafluoroethylene (PTFE) lined flexible hoses used in oxygen service. Stainless steel braided flexible hoses lined with PTFE were tested in a high-volume pneumatic-impact system. The objective of the testing was to characterize the ignition mechanism by determining the effects on ignition of impact pressure, pressurization rate, and volume upstream and downstream of the flexible hose. Ignitions occurred at impact pressures well below the working pressure of the hoses, and at pressurization rates that can easily be obtained with manually operated valves. The hoses ignited at the downstream end and combustion propagated back toward the source of fresh oxygen. The addition of stainless steel hardline downstream from the hose prevented ignitions at all pressures and pressurization rate.

7.  Newton, Barry E. (JSC); Richard K. Langford; and Gene R. Meyer (Victor Equipment Company): Promoted Ignition in Oxygen Regulators. Presented at the Fourth International ASTM Symposium, April 11-13, 1989, Las Cruces, New Mexico.

The ignition containment capability of oxygen regulators subjected to promoted combustion was investigated. Oxygen regulators were internally contaminated with small quantities of hydrocarbon oil and ignited with an electric spark at the regulator inlet. The regulators were pressurized to 15.2 MPa (2200 psig) and preset to a flowrate of 7080 liters/min (250 scfh). Internal photocells were used to

ensure that ignition occurred immediately upstream of the regulator and propagated through the regulator's low-pressure cavity. Test articles were monitored by video to document their capability to contain the internal combustion. Eighteen single- and double-stage regulators were tested, and results ranged from complete containment to catastrophic burning with explosive energy release.

8.  Plante, B.; and W. Bannister (JSC): SCAPE Environmental Back Pack Evaluation. Presented at the NASA Pressure Systems Seminar, October 3-6, 1989, Sunnyvale, California.

    The NASA WSTF tested the pressure system in the Environmental Backpack (EBP) used on the Self-Contained Atmospheric Protection Ensemble (SCAPE). The project goal was to determine if the pressure system met the requirements of the Department of Transportation (DOT) Title 49 Code of Federal Regulations. The pressure system was checked for pressure vessel capacity, heat flow rate, wall thickness, vacuum jacket strength, pressure protection, materials composition and strength, weld strength and defects, and maximum service pressure capability. The maximum allowable working pressure (MAWP) was established at 1330 kPa (193 psig). With the exceptions of the vacuum jacket pressure relief device and the jacket wall thickness, the EBP pressure system met the requirements on the intent of the DOT code.

9.  Steinberg, Theodore A. (LESC); Michelle A. Rucker (JSC); and Harold D. Beeson (LESC): Promoted Combustion of Nine Structural Metals in High-Pressure Gaseous Oxygen; A Comparison of Ranking Methods. Presented at the Fourth International ASTM Symposium, April 11-13, 1989, Las Cruces, New Mexico.

    Nine structural metals were evaluated for relative nonflammability, in a high pressure oxygen environment. The metals studied were: 316, 321, 440C, and 17-4 PH stainless steels (SS), Inconel 600, Inconel 718, Waspaloy, Monel 400, and Aluminum 2219. A comparison is made between four methods which have been used to provide a relative flammability ranking of metals. A new relative ranking method is presented. Limitations of the ranking methods are assessed by investigating the effects of changes in test pressure, sample diameter, type of promoter, and sample configuration. Ranking methods which apply velocity as the primary ranking criterion are found to be limited by diameter effects.

10. Stoltzfus, J.M. (JSC); H.D. Beeson; and T.A. Steinberg (LESC): Development of Tests to Assess Fire Hazards Caused by the Ignition and Combustion of Metals in High-Pressure Oxygen Systems. Presented at the International Microgravity Combustion Workshop, January 25-26, 1989, Cleveland, Ohio.

    Fires aboard space vehicles must be detected early and extinguished quickly to maintain crew and equipment survivability and system functionality. Furthermore, fires involving metals in high-pressure oxygen systems are of particular concern. Such fires, once started and detectable, have usually exceeded the confines of the system, and catastrophic damage has occurred. NASA WSTF has recently developed three test methods to provide important metals ignition and combustion test data to engineers and scientists. The promoted combustion test is used to determine the relative flammability of alloys in oxygen. The frictional heating and particle impact tests are used to study two common ignition sources known to exist in oxygen systems.

11. Stoltzfus, Joel (JSC); and Howard Gabel (LESC): Determination of the Relative Compatibility of Aluminum Alloys With Oxygen. Presented at the National Institute of Standards Technology Workshop, September 6-7, 1989, Boulder, Colorado.

    The NASA WSTF was requested by the National Institute of Standards and

Technology to perform testing to determine the relative compatibility of several aluminum alloys with oxygen. The relative compatibility of the alloys will be evaluated in terms of their flammability and ignitability in liquid and gaseous oxygen. The approach to the project, the test apparatus, and the data obtained to date will be described.

12. Tapphorn, Ralph M.; Randy Kays (LESC); and Alan Porter (JSC): Infrared-Fiber-Optic Fire Sensor Developments: Role of Measurement Uncertainty in Evaluation of Background Limited Range. Presented at the 35th International Instrumentation Symposium, April 30 - May 4, 1989, Orlando, Florida.

Fire-detector systems based on distributed infrared fiber-sensors have been investigated for potential applications in the aerospace industry. Responsivities to blackbody and flame radiations were measured with various design configurations of an infrared fiber-optic sensor. Signal processing techniques were also investigated, and the results show significant differences in the fire-sensor performance depending on the design configuration. Measurement uncertainties were used to determine the background-limited ranges for the various fire-sensor concepts, and the probability of producing false alarms caused by fluctuations in the background signals were determined using extreme probability theory.

13. Tapphorn, Ralph M. (LESC); and Alan R. Porter (JSC): Infrared Fiber-Optic Fire Sensors: Concepts and Designs for Space Station Applications. Presented at the SPIE-33rd Annual Symposium, August 6-11, 1989, San Diego, California.

Concepts of infrared fiber-optic (IFO) sensors were investigated for application as distributed fire sensors for Space Station Freedom. Testing of breadboard configurations (based on those concepts) showed that IFO fire-sensors will be able to detect fires in complex spacecraft with a network of lightweight fibers interfaced to a central detector. Fiber-multiplex configurations are preferred for large areas or modules, while small spacecraft compartments can be monitored with fiber configurations that are not location-sensitive with respect to individual fibers. Single-fiber (250 to 300-$\mu$m diameter) responsivity measurements conducted with reflective and refractive optical configurations for the central detector system indicated background-limited-ranges (BLR) of 2 to 3 m for early sensing of hydrocarbon and hydrogen flames (area of approximately 3 cm$^2$). Signal processing techniques were also investigated, and the results showed significant differences in the fire sensor performance.

14. Williams, James H. (JSC): An Approach to Replacing Chlorofluorocarbons in Critical NASA Cleaning Applications. Panel Discussion at the 35th Annual Technical Meeting "Building Tomorrow's Environment," May 1-5, 1989, Anaheim, California.

NASA uses chlorofluorocarbon (CFC) 113 as the primary cleaning and cleanliness verification fluid for aerospace hardware. New environmental regulations (effective January 1989) place severe restrictions on the manufacture of this fluid. These restrictions will force NASA to find alternative cleaning procedures that do not use CFC 113. Oxidizing systems (for example, high-pressure oxygen systems) used in aerospace applications present unique cleaning problems. One of the most difficult problems facing NASA is how to verify that aerospace hardware is actually clean. Cleanliness of aerospace hardware is currently verified by rinsing the component with CFC 113 and sampling the rinsate for particulate and for nonvolatile residue.

1. Brown, J. W.; Carolyn S. Leach; and Patricia Santy (JSC): Human Factors and Productivity on Space Station Freedom. Presented at the 40th International Astronautical Congress of the IAF, October 13, 1989, Malaga, Spain.

   Man systems has been recognized as a major discipline in the Space Station Freedom Program, thereby underscoring the importance of human factors in contributing to the success of this undertaking. The human system impacts most of the other systems of the spacecraft: the crew must obtain information about and maintain the other systems, while the other systems maintain the health and productivity of the crew. This interaction is critical for mission success. There are three main facets of man systems: (1) specific hardware systems that focus on the human element (e.g., health maintenance, food, clothing, personal hygiene, waste management); (2) requirements definition concerning man-systems integration; and (3) crew interface and operations analysis. The latter two components are not restricted to the specific man-systems hardware design but are relevant to the design and operation of almost all vehicle systems and subsystems as well as experiments or payloads during a mission (e.g., maintaining the electrical power system via replacement of a modular package). Man systems is very much a distributed system. It includes all crewmembers wherever they go, whatever tasks are performed, and the ways crewmembers interact with equipment to carry out mission objectives. Under all of these circumstances, it is necessary to ensure that humans are safe and healthy, that they are capable of performing required functions, and that equipment is available and well designed to support required operations under both planned and contingency modes. Integration of the human system into the complex engineering and science systems planned on Freedom will require the close collaboration of engineers, physicians, psychologists, and human factors experts.

2. Huntoon, Carolyn Leach (JSC): Fluid/Electrolyte and Endocrine Changes in Space Flight. *Proceedings of the Nihon University Second International Symposium*, pp. 15-20, 1989. Presented at the Nihon University Second International Symposium on Aerospace Science, January 21-26, 1989, Tokyo, Japan.

   The primary effects of space flight that influence the endocrine system and fluid and electrolyte regulation 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 the alteration of some homeostatic set points for the environment of space. 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 in venous pressure. Hormones such as erythropoietin, atrial natriuretic peptide, aldosterone, cortisol, antidiuretic hormone, and growth hormone are involved in the dynamic processes that bring about the new set points. The inappropriateness of microgravity set points for 1-G conditions contributes to astronaut postflight responses.

3. Huntoon, Carolyn L. (JSC): Human Tolerance to Space Flight. American Institute of Aeronautics and Astronautics, Paper 89-5062. Presented at the AIAA/NASA Symposium on the maintainability of Aerospace Systems, July 26-27, 1989, Anaheim, California.

   Medical studies of astronauts and cosmonauts before, during, and after space missions have identified several effects of weightlessness and other factors that influence the ability of humans to tolerate space flight. Weightlessness effects include space motion sickness, cardiovascular abnormalities, reduction in immune system function, loss of red blood cells, loss of bone mass, and muscle atrophy. Extravehicular activity (EVA) increases the likelihood that decompression

sickness may occur. Radiation also gives reason for concern about the health of crewmembers, and psychological factors are important on long-term flights. Countermeasures that have been used include sensory preadaptation, prebreathing and use of various air mixtures for EVA, loading with water and electrolytes, exercise, use of pharmacological agents and special diets, and psychological support. Refinement of these countermeasures is continuing and new ones are being developed. The desirability of artificial gravity and what form it might take is being investigated in the U.S. It appears that humans can tolerate and recover satisfactorily from at least one year of space flight, but a number of conditions must be further ameliorated before long-duration missions can be considered routine.

4. Huntoon, Carolyn L. (JSC): Metabolism and Biochemistry in Hypogravity. *Proceedings of the 8th IAA Man in Space Symposium*, IAA-T-121, 1989. Presented at the 8th IAA Man in Space Symposium, September 29 - October 3, 1989, Tashkent, U.S.S.R.

The headward shift of body fluid and increase in stress-related hormones that occur in hypogravity bring about a number of changes in metabolism and biochemistry of the human body. Such alterations may have important effects on health during flight and during a recovery period after return to Earth. Body fluid and electrolytes are lost, and blood levels of several hormones that control metabolism are altered during space flight. Increased serum calcium may lead to an increased risk of renal stone formation during flight, and altered drug metabolism could influence the efficacy of therapeutic agents. Orthostatic intolerance and an increased risk of fracturing weakened bones are concerns at landing. It is important to understand biochemistry and metabolism in hypogravity so that clinically important developments can be anticipated and prevented or ameliorated.

5. Leach, Carolyn S.; and Mildred F. Reschke (JSC): Biochemical Correlates of Neurosensory Changes in Weightlessness. Presented at the 40th Congress of the International Astronautical Federation, October 7-12, 1989, Malaga, Spain.

To determine whether a relationship exists between space motion sickness (SMS) and chemical and biochemical variables measured in body fluids, clinical chemistry and endocrine measurements from blood and urine samples taken before and after Space Shuttle flights were analyzed, along with occurrence of SMS during flight and provocative testing before flight. Several preflight biochemical measurements were significantly correlated with severity of SMS symptoms. Significant positive correlations were observed with serum chloride and significant negative correlations with serum phosphate and uric acid and plasma thyroid simulating hormone (TSH). Measurements of urine sodium, calcium, and uric acid from samples collected on landing day had significant, positive correlations with symptom severity. Unpaired t tests with preflight data showed that serum chloride and uric acid, plasma cortisol and TSH, and urine volume were greater in crewmembers with no SMS symptoms than in those who exhibited symptoms. Urine specific gravity, osmolality, and phosphate were greater in crewmembers who had symptoms of SMS. The results suggest that metabolic rate and variables associated with fluid and electrolyte regulation should be included in statistical models of SMS susceptibility. Testing of such models will lead to a better understanding of the mechanism(s) involved in SMS as well as improved ability to predict the severity of SMS and ultimately to prevent it.

6. Leach Carolyn S. (JSC): Metabolic Changes Observed in Astronauts. Presented at the 73rd Annual Meeting of the Federation of American Societies for Experimental Biology, March 19-23, 1989, New Orleans, Louisiana.

Many aspects of human metabolism are affected by space flight. Loss of body water, which averaged 1.7% for the nine Skylab astronauts and 3% for three Space Shuttle crewmembers, occurs in the first two or three days of flight. Urinary output of sodium, potassium, and chloride increased during Skylab flights, and blood sodium and osmolality decreased. Spacelab experiments indicated that secretion of aldosterone may be less closely related to angiotensin levels than on Earth, but that aldosterone is important in the control of blood potassium levels. Plasma cortisol was increased throughout the Skylab flights and growth hormone was often increased over its preflight levels. These hormones have a number of effects on metabolism and may contribute to the atrophy of skeletal muscle and loss of bone mass on long-term space flights. Plasma insulin was sometimes reduced as much as 50% in Skylab astronauts, especially after a month in flight. Reduced insulin could also contribute to muscle atrophy. Changes in circulating levels of thyroxime and catecholamines might also alter the metabolism of astronauts. The metabolism of calcium is significantly affected by space flight, but the mechanism by which high levels of serum calcium are maintained is unknown. A 13% decrease in high density lipoprotein cholesterol after Shuttle flights and changes in the absorption of acetaminophen and scopolamine are other indications of metabolic changes during space flight. Although a number of the physiologic effects of space flight have been identified, a great deal remains to be done before the full impact of space travel on the human body can be understood.

7. Moore, Thomas P. (MH); Sam L. Pool (JSC); William E. Thornton (JSC); and John J. Uri (GE): Visual Suppression of the Vestibulo-ocular Reflex During Space Flight. NASA TM 102157, August 1989.

Visual suppression of the vestibulo-ocular reflex was studied in 16 subjects on four Space Shuttle missions. Eye movements were recorded by electro-oculography while subjects fixated a head-mounted target during active sinusoidal head oscillation at 0.3 Hz. Adequacy of suppression was evaluated by the number of nystagmus beats, the mean amplitude of each beat, and the cumulative amplitude of nystagmus during two head oscillation cycles. Vestibulo-ocular reflex suppression was unaffected by space flight. Subjects with space motion sickness during flight had significantly more nystagmus beats than unaffected individuals. These susceptible subjects also tended to have more nystagmus beats before flight.

1.  Bennett, Barbara S.; T. A. Holt (KRUG); and J. B. Charles (JSC): Development of a Portable Cardiovascular Laboratory. *Aviation Space and Environmental Medicine*, Vol. 60, No. 5, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

    A portable cardiovascular (CV) laboratory developed for the variable gravity environment of NASA's KC-135 aircraft may be applicable for noninvasive physiological studies requiring mobility and durability. A Toshiba T1100 + lap-top computer with a Toshiba hardware expansion box stores beat-by-beat digital output from a thoracic impedance device (BoMed NCCOM3), a finger blood pressure (BP) device (Ohmeda Finapres), and an accelerometer (ACC). A TEAC HR-30E cassette data recorder stores analog data, including BP and ACC wave forms.

2.  Bucana, C. D.; J. M. Jessup; (UTMDACC); T. J. Goodwin (KRUG); C. F. Sams; and D. A. Wolf (JSC): Matrix Association Culture System (MACS): A New Three-Dimensional Culture System for Growth Factor Analysis. Presented at the American Society of Cell Biology, January 29 - February 4, 1989, San Francisco, California.

    Differentiation in tissue culture may require appropriate three-dimensional interaction between stromal and epithelial cells to induce expression of structures seen in vivo. Two anchorage-dependent human colon adenocarcinoma lines HT-29 and KM-29 and KM-20 were grown in a new low-shear tissue culture vessel developed at NASA/JSC. Tumor cells were cultivated on collagen-coated (Cytodex-3) microcarrier beads (10 cells/bead and 5mg beads/ml of medium) with and without mixed normal human colonic fibroblasts which served as the stromal layer. Growth of the tumor cells in the absence of fibroblasts was slow (doubling time 30-50% longer), between beads, and limited to $4 \times 10^6$ cells/ml. When tumor cells were cultured with fibroblasts, the fibroblasts first covered the bead surface; then the tumor cells grew into three dimensional masses covering the beads, creating spheroids of up to .75cm with cell concentrations of $9.3 \times 10^6$ cells/ml. The surface membranes of cultures without fibroblasts were flat and interdigitated on scanning electron microscopy (SEM). In contrast, the surfaces of the cultures with fibroblasts developed crypt-like glandular structures with fibroblasts interacting with tumor cells. Cross sections of these spheroids demonstrated only minimal necrosis. The cultures with fibroblasts buffered acid production better than the cultures without fibroblasts, while both cultures consumed similar amounts of glucose. Both tumor cell lines gave similar results. The MACS may help to identify and isolate growth factors and structural processes within neoplastic and normal tissue.

3.  Caputo, M.; N. Hunter; S. Pathak; and G. Taylor (JSC): Assessment of Chromosome Aberrations Using Image Analysis: A Model for Monitoring Radiation-Induced In Vivo Cellular Damage. Presented at the American Medical Association, May 1-4, 1989, Washington, D.C.

    Cosmic radiation in outer space may impose health hazards and severe limits on long-duration manned space flight. One of the biologic effects of radiation is damage to DNA which may result in an increased chromosome aberration rate. We have compared the automated digital imaging chromosome analysis technique to conventional clinical methods to evaluate its usefulness as a tool in space biology research. Metaphase spreads were made from sequential peripheral blood samples of healthy normal donors and examined for aberrations using the automated imaging method and the classical technique. The ability of the computer-assisted method to emulate the classical method was evaluated. Automated analysis of chromosomes with chromatid breaks in metaphase

spreads produced high-quality results with a minimum of operator intervention. Analysis of a single cell and development of a finished karyogram took only a few minutes as opposed to several days required by the conventional method. Computer-assisted chromosome analysis produces images of diagnostic quality suitable for assessing chromosome aberrations. This makes it a useful tool for space experimentation where interaction with ground-based investigators and reduction of crew time is very important.

4.  Charles, John B.; C. N. Mukai (JSC); B. S. Bennett; K. F. Elton (KRUG); and C. M. Lathers (USRA): Changes in Blood Pressure and Total Peripheral Resistance Associated with Parabolic Flight. *Aviation Space Environmental Medicine*, Vol. 60, No. 5, p. 486, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

    Variable gravity (0 to 2g) is achieved in 72 sec on NASA's KC-135 aircraft during parabolic flight. Effects of gravity shifts on total peripheral resistance (TPR, mmHg/1/min), systolic (SP), diastolic (DP), and mean arterial (MAP) blood pressure (mmHg) were monitored in flight. In five subjects SP, DP, and MAP were monitored by the Ohmeda Finapres and cardiac output by the BoMed NCCOM3. Four postures [sitting (SI), standing (ST), supine (SU), and semi-supine (SS)] were assumed, one for each of four sets of eight parabolas. Five sec of data were averaged: immediately before parabola onset (1.3g); parabola entry (1.9g); 0g; and parabola exit (1.7g). Three to eight parabolas were averaged for subjects in each posture; mean values were determined.

5.  Chen, Y. M. (KRUG ); and Nitza M. Cintron (JSC): Stability of Human Atrial Natriuretic Factor and Cyclic GMP in Plasma Samples. *Aviation Space Environmental Medicine*, Vol. 60, No. 50, p. 510, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

    Human atrial natriuretic factor (ANF) and cyclic GMP (cGMP) are of significant importance in space-flight investigations concerned with fluid and electrolyte balance. To ensure precise measurement of these compounds, an extensive study was conducted to evaluate the stability of ANF and cGMP in plasma under various conditions of sample collection and storage. Samples were collected with heparin or EDTA; they were stored cold, at room temperature or frozen; inhibitors were or were not used. Radioimmunoassays (RIA) were performed to quantitate endogenous ANF levels before and after sample storage. High Performance Liquid Chromatography (HPLC) was employed to confirm RIA results and to determine if ANF or cGMP degraded during sample storage. The EDTA or heparinized plasma did not significantly affect ANF stability. Temperature, however, was a critical factor. ANF degraded in whole blood at room temperature but was stable for up to 4 hours when samples were placed in an ice bath. ANF was stable in the frozen plasma without an inhibitor. To ensure cGMP stability, EDTA was required. In EDTA plasma cGMP was unchanged for up to 24 hours at room temperature. In heparinized plasma, cGMP was completely degraded within 4 hours. These data are in agreement with the studies of Gerzer, et al. To accurately measure ANF and cGMP using the same sample, it is necessary to store EDTA plasma frozen; however, inhibitors are not required.

6.  Cintron, Nitza M.; C. S. Leach; J. M. Krauhs; and J. B. Charles (JSC): ANP and Other Fluid-Regulating Hormones in Spaceflight. *American Society of Hypertension Symposium Series*, Vol. 3: *Advances in Atrial Peptide Research* (B. M. Brenner and J. H. Laragh, eds.), New York: Raven Press, 1989.

    Action of a natriuretic factor has long been thought to contribute to loss of

fluid and electrolytes during spaceflight. Plasma ANP immunoactivity has now been measured in four Space Shuttle crewmembers 3 days before launch, on the second and seventh days of flight (FD2, FD7), and 1.5 hours and 3 and 10 days after landing. On FD2 the mean level of plasma immunoreactive ANP increased 82% to 29.5 pg/ml, but on FD7 ANP was 48% below its preflight level, a significant (P < .01) change from FD2. Plasma angiotensin I was 51% below its preflight level on FD2, but aldosterone decreased only 6.5%. Cortisol and adrenocorticotropin were elevated on FD2 (119%, 11%) and FD7 (86%, 17%). In other shuttle flights, antidiuretic hormone (ADH) was increased more than 100% throughout flight.

7. Cintron, Nitza M.; Helen W. Lane; and Carolyn S. Leach (JSC): Metabolic Consequences of Fluid Shifts Induced by Microgravity. Presented at the 11th Annual Meeting of the International Unison of Physiological Sciences, September 24-27, 1989, Lyon Cedex, France.

One of the primary effects of microgravity is redistribution of body fluid. After a period of dynamic change in many physiologic parameters, new homeostatic set points appear to be established. Serum sodium, plasma volume, total body water, and blood levels of atrial natriuretic peptide are lower than they are on Earth, and levels of plasma renin activity, antidiuretic hormone, and cortisol are elevated. Conditions of space flight unrelated or secondary to microgravity may also affect physiologic status. These include stress, space motion sickness, calorie and fluid intake, and countermeasures (such as exercise) against microgravity effects. Energy utilization is elevated during space flight, consistent with increases in plasma cortisol, growth hormone, and thyroxine, and decreases in catecholamines and insulin. Physiologic parameters such as blood flow to the kidney, liver, and gastrointestinal system, may influence efficacy of medications administered during flight.

8. Cintron, Nitza M.; and L. Putcha (JSC): Physiological Alterations and Pharmacokinetic Consequence of Space Flight. Presented at the International Academy of Astronautics, September 29 - October 4, 1989, Tashkent, U.S.S.R.

The biological effect elicited by a therapeutic agent in a given dosage form under any condition is a function of the intrinsic activity of the agent and its concentration at the site of action. The onset, intensity, and duration of the pharmacological/therapeutic response produced by drugs depends on the processes that characterize the absorption, distribution, metabolism and elimination, collectively known as pharmacokinetics of the drug. Physiological and biochemical alterations that are documented to occur during space flight may influence the pharmacokinetics and consequent therapeutics of medications administered to crewmembers. Understanding these alterations is significant to the design and development of safe and effective dosage regimens for optimum therapeutic efficient without undesirable side effects from drugs administered for the treatment of mission-induced pathophysiological conditions such as space motion sickness. Research in this area is being directed at identifying methods of assessing microgravity-induced changes in drug handling, validating these methods in flight, and using the data generated from these investigations to define methods of treatment that will be effective during missions. After groundbased studies validated the use of salivary drug monitoring as an effective, non-invasive means of predicting blood concentrations of acetaminophen, scopolamine, and dextroamphetamine, the method was used in flight to obtain preliminary information on the effects of space flight on the pharmacokinetics and dynamics of drugs.

Space and Life Sciences Directorate

9. Cohly Hari H. P. (BCM); Dennis R. Morrison (JSC); and M. Zouhair Atassi (BCM): Antigen Presentation by Non-Immune B-Cell Hybridoma Clones: Presentation of Synthetic Antigenic Sites Reveals Clones That Exhibit No Specificity and Clones That Represent Only One Epitope. *Immunological Investigations*, Vol. 18, No. 8, pp. 987-992, 1989.

Recently, we reported the preparation and antigen-presenting properties of hybridoma B-cell clones obtained after fusing non-secreting, non-antigen presenting Balb/c 653-myeloma cells with non-immune SJL spleen cells. It was found that antigen presentation at the clonal level can be specific or non-specific and one general presenter B-cell clones were tested for their epitope presentation ability to SJL T-cells that were specific to lysozyme or myoglobin. B-cell clone A1G12, a general presenter which presented both lysozyme and myoglobin to their respective T-cell lines, was found to present all five myoglobin epitopes while clone A1L16, a lysozyme specific presenter presented only one of the three epitopes of lysozyme. The latter reveals a hitherto unknown submolecular specificity (to a given epitope within a protein) for antigen presenting cells at the clonal level. Therefore, T cell recognition does not derive from the specificity of the T cell but may also be dependent on the epitope specificity of the B cell.

10. Cohly, Hari H. P. (BCM); Dennis R. Morrison (JSC); and M. Zouhair Atassi (BCM): Presentation of Antigen to T Lymphocytes By Non-Immune B-Cell Hybridoma Clones: Evidence for Specific and Non-Specific Presentation. *Immunological Investigations*, Vol. 18, No. 5, pp. 651-656, 1989.

Non-immune SJL (H-2s) spleen cells were fused with non-secreting, non-antigen presenting (H-2d) Balb/c 653-myeloma cells and the hybridomas were cloned by two limiting dilutions. The resulting hybride B cell clones were tested for their antigen presentation capability to SJL T cell lines that were specific for either lysozyme or myoglobin. In proliferative assays, 53% of the antigen presenting B cell clones presented both myoglobin and lysozyme (general presenters) while the other 47% presented specifically either myoglobin or lysozyme (specific presenters). The ability to selectively present either myoglobin or lysozyme indicates that antigen presentation at the clonal level can be specific or non-specific depending on the particular B cell clone.

11. Creager, Gerald J. (KRUG): Critical Care Medicine in Space. Presented at the Texas Respiratory Therapy Association Meeting, June 10, 1989, Austin, Texas.

Over the 27-year history of the U. S. Space Program, there have been few in-flight medical incidents or emergencies. As space missions become progressively longer and more complex, and as the crew perform more extravehicular activities, the potential for injury and illness increases. The medical events and capabilities of past Soviet and U. S. Space programs, and plans for a Health Maintenance Facility (HMF) to support the Space Station Freedom (SSF) will be reviewed. A discussion of risks, capabilities, in-flight experience base and expected scenarios that require a health maintenance system will be addressed. Physiologic problems associated with extended duration spaceflight, such as bone demineralization and intravascular fluid shifts, will be described. Special emphasis will be placed on the critical care capability planned for SSF HMF.

12. Crosier, William G.; and Kathleen M. Duncan (KRUG): A Data Acquisition and Analysis Program for Visual Tracking and Vestibular Research. Presented at the Annual Conference of the IEEE/EMBS, November 1989, Seattle, Washington.

A Macintosh program has been developed to perform data acquisition and

analysis of eye movements and related signals during vestibular testing at the NASA JSC Neuroscience Research Laboratory. The program is designed for studies of visual tracking and vestibulo-ocular reflex (VOR) function.

The software controls digitization of test data, with interactive calibration and calculation of eye and head velocities from sampled position data. A selection of digital filters and plot scale factors is provided. Saccades, blinks, and artifacts can be removed easily during the interactive data reduction process. Comparison of eye and head movements is performed using non-linear least squares curve fitting of the reduced data, separately for the head (stimulus) and eye (response) movement data, to compute the gain and phase of the VOR transfer function.

13. Crosier, William G.; K. Duncan; F. Ferrara (KRUG); D. L. Harm (JSC); and D. E. Parker (MU): Development of Trainers to Preadapt Astronauts to Sensory Rearrangements Produced by Microgravity. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

The goal of Preflight Adaptation Training (PAT) is to reduce or eliminate Space Motion Sickness (SMS) symptoms. Design concepts for a set of four part-tasks trainers were developed and evaluated. This paper describes the features of two PAT devices that have been recently completed.

14. Davis, J. D. (JSC): Life Sciences Concerns for Human Exploration. Presented at the Aerospace Medical Association Meeting, May 1989, New Orleans, Louisiana.

15. Davis, Jeffrey R (JSC); D. L. Baisden (KRUG); and R. T. Jennings (JSC): Incidence of Postflight Disequilibrium in Space Shuttle Crewmembers. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Space Shuttle crewmembers report symptoms of disequilibrium after landing such as balance instability, vertigo, nausea, and vomiting. This study attempts to clarify the incidence of these symptoms and compare postflight disequilibrium with inflight Space Motion Sickness (SMS). An oral debriefing with each Shuttle crewmember was conducted by a NASA flight surgeon within two hours after landing using a standardized questionnaire. The analysis was based on data from 42 crewmembers after their first Shuttle flight. Symptoms of postflight disequilibrium were reported by 39 of 41 crewmembers (93%). Vertigo was reported by 7 of 42 (17%), and nausea and vomiting by 4 (10%). Thirty of 31 crewmembers who reported inflight SMS also noted postflight disequilibrium (97%), yet 9 of 11 without inflight SMS also reported postflight disequilibrium. This lead to a poor correlation between postflight disequilibrium. and inflight SMS (r = .25). The severity of inflight SMS (r = .36), however, was the absence of postflight vertigo, nausea, and vomiting in those crewmembers who did not have inflight SMS. The reported incidence of postflight disequilibrium is 93% in Shuttle crewmembers after their initial flight. Postflight disequilibrium is not well correlated with inflight SMS, yet those crewmembers who do not report SMS also do not report more serious postflight symptoms of vertigo, nausea, and vomiting.

16. Diamandis, P. H.; Chiaki N. Mukai; M. W. Bungo (JSC); K. F. Elton; J. M. Riddle (KRUG); and C. M. Lathers (USRA): Orthostatic Function During a Stand Test Before and After Head-Up or Head-Down Bedrest. *Aviation Space Environmental Medicine*, Vol. 60, No. 5, p. 481, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

After space flight crewmembers may exhibit orthostatic dysfunction immediately upon return to 1g. Understanding cardiovascular (CV) changes at simulated 0g will provide insights into the mechanisms of the loss of orthostatic tolerance.

Young male adults were placed at -5°, +10, +20, or +42° bedrest (0, 1/6, 1/3, and 2/3g, respectively) for 6 hours on 4 different days. This was preceded and followed by a stand (ST) test: 5 min each supine (SU), then standing with the feet 9 inches apart and 6 inches from the wall.

17. Fortney, Suzanne M. (JSC); C. Tankersley (PSU); J. T. Lightfoot; G. Gerstenblith; L. Becker (JHU); J. Fleg; and E. Lakatta (GRC): Cardiac Volumes in Aerobically Fit and Unfit Older Men During Lower Body Negative Pressure. *Medicine Science in Sports and Exercise*, Vol. 21, No. 2, p. 542, 1989. Presented at the American College of Sports Medicine Conference, May 31, 1989, Baltimore, Maryland.

   This study examined the cardiac volumes of 18 men (60-75 yrs) during exposure to lower body negative pressure (LBNP). Nine men (CONT) had an average level of aerobic fitness ($VO2$ max = 31.0 ± 4.8 ml/kg/min, mean ± SD), and 9 men (ATHL) were long distance runners (80-250 miles/ mo) with an exceptionally high fitness (52.4 ± 2.7 ml/kg/min). Cardiac Index (CI), stroke volume index (SVI), end diastolic volume index (EDVI), and end systolic volume (ESVI) were measured (multiple gated blood pool analysis) at rest during each 3 min stage of LBNP (-8, -16, -32, -40, and -50 mmHg). Heart rate (HR) and mean blood pressure (MBP) also were measured. The resting values and the absolute changes from rest to -50 mmHg (mean ± SE) are discussed in this article.

18. Fortney, Suzanne M.; J. B. Charles; M. W. Bungo (JSC); J. Riddle (KRUG); and C. M. Lathers (USRA): Cardiac Volumes and Orthostatic Responses During Extended Bedrest. *Aviation Space Environmental Medicine*, Vol. 60, No. 5, p. 487, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington D. C.

   Cardiac volumes decrease rapidly during the initial days of space flight and remain depressed during flights lasting up to 10 days. This decrease is thought to reflect a loss of plasma volume which has a detrimental effect on orthostatic responses. We compared changes in cardiac volumes to changes in the heart rate response to lower body negative pressure (LBNP) during prolonged bed rest. We predicted that after 3 days of bed rest (BR), both changes in cardiac volumes and orthostatic responses would stabilize. Data have been analyzed from three male subjects during the first 24 days of bed rest.

19. Fortney, Suzanne M. (JSC); and Elizabeth Miescher (JHUMS): Responses to Dehydration and Rehydration During Heat Exposure in Young and Older Men. *American Journal of Physiology*, p. 257, February 16, 1989. Presented at the Workshop on the Use of Carbohydrate-Electrolyte Replacement Beverages, February 16-17, 1989, Washington, D. C.

   The ability to maintain body temperature, plasma responses, and subjective ratings of thirst and hotness was studied during a period of thermal dehydration and subsequent rehydration in five older men (OM, 61-67 years) and six younger men (YM, 21-29 years). The men sat for 240 min in a hot dry chamber (45°C, 25% rh). The results were presented at this workshop.

20. Fortney, Suzanne M. (JSC): Prevention of Cardiovascular Deconditioning During Space Flight. Presented at the Winter Meeting of the Mid-West Regional Chapter, American College of Sports Medicine, February 1-3, 1989, Alma, Michigan.

21. Fujii, Mavis D.; M. C. Greenisen; S. F. Siconolfi; B. A. Harris, Jr. (JSC); R. P. Elam (WU); and G. Mussacca (KRUG): Differences in Biomechanical Parameters During Treadmill Running at Equivalent Metabolic Effort. *Aviation Space and*

*Environmental Medicine*, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

To counteract muscle atrophy and bone demineralization which occur during space flight, an exercise program is being developed. The purpose of this pilot study was to determine the differences in muscle activity and treadmill reaction forces at different combinations of inclinations and speeds which yield equivalent metabolic workloads.

22. Gosbee, John (KRUG): Clinical Engineering of the Health Maintenance Facility. Presented at the 1989 NASA Space and Life Sciences Training Program, July 17, 1989, Kennedy Space Center, Florida.

The Health Maintenance Facility (HMF) will provide in-flight medical care for the crewmembers of the Space Station Freedom. The disciplines of both medicine and engineering are important in the development of the HMF. HMF medical operations will be consistent with terrestrial medical practice, as well as operate within the constraints of the Space Station Freedom environment. The Space Station Freedom will be a closed, weightless environment, with limited resources. Thus, some of the important engineering activities for the HMF include: (1) minimizing weight, volume, and power consumption; (2) identifying the effects of weightlessness; and (3) simplifying the logistics. However, these engineering activities are shaped and influenced by medical concerns. This presentation will discuss the multidisciplinary process by which medical equipment and supplies are selected and developed for use in the environment of space.

23. Harm, Deborah L. (JSC); Linda Michaud (KRUG); and Donald E. Parker (MU): Changes in the Vestibulo-Ocular Reflex Associated with Simulated Stimulus Conditions of Space Flight. Presented at the Society for Neuroscience, October 29 - November 3, 1989, Phoenix, Arizona.

The Otolith Tilt-Translation Reinterpretation (OTTR) model of adaptation to weightlessness suggests that graviceptor tilt signals are reinterpreted by the brain as translation during prolonged exposure to microgravity. Exposure to a Tilt-Translation Device (TTD) that simulates the stimulus rearrangement present during spaceflight should facilitate the translation interpretation and suppress the tilt interpretation. Ten naive subjects participated in both a TTD and control (tilt in darkness) condition. Subjects were restrained on a one degree-of-freedom moving base. Linear vection was induced by a combination of Y-axis pitch tilt and X-axis linear translation of an optolinetic visual scene. Electro-oculography recordings of compensatory vertical eye movements (VVOR) were obtained before, during, and immediately after each condition.

24. Harm, Deborah L.; and M. F. Reschke (JSC): Preliminary Investigation of Cardiovascular Responses to Parabolic Flight in Sick and Non-Sick Individuals. *Aviation Space and Environmental Medicine*, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Heart rate (HR) responses have been reported to increase during hypergravic phases and to decrease during hypogravic phases of parabolic flight. The purpose of the present study was to examine difference in HR and blood pressure (BP) responses during Og in sick and non-sick subjects. Seven subjects (three sick and four non-sick) were tested aboard the KC-135 (a NASA experimental aircraft) flown in a roller coaster pattern consisting of five sets of eight parabolas each. Heart rate and BP measurements were obtained pre- and postflight, during Og phases of the first and last two parabolas in each set, and during breaks between sets. Both HR and BP values were higher in sick than non-sick individuals, with HR showing the largest differences.

25. Harris, Bernard A., Jr. (SBRI); and Donald F. Stewart (JSC): Workshop on Exercise Prescription for Long-Duration Space Flight. NASA CP 3051, September 1989.

The National Aeronautics and Space Administration has a dedicated history of enduring human safety and productivity in flight. Working and living in space long term represents the challenge of the future. Our concerns are no longer getting a man into space but in determining the effects on the human body of living in space. Space flight provides a powerful stimulus for adaptation, such as cardiovascular and musculoskeletal deconditioning. Extended-duration space flight will influence a great many systems in the human body. We must understand the process by which this adaptation occurs. The NASA is agressively involved in developing programs which will act as a foundation for this new field of "space medicine." The hallmark of these programs deals with prevention of deconditioning, currently referred to as "countermeasures to zero g." Exercise appears to be most effective in preventing the cardiovascular and musculoskeletal degradation of microgravity. This document is a culmination of discussions from an exercise workshop held at the NASA Johnson Space Center. The proceedings from this session provide a comprehensive review of the physiology of exercise and recommendations on the use of exercise as a countermeasure for adaptation to a microgravity environment.

26. Horrigan, David J., Jr.; C. K. Lapinta (JSC); and J. Conkin (KRUG): NASA Requirements for Underwater Training and Surface Intervals Before Flying. *Proceedings of Workshop on Flying after Diving*, pp. 11-27, June 1, 1989. Presented at the Workshop on Flying After Diving, February 24, 1989, Bethesda, Maryland.

Underwater training has been useful in preparing astronauts for extravehicular activity (EVA) in space. The training program for EVA crewmembers utilizes the Weightless Environment Training Facility (WETF) at JSC, and at comparable facilities elsewhere. A simulated EVA workstation is set up underwater and the astronaut practices EVA specific techniques and the use of tools that he will later be asked to use in space. This training has been found to be excellent preparation for EVA and it is planned to be continued in future programs. Since the crewmembers frequently fly soon after their training sessions, we have developed restrictions as to surface times after diving and before flight in training and commercial aircraft. This surface time depends on depth, time at depth, breathing gas, and intended altitudes of flight to prevent the likelihood of decompression sickness (DCS).

27. Horrigan, David J., Jr.; C. K. LaPinta; J. M. Waligora (JSC); J. Conkin and B. J. F. Edwards (KRUG): Development of Decompression Guidelines for Space Crews Flying Aircraft after Neutral Buoyancy Training. *Aviation Space and Environmental Medicine*, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Crewmembers training for extravehicular activity utilize the Water Environment Test Facility (WETF) at the JSC as well as underwater facilities of varying depths at other NASA Centers and contractor plants. The Space Station Freedom Program has included plans to construct a deeper (65 ft) Neutral Buoyancy Facility to accommodate planned training. Requirements to fly both as passengers in commercial aircraft and as pilots in NASA aircraft after this training prompted us to analyze our laboratory data on hypobaric decompressions and integrate it with selected hyperbaric data to develop NASA guidelines for safe surface intervals prior to flying.

28. Huls, M. H. (KRUG); Clarence F. Sams; and Peggy A. Whitson (JSC): Culture Time and Glial Cell-Conditioned Medium (GCCM) Increase Atrial Natriuretic Peptide (ANP) Binding and ANP-Induced cGMP Levels in Brain Microvessel Endothelial Cells (BMEC). Presented at the American Society for Cell Biology, November 5-9, 1989, Houston, Texas.

We and others have observed specific ANP binding in primary cultures of bovine BMECs, suggesting a role for this fluid-regulating hormone in the brain. After the cells formed a monolayer, we measured ANP binding with 2 and 10 days of further culture. The apparent Kd increased 10-fold and the number of ANP binding sites increased 35-fold during the 10-day period following confluence. Time- and concentration-dependent stimulation of cGMP levels by ANP indicates the presence of guanylate cyclase-linked ANP receptors in BMECs. Affinity cross-linking with disuccinimidyl suberate and radiolabeled ANP demonstrated the presence of a 70 kD receptor, consistent with the presence of the ANP binding sites could be increased by treating the cells for a 24-hour period with medium that had previously been conditioned by C6 glial cells for 48 hours. No significant differences in the total protein/well or the number of cells/well were observed with treatment of the GCCM as compared to the control. However, the increase in ANP binding by cells treated with GCCM corresponded to the observed increase in ANP-inducible cGMO levels, suggesting the presence of a diffusible factor(s) secreted by the glial cells which modulates the ANP receptors in primary cultures of BMECs. These data suggest that this in vitro culture system may be a valuable tool to examine ANP receptor expression in blood-brain barrier endothelial cells.

29. Hunt, L. D.; D. Houston; S. Smith; M. Stanford; and G. R. Taylor (JSC): Space Station Freedom Human-Oriented Reference Experiment Scenario. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Life sciences research is an important component in determining the effects of microgravity upon crewmembers and extended man's potential colonization of space. NASA-recommended science activities were divided into seven disciplines; Behavior and Performance, Cardiovascular, Cell and Developmental Biology, Musculoskeletal, Neuroscience, Radiation, and Regulatory Physiology. The reference experiments required for laboratory design were developed to provide maximum science return as early as possible in the Space Station Freedom assembly sequence. Reference experiments were defined according to physiologic priority, STS up-mass potential for laboratory equipment, Freedom phase of development, Freedom resource allocation (e.g., mass, volume, power), experiment complexity, and demands on crew time. Freedom's human-oriented reference experiment scenario is discussed. The described scenario includes reference experiments by science discipline and order of conduct on Freedom as well as in-flight laboratory procedures. The planning activities based on the Life Sciences Research Baseline Reference Experiment Scenario will provide for high-fidelity physiologic data to be obtained on Space Station Freedom.

30. Jackson, A. S. (UH); S. N. Blair (AI); M. T. Mahar (SC); L. T. Wier (JSC); J. E. Stuteville (KS); and R. M. Ross (Consultant): Prediction of VO2 Max Without Exercise Testing. Presented at the American College of Sports Medicine Annual Meeting, May 27, 1989, Baltimore, Maryland.

When not directly measured, VO2 Max is estimated either from maximum exercise or heart rate at submaximal exercise. The standard error (SE) for these prediction models range from 3 to over 5 ml-kg-min-1. The purpose of this study was to develop VO2 Max prediction models without using exercise tests (N-EX) and compare the accuracy with that obtained with Astrand's single stage submaximal

model (A-SSM). The data were from 2,249 subjects (91% male) who had a maximal Bruce treadmill test and negative exercise EKG. Metabolic data were continuously sampled with a computer-controlled operational circuit system. Heart rate was monitored by EKG. Sample characteristics were: mean VO2 Max (ml-kg-min-1) 38.8 ± 8.9 mean age 44.2 ± 8.8; and mean R 1.22 ± 0.11. The total sample was randomly divided into validation (N = 1,650) and cross-validation (N = 599) samples. Multiple regression (MR) was used to develop two VO2 Max equations from: age, self-report exercise history (SR-E); gender (M = 1: F = O); and either skinfold measured % fat or body mass index (BMI). SR-E was by a global assessment of exercise during the previous 30 days. The standardized regression weights (B) and regression statistics for the two models are presented. These equations were applied to the cross-validation sample and the validity was confirmed: N-EX1, r = 0.79. SE = 5.2 ml-kg-min-1; N-EX2, r = 0.77, SE = 5.5 ml-kg-min-1. Male and female SEs did not differ. The r's between A-SSM determined and measured VO2 Max (N = 2.039) ranged from 0.69 to 0.80 with SEs from 5.6 to 7.2 ml-kg-min-1. This confirmed that the N-EX models were as accurate as established submaximal treadmill prediction models. The N-EX models provide a cost-effective method of estimating VO2 Max in large populations.

31. Jacobs, F. O.; S. M. Fortney; John B. Charles; Chiaki N. Mukai (JSC); J. M. Riddle; K. F. Elton; B. S. Bennett (KRUG); C. M. Lathers; M. A. Frey (USRA); and J. Davis (ALMA): Effect of 10 weeks of Bedrest on Forearm Vascular Responses to Lower Body Negative Pressure. Aviation Space and Environmental Medicine, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D.C.

Acute changes in thoracic blood volume stimulate changes in forearm blood flow (FBF) by sympathetic reflexes acting on the skeletal muscle vascular beds. It is unclear how sustained headward fluid shifts in Og influence FBF. Knowledge of peripheral vascular resistance (PVR) responses to orthostatic stress will facilitate treatment of postflight orthostatic intolerance. Adult males underwent 2 weeks ambulatory control, 17 weeks of total bedrest and 5 weeks of recovery to document hypokinesia-induced Ca + + loss. As an adjunct study, lower body negative pressure (LBNP; 5 min each at -5, -10, -20, -30, -40, and -50 mm Hg) was done weekly to document changes in reflex responsiveness to central volume receptor unloading, measured by FBF (venous occlusion plethysmography; ml/min/100 gm tissue) and echocardiography.

32. Jennings, Richard T.; and D. K. McKenas (JSC): Space Shuttle Abort Landing Site Emergency Medical Services: Issues in Remote Medical Care. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Space Shuttle Transoceanic Abort Landing (TAL) sites, located on the African coast and in Spain, require advanced emergency medical capability for crewmembers who may be injured in an abort landing. The remote locations of the African TALs present unusual medical planning and logistical problems. Two options to provide medical care in these regions were jointly explored between NASA and the DOD. The first involved using a modified surgical response team, and the second involved using physician/medical technician (ATLS) teams. Research on the logistics of blood procurement, blood refrigerator and power requirements, air evacuation, and search and rescue (SAR) requirements led to an effective system development to support the medical concerns for a TAL in remote regions. The ATLS team concept was the most cost-effective solution for providing crewmember medical support in these regions. On scene stabilization by ATLS teams, and prompt air evacuation to high quality foreign trauma centers and DOD tertiary medical care centers by on-station search and rescue C-130

aircraft completed the system development. Remote region medical care planning requires attention to unusual details not encountered in routine medical care settings. The balance between on-site medical capability and cost-effectiveness issues is a primary determinant in planning and logistics.

33. Jennings, Richard T. (JSC): Reproduction in the Space Environment. *Aviation, Space and Environmental Medicine*, Vol. 60, No. 5, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

The exploration and colonization of space will ultimately depend on human ability to live, work, and reproduce in the space environment. Animal reproductive studies in microgravity have demonstrated that the space environment has significant effects on all aspects of reproductive function. Human studies have yet to be accomplished. A review of animal studies done in space or space-simulated environment was undertaken to identify aspects of microgravity which might impair human reproductive physiology and function. Those space environmental factors which impacted animal species studies included: microgravity, artificial gravity, radiation and closed life support systems (including breathing gas partial pressures and prolonged toxiocological exposures). These factors will act independently and in combination on men and women living in space. In assessing their impact on human reproduction, the effects of microgravity on other organ systems must also be considered. Gynecologic and obstetric paramenters which might be impaired by space flight are discussed, and the impact of space flight on male fertility and gamete quality is explored. Due to current constraints, human pregnancy is now contraindicated for space flight. A program to provide further answers to reproductive questions (including both ground and space-based studies) and to explore effective countermeasures for potential reproductive problems in space is necessary to ensure that the human species can successfully colonize space.

34. Jessup, J. M. (UTMDA); T. J. Goodwin (KRUG); C. D. Bucana (UTMDA); C. F. Sams; and D. A. Wolf (JSC): Matrix Association Cultures System (MACS): A New Three-Dimensional Culture System. Presented at the American Society of Cell Biology, January 29 - February 4, 1989, San Francisco, California.

Differentiation in tissue culture may require appropriate three-dimensional interaction between stromal and epithelial cells to induce expression of structures seen in vivo. Two anchorage-dependent human colon adenocarcinoma lines HT-29 and KM-20 were grown in a new low-sheer tissue culture vessel developed at NASA/JSC. Tumor cells were cultivated on collagen-coated (CYtodex-3) micro-carrier beads (10 cells/bead and 5mg beads/ml of medium) with and without mixed normal human colonic fibroblasts which served as the stromal layer. Growth of the tumor cells in the absence of fibroblasts was slow (doubling time 30-50% longer), between beads, and limited to $4 \times 10^6$ cells/ml. When tumor cells were cultured with fibroblasts, the fibroblasts first covered the bead surface; then the tumor cells grew into three dimensional masses covering the beads, creating spheroids of up to .75cm with cell concentrations of $9.3 \times 10^6$ cells/ml. The surface membranes of cultures without fibroblasts developed crypt-like glandular structures with fibroblasts interacting with tumor cells. Cross sections of these spheroids demonstrated only minimal necrosis. The cultures with fibroblasts buffered acid production better than the cultures without fibroblasts, while both cultures consumed similar amounts of glucose. Both tumor cell lines gave similar results. The MACS may help to identify and isolate growth factors, and structural processes within neoplastic and normal tissue.

35. Kilgore, M. V.; R. J. Zahorchak; and W. F. Arendale (Univ. of Alabama): *Definition of a Near Real-Time Microbiological Monitor for Space Vehicles*, NASA CR 185599, 1989.

36. Kohl, Randall Lee; and Dick S. Calkins (USRA): Human Vasopressing (AVP) and Adrenocorticotropin (ACTH) Responses to Stressful Sensory Input: Individual Differences and Adaptive Responses. Presented at the Society for Neuroscience, October 29 - November 3, 1989, Phoenix, Arizona.

    Plasma levels of AVP and ACTH were determined in human subjects before and after exposure to stressful Coriolis stimulation on a rotating chair assembly. Subjects made head movements out of the plane of rotation until stimulation of vestibular systems induced advanced nausea and autonomic system dysfunction (i.e., motion sickness). Pre- and post-test levels of AVP were linearly correlated ($r = 0.561$, $p < 0.05$). The amount of stimulation tolerated before nausea occurred was significantly correlated with the subjects' ability to mobilize AVP (Kruskal-Wallis 1-way ANOVA, $p < 0.04$), but not with resting levels of AVP or ACTH. The coefficient of variation determined from six measurements of resting levels of AVP was inversely correlated with susceptibility to stressful motion ($p < 0.006$). After five consecutive daily exposures to nausea, a significant diminution of postnausea AVP and ACTH occurred.

37. Kohl, Randall Lee (USRA): Relationship of Vasopressin (AVP) to Adrenocorticotropin (ACTH) and Nausea Before and After Adaptation to Motion Sickness. *Aviation Space and Environmental Medicine*, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D.C.

    Hormonal responses to stressful motion environments or to nausea may offer etiologic insight to the mechanisms underlying space sickness and explain the physiologic differences between individuals of differing susceptibilities. Seventeen subjects took Staircase Profile Tests until reaching the symptom of nausea II on five consecutive days. Blood samples were obtained pre- and post-test. Adapted subjects demonstrated smaller increments in AVP following nausea than on their previous test. This pattern persisted following placebo, doxepin or thyrotropin-releasing hormone.

38. Kohl, Randall Lee (USRA): The Role of Dopamine in Modulating Autonomic Dysfunction Following Stressful Sensory Input. Presented at the Winter Conference on Brain Research, January 22-29, 1989, Snowbird, Utah.

    Autonomic dysfunction following discordant and stressful sensory input, such as that following cross-coupled accelerative Coriolis stimulation, previously has been shown to be therapeutically responsive to psychostimulant drug treatment. Because drugs such as methylphenidate have been shown to be as efficacious as amphetamine, it was hypothesized that dopamine release may underlie the neurochemical actions through which psychostimulant drugs prevent autonomic dysfunction. The synergistic effects obtained following amphetamine combined with scopolamine led us to suggest that the role played by the basal ganglia may be important in sensory integration and autonomic system control. The data presented by this poster details our recent research with several drugs affecting dopaminergic activity through different mechanisms.

39. Kohl, Randall Lee (USRA); Louis D. Kinter; David B. Brooks; and William H. Huffman (SKFL): Vasopressin, A Modulator of Stress-Induced Autonomic Changes. Presented at the Winter Conference on Brain Research, January 22-29, 1989, Snowbird, Utah.

    Neuronal systems employing the neuromodulator vasopressin (AVP) have been

extensively characterized. Pathways interconnecting autonomic centers in the paraventricular hypothalamic nucleus and the medulla are well known. The workshop reviews the chemistry, pharmacology, neuroanatomy, and neurophysiology of AVP with the aim of understanding its role in the regulation of the autonomic nervous system during stress. Clinical data establishing a behavioral link between AVP, autonomic dysfunction, and nausea will be detailed. Some new human data will be presented to show that susceptibility to stressful motion environments correlates with the responsiveness of peripheral release of AVP. Discussion will focus on evaluating alternative models for AVP's possible autonomic regulatory role and the physiological functions of central and peripheral V1 and V2 receptors.

40. Krauhs, Jane M. (KRUG); Nitza Cintron; and C. Leach (JSC): Cluster and Factor Analyses of Space Shuttle Preflight and Postflight Endocrine Data. *Aviation, Space, and Environmental Medicine*, Vol. 60, No. 5, p. 511, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C. .

More astronauts have flown on the Space Shuttle than on any other American flight program and for 10 flights body fluid samples were obtained on landing day. Because of the relatively large number of subjects, it is possible to perform statistical analyses of these data that could not be done with data from other flight programs. Electrolytes, hormones, and other biochemical compounds were measured by standard clinical methods in blood samples and/or 24-hour urine pools obtained from 35 Shuttle astronauts before flight and on landing day. Statistical tests, including factor analysis and cluster analysis of variables and cases, were performed using BMDP biomedical computer programs. Results of factor analysis were slightly different for preflight and postflight; for example, growth hormone was elated to thyroid hormone at landing but not before flight. Adrenocorticotropin and insulin were related before and after flight, as were plasma renin activity and aldosterone. In 40% of the astronauts, however, aldosterone was about the same at landing, and before flight, whereas plasma renin activity increased significantly (178%) at landing. There was some clustering of astronauts on the same flights. Mathematical relationships between some endocrine variables were different after space flight. These results indicate avenues for further experimentation that could lead to a physiologic interpretation.

41. Kraus, Elizabeth; L. Neale (KRUG); B. Pietrzyk; R. Meehan; and C. Stuart (UTMB): Quantitation of Insulin Receptor Expression on the IM-9 Cell Line by Simultaneous Flow Cytometry Analysis and Ligand Binding. *Aviation, Space, and Environmental Medicine*, Vol. 60, No. 5, Abstract #35, p. 483, May 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

New methods employing Simply Cellular Microbeads (SCM), Quantitative Fluorescence Microbead Standards (QFMS), and flow cytometry (FCM) analysis were investigated to quantitate the density of available insulin receptors on IM-9 cells in comparison to the number of binding sites per cell determined by radiolabeled ligand binding (RLB). IM-9, a lymphoblastoid cell line, and SCM (Flow Cytometry Standards Corp.) were labeled with a fluorescently conjugated monoclonal antibody recognizing the insulin receptor. Labeled samples were analyzed by FCM in conjunction with a series of QFMS of known size and fluorescent intensity to generate a standard curve. From this curve the fluorescence to protein ratio (F/P ratio) was calculated to ascertain the number of receptors per IM-9 cell. For the insulin binding assays, cultured cells were incubated at 15° C for 90 minutes with radiolabeled insulin. Scatchard analysis of RLB data was used to determine the number of insulin binding sites per cell. Ligand binding data consistently indicated a greater number of insulin binding sites per cell than FCM data. However,

correlation between the two methods was significant; r = 0.99. These data indicate that quantitation of cell surface receptors by FCM provides the necessary sensitivity without the laborious procedures and hazards associated with RLB.

42. Krebs, Jean M.; A. LeBlanc; H. Evans; M. Kuo (KRUG); and V. S. Schneider (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.

Continuous bedrest is utilized 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 ± 5.0 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.

43. Kumar, K. V.; and J. M. Waligora (JSC): The Effects of Different Rates of Ascent on the Incidence of Altitude Decompression Sickness. NASA TM 100472, March 1989.

The effect of ascent rates on Decompression Sickness (DCS) was examined in a retrospective study. Information on 150 altitude studies (14,123 exposures) were collected. The data was classified on the basis of altitude reached (up to 38,000 ft), denitrogenation at ground level, duration of stay at altitude, rest or exercise at altitude, frequency of exercise and ascent rates in each study. Distribution of data showed mean ± SE of 31,697 ± 573 ft of exposure altitude, 2.8 ± 0.2 hours of exposure, 0.9 ± 0.1 hours of denitrogenation, 5896 ± 597.6 ft/min of ascent rates (1,100 to 53,000 ft/min) in these studies. No denitrogenation was done in 59% (89/150) and exercise at altitude was undertaken in 79% (119/150) of all studies. Analysis of the data using multiple linear regression showed that rate of ascent was not a significant predictor (p > 0.05) of symptoms of DCS, but showed high correlation with other independent factors (R = 0.32; p < 0.01). Tests for homogeneity showed that while ascent rates below and above 2,500 ft/min were significantly different (p = 0.03), no such difference was evident in rates from 2,500 ft/min up to 53,000 ft/min.

44. Kumei, Y.; N. M. Cintron (JSC); and P. A. Whitson (KRUG): Rapid Increase in Inositol Trisphosphate in Hela Cells after Hypergravity Exposure. Presented at the American Society for Gravitational and Space Biology. October 25-28, 1989, Cocoa Beach, Florida.

The objective of this study was to clarify the mechanism by which gravity stimulus is transmitted in mammalian cells. The levels of the second messenger inositol trisphosphate (IP3) were time-dependently altered in HeLa cells exposed to hypergravity as compared to control cells.

45. Kuo, C. M.; J. R. Schultz (KRUG); R. Sauer, and Nitza Cintron (JSC): Determination of Total Fluoride in Blood Plasma by Ion Chromatography. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

In a series of long-term bedrest studies, the use of fluoride is being evaluated as a method of reducing bone calcium loss during space flight. The analysis of total fluoride in food, feces, urine, and blood plasma is necessary to optimize the fluoride dose. The commonly used ion selective electrode method requires an extended amount of time to perform measurements because of slow electrode response at low concentrations. A study was undertaken to evaluate the use of

ion chromatography as an alternative to ion selective electrodes. Blood plasma samples were pretreated by fixation with magnesium acetate, ashing at 500°C, and subsequent dissolution of the ash with perchloric acid. The fluoride ions were then isolated by overnight diffusion into a sodium hydroxide solution. The fluoride content of the NaOH solution was determined using ion chromatography. A Dionex 4000i ion chromatograph equipped with an AS4A anion separator column and an anion membrane suppressor was used. Ten replicate determinations of a blood plasma sample yielded an average fluoride concentration of 0.092 ug/ml, with a standard deviation of 0.013 ug/ml. Recovery tests with up to 0.5 ug of inorganic fluoride and up to 0.4 ug of organic fluoride demonstrated a near 100% recover. Ion chromatography can be used to increase the sensitivity and to decrease the analysis time required to determine fluoride levels in blood plasma.

46.  Lam, Chiu-Wing; T. Galen (KRUG); and D. Pierson (JSC):  Toxicokinetic Study of Humans Exposed to Halon 1301 (The Shuttle Fire Extinguishant). Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Halon 1301 (Bromotrifluoromethane) is used as a fire extinguishing agent in the Space Shuttle. If a fire or potential fire occurs, Halon 1301 could be discharged and result in a concentration of up to 1% in the crew module atmosphere. To examine the effects of Halon 1301 on physiological and mental performance, NASA sponsored a human inhalation study. As part of this study, blood and breath samples were collected to examine the toxicokinetics of Halon 1301 in the body. Four pairs of test subjects were exposed in a double-blind fashion for 24 hours to air and to a 1% Halon 1301/air mixture in two separate exposures approximately one week apart. Performance battery tests were administered; clinical chemistries, cardiac and pulmonary functions were measured. During and after each of the exposures, the blood and breath samples were collected for the toxicokinetic study. Blood Halon 1301 levels reached a steady state concentration of about 3-4 mg/ml within 2 hours. Breath samples reflected the chamber concentration relatively closely. After exposure both blood and breath showed an initial fast phase of Halon 1301 elimination followed by a slow phase of elimination. The fast and slow elimination phases probably reflect the elimination of Halon 1301 from the well-perfused tissues and slow-perfused tissues (such as fat), respectively. The toxicokinetics of Halon 1301 in the body are similar to that of other organic gases.

47.  Landry, R. (KRUG); and Nitza Cintron (JSC):  Clinical Evaluation of the Clay Adams QBC II Centrifugal Hematology System. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

The Space Station Health Maintenance Facility (HMF) will require a clinical hematology capability to monitor and diagnose the health status of crewmembers. Since conventional techniques present unique problems in a reduced-gravity environment, the Clay Adams QBC II Centrifugal Hematology System was evaluated for possible use in the HMF. Hematocrit, platelet, total leukocytes, granulocyte and agranulocyte counts were measured. Blood samples were collected from 107 hospitalized patients (medical and surgical). Specimens were analyzed on the QBC II, a Coulter S Plus II, and a Sysmex 5000 for comparison purposes. Manual differential counts were performed and centrifuged microhematocrits were measured.  QBC hematocrit data were closer to the reference microhematocrit than the data from the Coulter and Sysmex. Total leukocyte and platelet counts from the QBC showed good correlation with both electronic methods. The QBC modified differential compared favorably with interlaboratory data when manual

differential cell classes were appropriately combined. Nonseparation of erythrocytes and granulocytes resulted in loss of leukocyte data with 8.4% of the specimens. The QBC II is easy to use and can provide reliable basic hematology data. Data are limited to hematocrit and platelet count in some specimens due to overlapping erythrocyte/leukocyte density.

48. Lane, Helen W. (JSC): Physological Changes in Space Flight That Affect Nutritional Requirements. Presented at the Tall Pines Dietetic Association, November 9, 1989, Kingwood, Texas.

49. Lathers, Claire M. (USRA); J. B. Charles; T. A. Holt; C. Mukai; M. W. Bungo (JSC); K. F. Elton; and B. S. Bennett; (KRUG): Acute Hemodynamic Responses to Weightlessness in Humans. *Journal of Clinical Pharmacology*, Vol. 29, No. 7, July 1989.

As NASA designs space flights requiring prolonged periods of weightlessness for a broader segment of the population, it will be important to know the acute and sustained effects of weightlessness on the cardiovascular system since this information will contribute to understanding of the clinical pharmacology of drugs administered in space. Due to operational constraints on space flights, earliest effects of weightlessness have not been documented. We examined hemodynamic responses of humans to transitions from acceleration to weightlessness during parabolic flight on NASA's KC-135 aircraft. Impedance cardiography data were collected over four sets of 8-10 parabolas, with a brief rest period between sets. Each parabola included a period of 1.8 Gz, then approximately 20 seconds of weightlessness, and finally a period of 1.6 Gz; the cycle repeated almost immediately for the remainder of the set. Subjects were semi-supine (Shuttle launch posture) for the first set, the randomly supine, sitting and standing for each subsequent set. Transition to weightlessness while standing produced decreased heart rate, increased thoracic fluid content, and increased stroke index. Surprisingly, the onset of weightlessness in the semi-supine posture produced little evidence of a headward fluid shift. Heart rate, stroke index, and cardiac index are virtually unchanged after 20 seconds of weightlessness, and thoracic fluid content is slightly decreased. Semi-supine responses run counter to Shuttle crewmember reports of noticeable fluid shift after minutes to hours in orbit. Apparently, the headward fluid shift commences in the semi-supine posture before launch, is augmented by launch acceleration, but briefly interrupted immediately in orbit, then resumes and is completed over the next hours.

50. Lathers, Claire M. (USRA); P. H. Diamandis (MIT); K. F. Elton; J. M. Riddle (KRUG); Chiaki N. Mukai; M. W. Bungo; and J. B. Charles (JSC): Acute and Intermediate Cardiovascular (CV) Responses to Simulated OG and Fractional Gravity Loads. *Aviation Space and Environmental Medicine*, Vol. 60, No. 5, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Determination of early CV responses to simulated gravity levels between 0 and 1g will add knowledge of CV responses to space flight. CV responses to 6 h in a -5° head-down bedrest model of weightlessness (Og) 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. The results of this study were presented at this meeting.

51. Lathers, Claire M. (USRA); John B. Charles; and Michael W. Bungo (JSC): Pharma-
cology in Space. Controlling Motion Sickness. *Trends in Pharmacological
Sciences*, Vol. 10, No. 6, June 1989. Presented at the Aerospace Medical
Association, May 7-11, 1989, Washington, D. C.

This second article in the two-part series on pharmacology in space, discuss
the pharmacology of drugs used to control motion sickness in space and note that
the pharmacology of the 'ideal' agent has yet to be worked out. That motion
sickness may impair the pharmacological action of a drug by interfering with its
absorption and distribution because of alteration of physiology is a problem
unique to pharmacology in space. The authors comment on the problem of
designing suitable ground-based studies to evaluate the pharmacological effect of
drugs to be used in space and discuss the use of salivary samples collected
during space flight to allow pharmacokinetic evaluations necessary for non-
invasive clinical drug monitoring.

52. Lathers, Claire (USRA); J. B. Charles; and M. W. Bungo (JSC): Pharmacology in
Space. Influence of Adaptive Changes on Pharmacokinetics. *Trends in
Pharmocological Sciences*, Vol. 10, No. 5, May 1989.

The topic of pharmacology in space, i.e., the administration of drugs during
space flight and the subsequent pharmacokinetic handling of the pharmaceuticals,
is a new field about which little is known. In a two-part series, Claire Lathers and
colleagues highlight some of the current questions in this field. In this first article
the physiological and biochemical changes associated with weightlessness in
space are discussed. These changes induce adaptive alterations which may
influence the pharmacokinetic properties of drugs. The cardiovascular system is
of particular relevance here. Also discussed are the classes of pharmacological
agent that are most likely to be used during space flight for medical problems and
thus, by necessity, will become drugs to be examined in space to determine
whether their pharmacokinetic and pharmacodynamic properties are altered.

53. Lathers, Claire (USRA); K. F. Elton; T. A. Holt; B. S. Bennett; (KRUG); J. B. Charles;
C. Mukai; and M. W. Bungo (JSC): Hemodynamic Changes to Brief Weight-
lessness. *Journal of Clinical Pharamacology*, Vol. 29, p. 833, 1989. Presented at
the Annual Meeting of the American College of Clinical Pharmacology, October
1989, Baltimore, Maryland.

Knowledge of acute and sustained effects of weightlessness on the cardio-
vascular system will contribute to understanding the clinical pharmacology of
drugs administered in space. The earliest effects of 0-G in space flights have not
been well documented because of crew involvement in mission tasks required
immediately postlaunch. This study used parabolic flight on NASA's KC-135 air-
craft to examine hemodynamic responses of humans to transitions from accelera-
tion to 0-G. Impedance cardiography data were collected during the first parabola
in each of four sets of 8-10 parabolas. Each parabola included a period of 1.8 G,
then 20 sec of 0-G, and finally a period of 1.6 G. Subjects were positioned in the
semi-supine (Shuttle launch posture) for the first set, then randomly supine, sitting
and standing for each subsequent set heart rate (HR) decreased during the transi-
tion to 0-G; thoracic fluid content (TFC) and stroke index (SI) increased in the
standing position. Onset of 0-G in the semi-supine posture produced little
evidence of a headward fluid shift. After 20 sec of 0-G HR, SI, and cardiac index
were unchanged; TFC was slightly decreased. Thus, head fluid shift may not
occur immediately on reaching orbit, counter to Shuttle crewmember reports of
noticeable fluid shift after min to hr in orbit.

54. Marino, Lori Ann (KRUG); C. M. Verrett; F. O. Black; S. J. Wood; and M. F. Reschke (JSC): Normative Study of a Preflight/Postflight Space Vestibulo-Ocular Test Battery. *Aviation, Space, and Environmental Medicine*, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Visual-vestibular responses as a function of experimental testing during space flight could be compromised by abnormal or inappropriate responses. Prior evaluation with properly selected tests is necessary to assist in the interpretation of experimental data. With this objective in mind, a study was designed to establish baseline normative responses to a test battery that can be used with crewmembers serving as subjects. Sixteen males and four females participated in this study. These subjects were closely matched to the astronaut population in mean age, age range, sex ratio, and motion sickness susceptibility. A battery of tests, including tests for benign paroxysmal nystagmus, positional nystagmus, gaze nystagmus, ocular dysmetria, pursuit tracking ability, postural equilibrium, and rod-and-frame performance were used to screen the subject population.

55. McKinley, Bruce A. (KRUG): Development of a Clinical Chemistry Analyzer for Medical Laboratory Diagnosis at the NASA International Space Station Freedom. Presented at the Japan Society for Clinical Laboratory Automation, September 8, 1989, Tokyo, Japan.

NASA's International Space Station Freedom Program is in the planning and design phases. An operational concern cited early in the program is medical care for the Space Station Freedom crew. An integrated medical care system, called the Health Maintenance Facility (HMF), is being designed for the Space Station Freedom. The HMF will provide necessary equipment and supplies to facilitate medical care by a crew medical officer (care provider) assisted by Earth-based medical consultants. The basis for design is current U.S. medical practice and theassumption that disease processes will not be significantly different in space. As with Earth-based medical care, facilities, laboratory diagnostics, and clinical chemistry are planned functional components of the HMF. For a crewmember/patient in the remote setting of a space station in the care of a non-physician, the data obtained from a clinical chemistry analyzer (and other laboratory diagnostic equipment) may be the most definitive criteria for decisions to initiate, guide, or terminate therapy, or to attempt patient transport to Earth.

56. Meehan, R. T. (UTMB); N. M. Cintron (JSC); W. J. Kramer; and A. Cymerman (USARIEM): Association between ACTH and Beta-Endorphin Levels and Susceptibility to Acute Mountain Sickness. *Aviation Space Environmental Medicine*, Vol. 60, No. 5, P. 482, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

The role of neuropeptide hormones in the pathogenesis of acute mountain sickness (AMS) was investigated. Fasting a.m. blood samples were collected from 9 subjects at sea level and after 4 days and 17 days on the summit of Pikes Peak (14,110 ft). Plasma ACTH and beta endorphin levels were analyzed by RIA and the severity of AMS was identified by cerebral symptom scores on a validated symptom rating scale (Environmental Symptom Questionnaire, ESQ-C). Elevated ACTH and beta-endorphin levels were noted after 4 days at altitude: $29 \pm 3$ vs $37 \pm 4$ pg/dl ACTH and $6.8 \pm 0.6$ vs $8.9 \pm 1.1$ pmol/L endorphin ($p < .01$ sea level vs altitude respectively). These levels were inversely correlated ($r = -0.81$ endorphin and $r = -0.73$ for % change in ACTH levels) with AMS symptoms. These results suggest that persons who produce higher levels of neuropeptide hormones during hypoxic stress are less susceptible to AMS. Since AMS may represent a mild form of cerebral edema, endogenous hormone production may protect against increased cerebral hydration during hypobaric-hypoxia.

57.  Mishra, S. K.; H. D. Brown; R. D. Taylor; and D. L. Pierson (JSC):  Telemycology:
     A Novel Approach to Monitoring Environmental Microbial Load.  Presented at the
     SAE 19th Intersociety Conference on Environmental System, July 24-26, 1989,
     San Diego, California.

     The current available methods for monitoring environmental microbial load call
     for the cultivation of microbes on laboratory media, a time- and material-
     consuming task that is potentially hazardous.  Telemycology proposed in this
     communication is designed to eliminate the need for growing microbes, especially
     fungi, on board the spacecraft and to shift bulk of the work-load to the ground-
     based Microbiology Laboratory.  The system is based on the principle of trapping
     microbial propagules on a membrane filter, treating it with a microbe-enhancing
     reagent and examining under a microscope down-linked to the central laboratory
     equipped with a synchronized televideo, telerobotics and image banking system.

58.  Morrison, Dennis R. (JSC); and Gunter A. Hofmann (BTX):  Cell Separation and
     Electrofusion in Space.  Presented at the AIAA Symposium on Space Commer-
     cialization:  Roles of Developing Countries, March 5-10, 1989, Nashville,
     Tennessee.

     Biotechnology and related molecular biology research are often held back by
     inadequate methods to isolate and culture target cells.  In microgravity free-fluid
     electrophoretic methods for separating living cells and proteins are significantly
     improved by the absence of gravity driven phenomena.  Cell fusion, culture and
     other bioprocessing steps are being investigated to better understand the limits of
     Earth-based processing.  A synopsis of bioprocessing and cell biology experi-
     ments in microgravity is discussed with potential applications for production and
     purification of human hormones, fibrinolytic enzymes, Interferon, specific target
     cells for transplantation, antigen specific lymphocytes, hybridomas, and mono-
     clonal antibodies.  A multi-step space bioprocess is described which includes
     electrophoretic separation of human target cells, single cell manipulations using
     receptor specific antibodies, electrofusion to produce immortal hybridomas,
     gentle suspension culture and monoclonal antibody recovery using continuous
     flow electrophoresis or recirculating isoelectric focusing.  Improvements in
     several key steps already have been demonstrated by space experiments and
     others will be studied on the U.S. Space Station.  Applications of the commercial
     products from space include diagnosis and treatment of certain cancers and
     autoimmune diseases.  Technology spin-offs of compact, automated research
     devices developed for spaceflight are described including bench-top systems
     which can be used for biotechnology and biomedical research or small scale
     pharmaceutical production in developing countries.

59.  Morrison, Dennis R. (JSC):  Space Applications of Bioprocessing:  Purification of
     Cells and Secretory Products.  *Aerospace Application in Biotechnology Proceed-
     ings*, July 1989.  Presented at the Aerospace Application in Biotechnology, March
     1-2, 1989, Colorado Springs, Colorado.

     Space bioprocessing research began 20 years ago with attempts to enhance
     the efficiency of free-fluid electrokinetic methods for separation of certain living
     cells which secrete medically important hormones and enzymes.  Flight experi-
     ments have included preparation, cultivation, isolation of target cells, studies of
     cell-cell interactions, and secretory function in microgravity.  Analytical and pre-
     parative electrophoresis methods have been compared to determine the relation-
     ship between cell surface charge and target cell functions.  A 1-g version of the
     Shuttle continuous flow electrophoresis (CFE) system was compared with com-
     mercial CFE and recirculating isoelectric focusing (RIEF) devices for separating
     living cells and protein.  Correlations were made among electrophoretic mobility

(EPM), secretory functions and input sample concentration. A significant reduction in mean and range of EPM is shown when input sample concentrations exceed a low threshold in unit gravity.

60. Mukai, Chiaki N.; J. B. Charles (JSC); B. S. Bennett; K. F. Elton (KRUG); C. M. Lathers (USRA): Acute Hemodynamic Responses to Og Induced by Parabolic Flight. *Aviation, Space, and Environmental Medicine*, Vol. 60, No. 5, pg. 509, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Pilots and astronauts experience fluid shifts in variable gravity. Acute effects of fluid shifts on the cardiovascular (CV) system were monitored on NASA's KC-135 aircraft during parabolic flight. In seven subjects a BoMed NCCOM3 monitored thoracic fluid index (TFI, ohms), heart rate (HR, bpm), stroke volume (SV, ml), cardiac output (CO, 1/min), and the ejection velocity index were stored on a laptop computer with the subject in one of four postures [sitting (SI), standing (ST), supine (SU), and semi-supine (SS)] during one of four sets of 8 to 10 parabolas.

61. Nachtman, R. (KRUG); T. Driscoll; L. Rice; and C. Alfrey (BCM): Red Blood Cell Survival After Blood Volume Expansion in Rats. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

During space flight humans lose up to 15% of their circulating red blood cells (RBCs). This anemia appears to be time dependent and to plateau after 30 days. Sequestration, escape, or destruction of RBCs may plan a role in the anemia by decreassing RBC surival (RCS). The relative hypervolemia from the cephalic fluid shift in weightlessness or the relative polycythemia that develops after circulatory adjustments correct the fluid shift may initiate mechanisms to rid the body of "excess" RBCs. Thus, the aim of this study was to determine if an absolute expansion of the blood volume by transfusion alters RCS. Male Sprague-Dawley rats (250 g.) received no treatment or 5-ml of rat plasma, whole blood, washed RBCs, or saline through a catheter placed in a tail vein for 30 minutes. Before transfusion each rat received 0.2 ml of 51Cr-labeled rat RBCs as a life span marker. Red cell mass (RCM) measurements using 99mTc-tagged RBCs and blood samples were obtained on 10 different days. RBC transfusions increased the hematocrit, hemoglobin, RBC count and size distribution width (RDW). Increased values for the first three RBC indices were maintained until day 8. RDW increased slowly until it peaked about day 18. No changes in RCS were observed. The changes in RBC indices from the RBC transfusions resembled those known to occur in humans during spaceflight. The significance of the RDW change is unknown. Expansion of the blood volume up to 33% did not alter RCS.

62. Nachtwey, D. Stuart (JSC): Radiation Issues for Exploratory Class Missions in Space. Presented at the Workshop on Biomedical and Space-Related Research with Heavy Ions at the BEVALAC, March 16, 1989, Berkeley, California.

The crewmembers of a piloted mission to Mars will be unavoidably exposed to ionizing radiation as they pass through the inner trapped proton belt, the outer trapped electron belt, and through the galactic cosmic ray (GCR) flux of interplanetary space. Moreover, outside of the Earth's magnetosphere, there is the possibility for exposure to proton radiation from solar particle events (SPE). On the surface of Mars, the GCR and SPE fluxes will be less than half that of free space because of the shielding by the planetary mass and the shielding provided by the thin Martian atmosphere. Following are some representative dose equivalents in these regions during an opposition class Mars mission in a spacecraft with 0.75 cm Al walls: outbound (Van Allen Belts) <0.02 Sv; Earth to Mars (205

days exposure to free space GCR) 0.3 Sv; 30 days on the Martian surface (GCR) 0.02 Sv; Mars to Earth (Van Allen Belts) <0.02 Sv.

63. Nachtwey, D. Stuart (JSC): Radiological Health Risks. Presented at the SAE Inter-society Conference on Environmental Systems, July 24-27, 1989, San Diego, California.

The crew of a manned Mars mission will be unavoidably exposed to galactic cosmic ray (GCR) flux. If one employs conventional radiological health practices involving absorbed dose (D), dose-equivalents (H), and LET-dependent quality factors (Q), the Mars mission crew shielded by 2 g/cm2 Al could receive about 0.7 Sv in a 460-day mission at solar minimum. However, three-fourths of this dose-equivalent in free space is contributed by high LET heavy ions ($Z \geq 3$) and target fragments with average Q of 10.3 and 20, respectively. Such high quality factors for these particles may be inappropriate. Moreover, in a 460-day mission less than half of the nuclei in the body of an astronaut will have been traversed by a single heavy particle. The entire concept of D/Q/H as applied to GCR must be reconsidered.

64. Pak, C. Y. C.; K. Hill; Nitza M. Cintron; and C. Huntoon (JSC): Assessing Applicants to the NASA Flight Program for Their Renal Stone-forming Potential. *Aviation Space Environmental Medicine*, Vol. 60, pp. 157-161, 1989.

65. Parker, Donald E. (MU); L. Michaud; N. Skinner (KRUG); D. L. Harm; and M. F. Reschke (JSC): Effects of Body Tilt/Visual Surround Motion Phase Relations on Linear Vection. *Aviation Space and Environmental Medicine*, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Visual, vestibular, and proprioceptive information contribute to self-motion perception (vection). The purpose of the present study was to determine the phase relation between whole body tilts (pitch) and visual surround motion that would produce the greatest perceived linear translation. Four experiments were performed with ten naive subjects participating in each experiment.

66. Pool, Sam L.; Edward C. Moseley (JSC); and Arnauld E. Nicogossian (NASA Head-quarters): Longitudinal Investigation of Astronaut Health. Presented at the 2nd Nihon University International Symposium on Aerospace Science, January 21-26, 1989, Tokyo, Japan.

A longitudinal study of astronaut health employing the traditional techniques of epidemiology and statistics is currently not feasible because of the small size of the astronaut group. The fact that the current astronaut corps is too small, how-ever, does not dictate that a longitudinal study should be started now. It is expected that over a period of years the number of astronauts will increase as will the number of astronauts who have flown in space. In anticipation of future space-flight requirements, NASA is working to develop an investigation protocol using techniques developed in larger epidemiological studies for a longitudinal evalua-tion of the health of space travelers. Over a period of time, the data base result-ing from this study should grow sufficiently to permit definite conclusions to be drawn about the long-term effects of space flight on human health.

67. Pool, Sam L. (JSC); and Arnauld E. Nicogossian (NASA Hqs): Medical Evaluation of Astronaut Applicants in the Space Station Era. Presented at the 2nd Nihon University International Symposium on Aerospace Science, January 21-26, 1989, Tokyo, Japan.

Medical evaluation of astronaut applicants has evolved considerably since the

first astronaut selection in 1959. During the past 29 years we have enough experience with named space flight to know that astronauts selected for duty on the Space Station will need to have some special attributes, and the ability to cope with special situations will be particularly important on longer missions. An attempt is being made through a variety of means to better define the astronaut selection criteria so that we are in a position to meet the demands of the Space Station era.

68. Pratt, Wanda (JSC); L. Webster; J. C. Hayes; G. D. Mazzocca (KRUG); S. F. Siconolfi; and B. A. Harris (SBRI): A Comparison Between Computer Controlled and Set Work Rate Exercise Based on Target Heart Rate. *Aviation Space and Environmental Medicine*, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

The goal of a good exercise prescription is to provide a work rate (WR) that maintains heart rate (HR) in a target zone and a relative percentage of maximum MET. HR and MET were compared between the specified target values and those observed form the computer controlled WR and set WR exercise. The time in target HR zone (TIZ) also was examined between the two methods. Eight subject's exercise prescriptions were based on 65% of the subjects estimated maximum MET (treadmill) and expressed as a target HR. Set WR exercise session utilized a constant speed calculated from the target HR and graded exercise test.

69. Putcha, L. (KRUG); J. Tsui.; N. M. Cintron; J. M. Vanderploeg; and W. G. Kramer (JSC): Pharmacokinetics and Oral Bioavailability of Scopolamine in Normal Subjects. *Pharmaceutical Research*, Vol 6, pp, 481-485, 1989.

70. Putcha, L. (KRUG); Nitza M. Cintron; and J. M. Vanderploeg (JSC): Pharmacokinetics of Scopolamine in Normal Subjects Placed on Antiorthostatic Bedrest. *Aviation Space Environmental Medicine*, Vol 60, No. 50, p. 483, 1989.

Microgravity induces physiologic changes that may alter the disposition of medications administered to crewmembers during space flight. Since antiorthostatic bedrest simulates some of these physiologic changes, pharmacokinetics and bioavailability of scopolamine in subjects placed on -6° head-down bedrest were examined. Seven subjects received 0.4 mg of scopolamine by IV and oral administrations during a control phase and during bedrest. Blood samples were collected at regular intervals for 12 hours after administration and analyzed for scopolamine concentrations. Pharmacokinetic parameters and bioavailability were determined using standard data analysis programs. After IV administration areas under plasma concentration-time curve (AUC) decreased in some of the subjects during bedrest (e.g., 106 for control to 44 ng.min/ml) and increased in others (e.g., 43 for control to 130 ng.min/ml). The half-life of scopolamine did not change significantly between control and bedrest phases and ranged between 38 and 120 min. After oral administration, scopolamine half-lives were shorter and AUCs were lower with a significant decrease in the Cmax and AUC during bedrest in some subjects. Significant changes in the distribution of scopolamine were noticed in subjects during bedrest as indicated by AUCs. Alterations in scopolamine pharmacokinetics in subjects placed on bedrest appear to be variable among subjects Bioavailability of oral scopolamine was poor and variable during both phases of the study. Pharmacokinetics of other model drugs will be evaluated using bedrest to simulate the effects of microgravity.

71.  Riddle, J. M.;  K. F. Elton; B. S. Bennett; (KRUG); Chiaki N. Mukai; M. W. Bungo; J.
     B. Charles (JSC); and C. M. Lathers (USRA): Comparison of Cardiac Parameters
     Measured with Echocardiography and Impedance Cardiography During Six Hours
     of Head-up or Head-down Bedrest. *Aviation, Space, and Environmental Medicine*,
     May 7, 1989.  Presented at the Aerospace Medical Association, May 7-11, 1989,
     Washington, D. C.
        This study compared left ventricular ejection fraction (EF), end diastolic volume
     (EDV), stroke volume (SV), and cardiac output (CO) values measured with echo-
     cardiography and with impedance cardiography.  An Ultramark 8 Echocardio-
     graph (ATL) and a NCCOM3-R7 thoracic impedance device (BoMed) were used.
     On four different days, six healthy male subjects spent 6 hrs on a tilt table at one
     of four different tilt angles (-5, +10, +20, or +42°) which were selected in
     random order.

72.  Russo, Dane M. (JSC); and Dennis Casserly (UHCL):  Identifying Atmospheric Moni-
     toring Needs for Space Station.  Presented at the AIHC, May 1989, St. Louis,
     Missouri.
        An environmental health monitoring plan for Space Station will ensure crew
     health during prolonged habitation.  The Space Station will operate for extended
     periods, 90+ days, without resupply.  A regenerative, closed loop life support
     system will be utilized in order to minimize resupply logistics and costs.  Over-
     board disposal of wastes and venting of gases to space will be minimal.  All waste
     materials will be treated and recycled.  The concentrated wastes will be stabilized
     and stored for ground disposal.  The expected useful life of the station (decades)
     and the diversity of materials brought aboard for experimental or manufacturing
     purposes increases the likelihood of cabin contamination.  Processes by which
     cabin contamination can occur include:  biological waste production, material off-
     gasing, process leakage, accidental containment breach, and accumulation due
     to poor removal efficiencies of the purification units.

73.  Russo, Dane (JSC); and Elizabeth E. Richard (KRUG):  An Overview of the Space
     Station Environmental Health System.  Presented at the Intersociety Conference
     on Environmental Systems, July 24-26, 1989, San Diego, California.
        The closed environment of Space Station Freedom, unique in its dependence
     on recycled air and water and extended tours of crew duty, will pose unparalleled
     challenges in the area of internal contamination control and environmental health.
     Various planned operational activities will have the potential to contribute to the
     contamination load of the Space Station environment.  Materials processing and
     life science experiments will involve the use and transport of chemicals and pro-
     cess fluids, laboratory animals, and experimental wastes.  Potable and hygiene
     water will be recycled, requiring stringent monitoring and detection methods to
     prevent inadvertent distribution of chemical toxicants or the proliferation of micro-
     organisms through the water system.  Sensitive and efficient detection methods
     will be required to alert crewmembers if contamination levels exceed the maxi-
     mum allowable limits established to ensure crew health and safety.  The Environ-
     mental Health System (EHS) is being developed to provide Freedom with capabili-
     ties for environmental sample collecton, processing, and analysis of the breathing
     atmosphere, potable and hygiene water, and internal surfaces.  The EHS will pro-
     vide monitoring capabilities utilizing six subsystems:  microbiology, toxicology,
     water quality, radiological health, vibroacoustics, and barothermal physiology.
     This paper will describe the function and associated hardware of each subsystem.

74. Sams, Clarence F.; D. A. Wolf (JSC); J. M. Jessup; C. D. Bucana (UTMDACC); and T. J. Goodwin (KRUG): Rotating Wall Vessels (RWVs) Simulate Some Aspects of Microgravity and Permit Expression of Differentiation of Colon Carcinoma. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

RWVs are tissue culture vessels that rotate cells slowly around the horizontal axis. This nearly averages the gravity vector to zero. As a result, RWVs exhibit lower shear than other culture vessels. The purpose of this study was to determine whether the low shear of the RWVs permits differentiation of human colon carcinoma in vitro similar to that observed in vivo. HT-29, an adenocarcinoma of the human colon, and HT-29KM, a subline of HT-29, form morphologically distinct tumors when injected into nude mice. HT-29 is an undifferentiated mass of cells while HT-29KM forms glands. Each cell line was inoculated into RWVs with microcarrier beads and cultured at 37°C under low shear for up to 3 weeks. Both lines are undifferentiated with maximum cell concentrations of 2-4 x 106 cells/ml and HT-29 forms undifferentiated tumor spheroids while HT-29KM forms glands. In addition, the cocultures consume less glucose per cell than fibroblasts or either tumor cell lines cultured alone. Cocultures in the RWVs recreate morphology observed in vivo in nude mice. Since glucose deprivation induces differentiation of HT-29 in vitro, the RWVs permit cell interaction which produces signals similar to those occurring in vivo. Actual microgravity may permit larger structures and facilitate studies of differentiation.

75. Santy, P. A. (JSC): Biobehavioral Research. Presented at the 8th IAA Man in Space Symposium, September 29 - October 4, 1989, Tashkent, Uzbekistan, U.S.S.R.

The scheduling of crew rotations for up to 180 days on Space Station Freedom presents a special challenge for behavioral scientists who are tasked with providing psychological support for both the crews, their families, and mission flight controllers. It is essential that mission planning take into account the psychological well being of the crew, both as individuals and as a group. This task requires that we think of the crew as participants in a complex social "system" that incorporates not only the crew and the environment of Space Station Freedom, but also all the individuals and groups who interact with them throughout the duration of the mission. All the participants in this social system will have dramatic impact on the health and psychological well-being of crewmembers.

76. Santy, Patricia A.; Richard T. Jennings; and David Craigie (JSC): Reproduction in the Space Environment: Part 1. Animal Reproductive Studies. Obstetrics and Gynecology Survey, Vol. 45, No. 1, pp. 1-6, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D.C.

Mankind's exploration and colonization of the frontier of space will ultimately depend on men's and women's ability to live, work, and reproduce in the space environment. This paper reviews animal studies, from microorganisms to mammals, done in space or under space-simulated conditions, which identify some of the key areas which might interfere with human reproductive physiology and/or embryonic development.

Those space environmental factors which impacted almost all species included: microgravity, artificial gravity, radiation, and closed life support systems. These factors may act independently and in combination to produce their effects. To date, there have been no studies which have looked at the entire process of reproduction in any animal species. This type of investigation will be

critical in understanding and preventing the problems which will affect human reproduction.

77.  Santy, Patricia A.; and Richard T. Jennings (JSC):  Reproduction in the Space Environment:  Part II.  Concerns for Human Reproduction.  *Obstetrics and Gynecology Survey*, 45, No. 1, pp. 1-6, 1989.  Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D.C.

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 for 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.  However, a program to explore effective countermeasures to current constraints and develop the required health care delivery capability for extended-duration space flight is suggested.  A program of Earth- and space-based research to provide further answers to reproductive questions is suggested.

78.  Santy, Patricia A. (JSC); K. L. Mathes; and N. Karakulko (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 were either not followed, or were ineffective.  Five of the last seven STS flights (to STS 61-C) 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 its initial successes in the Apollo Program and early STS flights.

79.  Sauer, R.; D. Pierson (JSC); J. Schultz; R. Taylor; D. Flanagan; R. Gibbons; and H. Brown (KRUG):  Biofilm Formation Potential and Control in a Simulated Spacecraft Water System.  Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Space Station Freedom will require the use of water recycle systems to avoid resupply penalties.  Recent evidence indicates that iodine-resistant bacteria may develop biofilms in such systems and create a potential health hazard.  A long-term study is being performed to determine if iodine can control biofilm formation in a simulated water system.  Two stainless steel water systems were constructed, each consisting of a 10 L storage tank, a recirculation loop with pump, and a distribution branch.  In one system a 2.5 mg/L iodine level is maintained by an iodinated ion exchange resin.  Three 2 L water samples are taken from each system daily and are replaced with ultrapure water.  Coupon manifolds are placed in the recirculation loop and branch line of each system to monitor biofilm formation.  Coupons are evaluated by culture methods, epifluorescence, and scanning

electron microscopy. The microbial and chemical quality of the water is regularly monitored. Preliminary results indicate that 2.5mg/L of iodine has been successful in preventing microbial colonization of the iodinated system. The noniodinated system, however, has shown colonization after 3 weeks. Chemical analyses indicate no significant corrosion of either system. Final results will be useful in developing technology for use in the design of spacecraft water systems for long-term use.

80. Siconolfi, Steven F.; B. A. Harris, Jr.; J. B. Charles; and M. W. Bungo (JSC): The Impact of Fluid Loading and Cardiovascular Fitness on the Cardiovascular Index of Deconditioning. *Aviation Space and Environmental Medicine*, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D.C.

Saline ingestion prior to return from space flight has been shown to improve orthostatic tolerance. Fitness also may be an effective countermeasure. We examined the impact of fluid loading and preflight relative cardiovascular fitness on the cardiovascular index of deconditioning (CID). Relative cardiovascular fitness was defined by standing rate pressure product (RPP), an indicator of myocardial oxygen uptake.

81. Siconolfi, Steven F.; B. A. Harris; J. B. Charles; and M. W. Bungo (JSC): The Impact of Initial Fitness and Space Flight Duration on Cardiovascular Deconditioning. Presented at the 1989 Annual Meeting of the American Society for Gravitational and Space Biology, October 25-28, 1989, Cocoa Beach, Florida.

This study examined the affects of initial fitness and space flight duration on cardiovascular function. Heart rate (HR), systolic (S), and diastolic (D) blood pressure (BP) were measured during the stand test prior to and after shuttle missions lasting from 3 to 10 days. Crewmembers (n = 81) were grouped based on flight duration (3-5, 6, 7, and 8 days) and initial level of fitness (high and low). The high fit group exhibited significantly lower weight, HR, SBP, DBP, and body mass indicies than the low fit group prior to flight. ANOVAs of the postflight responses showed significant increases in deconditioning (increase in HR, RPP, cardiovascular index of deconditioning (CID)) with longer space flight durations for the low fit group only.

82. Siconofli, Steven F. (JSC); R. Finkel; and R. Lout (SC): Mental Stress Reactivity After Exercise Training at High and Low Intensities. Presented at the American College of Sports Medicine, May 31 - June 3, 1989, Baltimore, Maryland.

Mental stress (Stroop Color-Word Test) reactivity (R) has been defined as peak, mean, and post blood pressure (BP) minus rest BP (rest reactivity (RR)) or minus pretest BP (test reactivity (TR)). This has produced confusing results on the role of exercise and training on R. We examined the effects of exercise training at high (H: 80% of physical work capacity (PWC)) and low (L: 50% PWC) intensities on both types of R for systolic (S) and diastolic (D) BPs in 22 aged ($70 \pm 6$ yr) subjects. Rs were measured before and after each group completed 2MJ of work and after 6 months of training. However, the DBP peak and post RR increased with L but not with H training.

83. Siconolfi, Steven F.; B. A. Harris (JSC); K. T. Kear; and J. C. Hayes (KRUG): Muscle Performance and Leg Volume Changes After 7 Days of Bedrest. Presented at the Federation of American Societies for Experimental Biology, April 1-5, 1989, Washington, D. C.

Research findings report that body water, limb volumes, and strength decrease

after space flight and that these decreases may affect orthostasis. Skylab data reported a 2/3 decrease in limb volume due to fluid loss, with the remaining 1/3 loss due to muscle atrophy. This study examined changes in limb volumes, muscle strength, and endurance of the dominant leg in (n = 11) male subjects before and after 7 days of bedrest.

84.  Stanford, Michael (KRUG); and D. Stuart Nachtwey (JSC): Implications of the New Radiation Exposure Limits on Space Station Freedom Crews. Presented at the American Medical Association, May 7-11, 1989, Washington, D. C.

Space flight unavoidably increases the exposure of astronauts to natural ionizing radiation. Any increase in radiation exposure increases the risk of contracting cancer or inducing genetic mutations. Since risk avoidance is equivalent to dose avoidance and since complete dose avoidance in space is not possible, levels of acceptable risk must be established. Recent research over the last decade indicates that the cancer risk per dose-equivalent has increased and that the relative carcinogenic effectiveness of certain types of space radiations may be much higher than previously thought. Therefore, new dose-equivalent limits have been recommended to NASA by the National Council on Radiation Protection and Measurements (NCRP). For Freedom, the major radiation component which contributes to the total dose is trapped protons from the South Atlantic Anomaly (SAA). Based upon the new annual limits, an astronaut may not receive more than a depth-dose equivalent of 50 rem/year. Calculations indicate that a 180-day stay aboard Freedom could result in a worst-case depth-dose of roughly 30 rem. A 180-day mission in a nominally shielded spacecraft (1 g/cm2) in a nominal, constant atmospheric density orbit with a varying altitude could result in a depth-dose equivalent of roughly 10 rem. This is twice the annual allowable dose-equivalent for terrestrial radiation workers. Because of this, measurement and management of radiation exposures and assessment of the health risks involved will play a significant role in manned operations.

85.  Taylor, G.; R. Meehan; M. Caputo; and N. Hunter (JSC): Quantitative Digital Image Analysis of Retinal Vascular Responses During Hypobaric Hypoxia and 10° Head-Down Bedrest. Presented at the American Medical Association, May 7-11, 1989, Washington, D. C.

Previous investigators have attempted to quantitate changes in retinal vascular diameters, using techniques which lacked the precision to measure very subtle alterations in the caliber of retinal vessels. We describe a highly sensitive method to objectively quantitate subtle changes in retinal vessels that was used to investigate the possible role of increased brain hydration (mild vasogenic cerebral edema) in the pathogenesis of acute mountain sickness (AMS) and as an Earth-based model for investigating space adaptation syndrome (SAS).

86.  Taylor, R. D.; S. K. Mishra; H. D. Brown (KRUG); and Duane Pierson (JSC): Association of Rhodoccus Species with Ion-Exchange Resins. Presented at the 89th Annual Meeting of American Society Microbiology, May 14-18, 1989, New Orleans, Louisiana.

Rhodococcus contamination of a de-ionized water supply was traced to ion-exchange resin cartridges in the system. Exhausted resin cartridges were opened and sampled using aseptic techniques. One g portions of the resins were mixed with 9 mL of sterile physiological saline and vortexed vigorously for 2 minutes. After allowing the resin beads to settle, dilutions of the supernatant fluid were made into melted NZ amine agar and plated. Incubation was at 25°C for up to 6 weeks. Of the five resin samples examined, only actinomycetes of the genus Rhodococcus were isolated. The 21 isolates exhibited variable pigmentation

ranging from white to dark pink. The maximum colony size ranged from 1 to 2 mm and was reached only after several weeks of growth. No aerial hyphae were demonstrated, but branching was observed using oil immersion magnification. The isolates did not show obvious growth into the agar surface.

87. Waligora, James M.; R. T. Meehan (JSC); and J. C. Hoack (UTMB): The Impact of Hypobaric Protocols Simulating Extravehicular Activity on Platelet Activation. *Aviation, Space, and Environmental Medicine*, Abstract 74, Vol. 60, No. 5, p. 489, May 7, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

   Chamber tests simulating the pressure changes and activity involved in an extra vehicular activity (EVA) have shown a high incidence of venous gas bubbles detectable by Doppler. Analysis of pre- and post-test blood has shown only modest statistical changes in some platelet parameters. These measures may not reveal the effect of bubbles on platelets if activated platelets are swept from the sample site prior to the blood draw. This study incorporates analysis of plate-let activation on blood drawn prior to, during, and after hypobaric exposures resulting in venous gas bubbles. Ten subjects were exposed on two separate occasions in a hypobaric chamber to a pressure of 6.5 psi for a 3-hour period.

88. Whitson, P. A. (JSC); M. H. Huls (KRUG); and C. F. Sams (JSC): Culture Time and Glial Cell-Conditioned Medium Increase ANP Binding and ANP etc. *Journal of Cellular Biology*, Vol. 109, No. 331a, 1989. Presented at the American Society for Cell Biology, November 5-9, 1989, Houston, Texas.

   We and others have observed specific ANP binding in primary cultures of bovine BMECs, suggesting a role for this fluid-regulating hormone in the brain. After the cells formed a monolayer, we measured ANP binding with 2 and 10 days of further culture. The apparent Kd increased 10-fold and the number of ANP binding sites increased 35-fold during the 10 day period following confluence. Time- and concentration-dependent stimulation of cGMP levels by ANP indicates the presence of guanylate cyclase-linked ANP receptors in BMECs. Affinity cross-linking with disuccinimidyl suberate and radiolabeled ANP demonstrated the presence of a 70 kD receptor, consistent with the presence of the ANP clearance receptor. In addition, we observed that the number of ANP binding sites could be increased by treating the cells for a 24-h period with medium that had previously been conditioned by C6 glial cells for 48 h. No significant differences in the total protein/well or the number of cells/well were observed with treatment of the GCCM as compared to the control. However, the increase in ANP binding by cells treated with GCCM corresponded to the observed increase in ANP-inducible cGMP levels, suggesting the presence of a diffusible factor(s) secreted by the glial cells which modulates the ANP receptors in primary cultures of BMECs. These data suggest that this in vitro culture system may be a valuable tool to examine ANP receptor expression in blood-brain barrier endothelial cells.

89. Whitson, P. A.; C. A. Stuart; M. H. Huls (KRUG); C. F. Sams; and Nitza M. Cintron (JSC): Dexamethasone Effects on Creatinine Activity and Insulin-like Growth Factor Receptors in Cultured Muscle Cells. *Journal of Cellular Physiology*, Vol. 140, pp. 8-17, 1989.

90. Wier, Larry T (JSC); and Andrew S. Jackson (UH): Factors Affecting Compliance in the NASA/Johnson Space Center Fitness Program. *Sports Medicine, ADIS Press Limited*, Vol. 8, No. 1, pp. 9-14, July 1989.

   Research has documented that a regular pattern of physical exercise improves

aerobic fitness (VO2 Max) and body composition, and, if maintained over the years, reduces cardiovascular disease (CVD) risk, reduces premature disease-related death risk, and increases the life expectancy. Employee fitness programs have been developed in North America on the assumption that this exercise-fitness-health linkage improves worker morale and productivity and reduces health-care costs and absenteeism. Research on industrial fitness programs have documented this trend for exercise adherents. However, there is an apparent disparity between meeting the exercise potential and motivating participants to comply with recommended exercise. Studies have shown that only 20% to 30% of the eligible employees enroll in the fitness programs, and approximately 50% of those who join drop out within six months. Additionally, many of the participants who maintain program membership do not follow their exercise prescriptions. Surveys in the United States and Canada have shown that although 60% of the adults questioned claimed to be physically active, only 20% were exercising at a level suitable to enhance fitness and health.

91.   Wolf, D. A.; C. F. Sams; C. D. Bucana; J. M. Jessup; and N. M. Cintron (JSC): Differentiation of HT-29 and HT-29kM in a Three-Dimensional Culture System in Glucose Medium. Presented at the 40th Annual Meeting of the Tissue Culture Association, June 1989, Orlando, Florida.

92.   Wolf, D. A. (JSC); R. P. Schwarz; M. L. Lewis; T. J. Goodwin (KRUG); J. H. Cross; C. F. Sams; J. M. Jessup (UTMDACC); and N. M. Cintron (JSC): Three-Dimensional Growth of Cells in Rotating Culture Systems. *Aviation Space Environmental Medicine*, Vol. 60, No. 5, p. 482, 1989. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

Rotating a liquid culture about a horizontal axis suspends anchorage-dependent cells on microcarrier beads without introducing internal agitation mechanisms which contribute to the fluid shear stress in conventional three-dimensional culture systems. This rotating culture system in unit gravity may allow prediction of results in microgravity where shear stress may be further reduced by a factor of 500. The purpose of this study was to determine if the low shear rotating culture system permits cells to form three-dimensionsl tissue structures. Fluid dynamic calculations determined the optimal rotation rates of 250 ml culture vessels over 10 to 100 RPM and quantified the gravitational effect on tissue trajectory and fluid shear. BHK cells formed uniform super-confluent (150 cells per bead) three-dimensional associations of 3 to 10 beads. Human fibroblasts cocultured with colon carcinoma formed three-dimensional arrays of cells at a concentration greater than 9 million cells per ml. The coculture formed 0.5 to 0.75 cm viable tissue masses with glandular structures not found in conventional flask cultures. Further tissue growth was inhibited due to increased shear when rotation rates exceeded 45 RPM in order to maintain suspension. Low shear rotating cultures in unit gravity allow growth of tissue like masses with three-dimensional structure. Results with this culture system predict the further shear reduction by operation in microgravity will allow assembly of larger and more complex tissues.

93.   Wong, K.; C. Lam; T. Galen (KRUG); M. Coleman; and D. Pierson (JSC): NASA JSC Toxicologic Database. Presented at the Aerospace Medical Association, May 7-11, 1989, Washington, D. C.

A clean and safe living environment in the spacecraft is essential to protect the health and well being of crewmembers. If a chemical spills or leaks in the Shuttle, the crew may be exposed to a toxic substance. To prepare for such an incident, preflight risk assessments of the chemicals the crew could be exposed to are

required. To facilitate the risk assessment process, a project was undertaken to compile a computerized toxicology database of those chemicals to be flown on Shuttle missions. Toxicology information on utility chemicals and chemicals used in payload experiments is reviewed and the relevant information is extracted and stored in the computerized database. The database consists of four major sections: physical and chemical properties, exposure limits, toxicities, and contingency procedures in the event of a spill. The database is continuously augmented as new chemical-containing experiments and payloads are approved for flight.

Toxicology information has been routinely utilized by NASA toxicologists in performing risk assessments on chemicals manifested on STS missions. The NASA JSC toxicology database allows for rapid retrieval of information by NASA toxicologists, flight surgeons, and crewmembers.

1.   Levitan, B. (JSC):  A Stowable Lower Body Negative Pressure Device for Use on the Space Shuttle.  Presented at the 1989 Annual Aerospace Medical Association Conference, May 7-12, 1989, Washington, D.C.

    Extended duration Shuttle flights may require the use of additional counter-measures for the problem of orthostatic deconditioning.  The available flight qualified Lower Body Negative Pressure Device (LBNPD) is too large for stowage in the orbiter mid-deck lockers, necessitating the design of a stowable LBNPD.  A collapsible frame of upright struts and oval rings was fabricated and the rings arewere sewn in a nomex cloth bag.  Each strut consists of four segments that are shock corded together and the bottom strut is attached to the bottom oval ring.  The struts are assembled and the nomex bag is pulled up, completing the rigid assembly of the LBNPD.

1.  Allton J. H. (LESC): How to Bag a Martian Rock: The Packaging of Rocks and Soils on Mars. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

    An expedition to Mars! The quarry: rocks and soils. The terrain for the hunt is rocky and dusty; temperature is 230°K; atmospheric pressure is 10 mb of 95% CO2; gravity is 40% of Earth's, and visible sunlight is 55% of Earth's. In addition, dust blows seasonally and frost forms on winter nights. The lone expedition member is an intelligent rover equipped with a scoop, a rake, a rock drill, and possibly a regolith drill to acquire samples. The samples will be split, imaged, and analyzed to decide whether or not the sample is a "keeper." But how shall we package the keepers so that they will remain pristine and unchanged when they are opened on Earth a year later?

2.  Amsbury, David L.; and Bremer, Jeffrey (JSC): Medium Format Cameras Used by NASA Astronauts. *Geocarto International*, 1989.

    Two types of cameras are used for most photography of Earth: Hasselblad and Linhof systems. On some missions 35-mm Nikon still cameras and 16-mm Arriflex motion-picture cameras have been used to record views of Earth; in general the products of these small-format systems are less useful tutorially, aesthetically and scientifically than those of larger-format cameras. Only the Hasselblad and Linhof film is catalogued systematically by the Space Shuttle Earth Observations Office because of budgetary constraints.

3.  Amsbury, David L. (JSC): Plate-Tectonic Implications of Late Quaternary History of the Gulf of Mexico Rim and Rio Grande Rift. Presented at the South-Central Section of the Geological Society of America, March 12-14, 1989, Arlington, Texas.

    Present movement of North America relative to Africa is estimated to be about 2.5 cm/yr westward (1.25 cm/yr half-rate); westward movement of the Colorado Plateau is estimated from volcanic deposits to be about 3 cm/yr for the past 3 my. Late Quaternary deposits and land forms around the Gulf of Mexico Basin, and within the southeastern Basin-and-Range, demonstrate that folding and faulting have been minimal during the past 130 ky as the continent moved some 1.5 to 4 km (5% to 20% of plate thickness).

    Hand-held photographs from space illustrate the physiographic expression of nearly-continuous, pre-Wisconsin shoreline deposits that rim the Gulf of Mexico Basin (Live Oak Ridge barrier in Texas and northern Mexico, Beaumont deltas in Texas, Miami Oolite and Key Largo reef rock in Florida, and carbonates in northeastern Yucatan). The deposits are probably Sangamonian (130-90 ky); if they were deposited during isotope stage 5e at about 6+ M sea level, they have been warped + 1 M in southern Florida, -1 to -2 M in Texas, and x in Yucatan. Lineaments that probably represent surface traces of vertical joint swarms affect drainage but no tectonic faulting or folding (distinct from growth faults and salt domes) is known.

4.  Arvidson, Raymond (WU); James L. Gooding (JSC); and Henry J. Moore (USGS): The Martian Surface as Imaged, Sampled, and Analyzed by the Viking Landers. *Reviews of Geophysics*, Vol. 27, No. 1, pp. 39-60, February 1989.

    The two Viking landers touched down on the surface of Mars in July and September of 1976. Viking Lander 1, renamed the Mutch Memorial Station (MMS), continued to operate for 3 Martian years in Chryse Planitia. The landing site is a rolling sparsely cratered plain. Impact crater size-frequency distributions demonstrate that only meters of vertical erosion have occurred over the lifetime of

the surface. The site exhibits bedrock exposure, numerous rocks excavated during cratering events, indurated fine-grained sediment (blocky material) mixed with dust and lithic fragments, and aeolian drifts that overlie the blocky material and which probably accumulated during global dust storms.

5.   Badhwar, Gautam D.; and Andrei Konradi (JSC):  Conversion of Omnidirectional Proton Fluxes into a Pitch Angle Distribution. *Journal of Spacecraft and Rockets*, 1989.

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 three 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 $\beta$, and the pitch angle of the loss cone $\alpha L$.

6.   Badhwar, Gautam D.; and Andrei Konradi (JSC):  Semianalytical Conversion of Omnidirectional Proton Flux in the AP-8 Model Into a Pitch Angle Distribution. Presented at the American Geophysical Union 1989 Spring Meeting, May 7-12, 1989, Baltimore, Maryland.

With the anticipated long-duration radiation exposures of astronauts in an oriented Space Station, accurate prediction of expected doses requires consideration of both the mass distribution of the spacecraft and the direction of the incident high-energy proton flux. The two components of the directionality of the high energy proton radiation are the highly peaked local pitch angle distribution and the East-West effect. Since the omnidirectional flux at some point along a field line is an integral over the pitch angle distribution in principle, an inversion of this integral should yield the desired pitch angle distribution. We have devised a semianalytical scheme to use the omnidirectional proton fluxes of the AP-8 model to extract time averaged pitch angle distributions of high energy protons. This distribution is expressed as a function of a scaling constant K, a shape parameter $\beta$, and the pitch angle of the loss cone $\alpha L$. The results compare well with the experimental data obtained by several satellites.

7.   Basu, Abhijit (IU); David S. McKay (JSC); and Susan J. Wentworth (LESC):  Regolith Breccias as Precursors of Present Day Regolith on the Moon. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

Mineralogical and compositional similarities between regolith breccias and local soils have led to the inference and an implicit consensus that regolith breccias, which obviously formed from existing local soils, generally reside in the vicinity of their origin. However, it is also possible that the similarity of composition between regolith breccias and local soils is because the present day soils are derived from regolith breccias. Any regolith breccia compositionally different from local soils is considered exotic, e.g., breccia 15205 at the Apollo 15 site. The soil itself might have been emplaced as a blanket from some other place either in response to an impact or by creep. Exposure ages from neutron fluence modeling may resolve the issue in specific cases. The ultimate origin of lunar soils is the disintegration of pristine rocks and breccias. Large impacts may also produce enough "dust" to contribute to the regolith; Apollo 16 fragmental felspathic breccias represent some such ancient regolith. Some boulders of rocks and

breccias may even be recognized as direct sources of some soils. For example, House Rock at the Apollo 16 site is recognized as the parent of soil 67941. In response to the present day micrometeoritic flux, all exposed boulders, including regolith breccias, chip and disintegrate to contribute to soil formation.

8.  Basu, Abhijit (IU); David S. McKay (JSC); and Susan J. Wentworth (LESC): Lunar Pyroclastic Soils of the Apollo 17 Double Drive Tube 74001/2. Presented at the Workshop on Lunar Volcanic Glasses: Scientific and Resources Potential, October 10-11, 1989, Houston, Texas.

    The soils of the double drive tube core 74001/2 below ~5 cm do not contain any agglutinate and are apparently devoid of any measurable surface exposure. The soils, which must have erupted and then buried within a matter of hours, are unique samples of pure lunar pyroclastic material. Only one pair of initial petrologic studies of this soil has been carried out. The purpose of this note is to present some new data on this soil.

9.  Blanchard, Douglas P. (JSC): Sharing Rare and Unique Samples. Presented at the American Association for the Advancement of Science, January 14-19, 1989, San Francisco, California.

    The Lunar Curatorial Facility at NASA JSC houses rare and unique samples. Samples are available to selected scientists for further study. The experience of directing this facility has provided insight into a range of issues: What criteria should govern the inclusion or exclusion of samples from such a facility? What kinds of documentation are needed, and what additional kinds of assistance are borrowers likely to need? What criteria should govern the lending of samples? What kinds of support are needed for facilities of this kind? What research possibilities depend on the sharing of rare and unique samples? What issues arise with respect to international sharing?

10. Bogard, Donald D. (KSC); and D. H. Garrison (LESC): $^{39}$Ar-$^{40}$Ar Ages of Eucrites: Did the HED Parent Body Experience a Long Period of Thermal Events Due to Major Impacts? Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

    We are determining $^{39}$Ar-$^{40}$Ar ages of a variety of eucrites for two purposes: (1) Several of these meteorites are objects of collaborative studies, and our $^{39}$Ar-$^{40}$Ar data, along with petrological, chemical, and radiometric studies of other investigators, are intended to provide information on the formation and history of individual eucrites; and (2) We wish to compare the $^{39}$Ar-$^{40}$Ar chronology of impact and other thermal events on the HED parent body with that observed for the mesosiderite parent body, chondrites, and the Moon to examine similarities and differences in early bombardment histories. We envisaged that reset Ar ages of HED meteorites are the result of their residence times in heated impact ejecta on the parent body. Recent work has concentrated on collaborative studies of individual clasts with the hope that these have had a simpler history compared to the whole-rock breccia. This presentation is a progress report of our studies.

11. Bogard, Donald D.; Friedrich Horz; and Pratt Johnson (JSC): Shock-implanted Noble Gases II: Additional Experimental Studies and Recognition in Naturally Shocked Terrestrial Materials. *Meteoritics*, Vol. 24, pp. 113-123, 1989.

    Several experimentally and naturally shocked silicate samples were analyzed for noble gas contents to further characterize the phenomenon by which ambient gases can be strongly implanted into silicates by shock and to evaluate the possible importance of this process in capturing planetary atmospheres in naturally

shocked samples. Gas implantation efficiency is apparently mineral independent, as mono-mineralic powders of oligoclase, labradorite, and diopside and a powdered basalt shocked to 20 GPa show similar efficiencies. The retentivity of shock-implanted gas during stepwise heating in the laboratory is defined in terms of two parameters: activation energy for diffusion as determined from Arrhenius plots, and the extraction temperature at which 50% of the gas is released, both of which correlate with shock pressure. These gas diffusion parameters are essential identical for radiogenic $^{40}Ar$ and shock-implanted $^{40}Ar$ in oligoclase and labradorite shocked to 20 GPa, suggesting that the two $^{40}Ar$ components occupy analogous lattice sites. Our experiments indicate that gas implantation occurs through an increasing production of microcracks/defects in the lattice with increasing shock pressure. The ease of diffusive loss of implanted gas is controlled by the degree of annealing of these microcracks/defects.

12. Christiansen, Eric 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 were 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 conditions.

13. Coombs, Cassandra R. (JSC); B. Ray Hawke; and Beth Clark (HI): Regional Pyroclastic Deposits as a Lunar Resource. Presented at the 1989 Geological Society of America, November 6-9, 1989, St. Louis, Missouri.

With the onset of the next century it is likely that the U.S. will return to the Moon and establish a Permanent Lunar Base (PLB). Along with the construction of a science outpost for geological, astronomical, and other basic research, a viable permanent settlement must return major benefits to the near-Earth space infrastructure. Among the benefits include the production of oxygen propellant and Helium-3 from ilmenite-rich material in the lunar regolith. Ilmenite is readily extractable and relatively abundant in many lunar soils and can be stripped of its oxygen by relatively simple means. Another important by-product of lunar ilmenite is He-3, which is concentrated in the $<50$ $\mu m$ size fraction of regoliths. The exploitation of lunar helium-3 could dramatically improve our energy future; available quantities of lunar He-3 could provide the equivalent of 40,000 years of the 1985 generated electrical power demand in the U.S. The extraction of He-3 from the lunar regolith will also provide other valuable volatiles such as those implanted by the solar wind ($H_2$, $N_2$, $CO_2$, $CH_4$) and certain surface correlated elements (S, Cu, Ni, Pb, Zn, Cd). Thus far, efforts to locate the PLB in areas suitable for mining helium and oxygen have centered on hi-Ti maria. We propose, instead, that the ilmenite-rich regional pyroclastic deposits would make far superior sites for mining operations.

14. Cour-Palais, Burton (MDSSC); Randy Tullos; Walt Gray; and Scott Mullin (SRI): A Hypervelocity Launcher for Simulated Large Fragment Space Debris Impacts at 10 km/s. Presented at the AIAA 30th Structures, Structural Dynamics and Materials Conference, April 3-5, 1989, Mobile, Alabama.

An explosive hypervelocity fragment launcher has been developed for use

as a space debris simulation device to support assessment of certain critical issues relevant to the development of the Space Station. The launcher is unique since it is capable of projecting large aluminum fragments (greater than one gram mass) at velocities in excess of 10 km/s. This will allow space debris certification of Space Station materials and designs to be carried out in a laboratory environment. The emphasis in this paper is placed on the characterization of the shape, size, and velocity of the fragments.

15. Crews, Jeanne Lee (JSC); and Burton Cour-Palais (MDSSC): A "Shocking" New Shield Concept or How to Make a 7km/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 (HIRL) 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 multi-shock (MS) shielding technique where ultra-thin (ts) spaced, shield elements are used to repeatedly shock the impacting projectile (diameter dp) to a high enough energy state to cause melting and vaporization at velocities which normally would not produce these results. Although the concept of multi-sheet shields has been proposed and tested many times (Richardson, 1970; Rajendra and Elfer, 1989; Gehring, 1970; Christiansen, 1987), the ts/dp ratio has always been large enough that the shield material has provided a large percentage of the debris plume mass which the back sheet must withstand. This concept does not produce the same results. The low ts/dp adds very little shield material to the debris plume allowing a substantial decrease in the thickness (strength) of the back sheet and the proper spacing between sheets prevents the debris plume from destroying successive sheets prior to the particulates reaching the sheet. The present concept, using aluminum as an analog for comparison to a dual sheet (aluminum) "Whipple shield" results in a 30% reduction in weight.

16. Cullingford, Hatice S. (JSC): CELSS Emulator Development. Presented at the CELSS PI Meeting, February 5-8, 1989, Orlando, Florida.

The Controlled Ecological Life Support System (CELSS) Emulator has been under development at the NASA JSC to analyze computer simulations of integrated CELSS operations involving humans, plants, and processors. This presentation will describe Version 1.0 of the CELSS Emulator that was initiated in mid FY88 on the JSC Multipurpose Application Console Test Bed as the simulation framework. The run module of the simulation package now contains a CELSS model that was developed earlier by Drs. John Rummel and Tyler Volk. The CELSS Emulator allows the user to generate organized data sets, store libraries of results for further analysis, and display plots of variables as a function of time.

17. Cullingford, Hatice S. (JSC); Steven H. Schwartzkopf (LESC); and Mel W. Oleson (BAC): Conceptual Design of a Closed Loop Nutrient Solution Delivery System for CELSS Implementation in a Micro-Gravity Environment. Presented at the 19th ICES Conference, July 24-27, 1989, San Diego, California.

This paper describes the results of a study to develop a conceptual design for an experimental, closed-loop fluid handling system capable of monitoring, controlling, and supplying nutrient solution to higher plants. The plant feeder experiment (PFX) is designed to be flight tested in a micro-gravity (micro-g) environment and was developed under NASA's In-Space Technology Experiments Program

(INSTEP). When flown, PFX will provide information on both the generic problems of micro-g fluid handling and the specific problems associated with the delivery of nutrient solution in a micro-g environment. The experimental hardware is designed to fit into two middeck lockers on the Space Shuttle and incorporates several components that have previously been flight tested.

18.  Cullingford, Hatice S. (JSC); Steven H. Schwartzkopf (LESC); and Mel W. Oleson (BAC): Conceptual Design for a Micro-Gravity Nutrient Delivery System for CELSS Use. Presented at CELSS PI Meeting, February 5-8, 1989, Orlando, Florida.

This presentation describes a conceptual design for a closed-loop fluid handling system capable of monitoring, controlling, and supplying nutrient solution to higher plants for CELSS applications. The system is designed to be flight tested in a micro-gravity (micro-g) environment and was developed under NASA's In-Space Technology Experiments Program. When flown, the experiment will provide data relevant to the generic problem of micro-gravity fluid handling, the availability of nutrient elements to plant roots, and mechanisms for recycling water in a micro-gravity environment.

19.  Cullingford, Hatice S. (JSC); Steven H. Schwartzkopf; and C. E. Rudiger (LESC): Conceptual Design Study for Lunar Base CELSS. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

Only three days of travel from Earth, the Moon offers an excellent opportunity to learn about living and working in extraterrestrial environments. The next step in NASA's exploration of space could be a lunar base. The JSC has recently completed a competitive procurement and initiated a study with Lockheed for the preliminary conceptual design of a Lunar Base Controlled Ecological Life Support System (LCELSS). The objective of this study is the conceptual design of an LCELSS that is capable of supporting a human population of as few as 4 and as many as 100.

20.  Cullingford, Hatice S. (JSC); W. P. Bennett; W. A. Holley; J. G. Carnes; and P. S. Jones (LESC): The Controlled Ecological Life Support System (CELSS) Emulator Development. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas; the 19th ICES 89 Conference, July 24-27, 1989, San Diego, California; and the CELSS PI Meeting, February 5-8, 1989, Orlando, Florida.

The CELSS emulator has been under development at the NASA JSC to analyze computer simulations of integrated CELSS operations involving humans, plants, and processors. This presentation will describe Version 1.0 of the CELSS Emulator that was initiated in 1988 on the JSC Multipurpose Applications Console Test Bed as the simulation framework. The run module of the simulation package now contains a CELSS model, called BLSS, that was developed by Drs. John Rummel and Tyler Volk. The CELSS Emulator allows us to generate model data sets, store libraries of results for further analysis, and display plots of model variables as a function of time.

21.  Cullingford, Hatice S. (JSC): Lunar Base CELSS. Presented at the CELSS PI Meeting, February 5-8, 1989, Orlando, Florida.

Since the release of the Ride report, a permanent organization was established in NASA to perform long-range planning for human exploration of the solar system. Only three days away from Earth, the Moon offers an excellent opportunity to learn about living and working in extraterrestrial environments. Under OSSA sponsorship, JSC has just completed a competitive procurement and initiated a

study with Lockheed Corporation for the preliminary conceptual design of a Lunar Base CELSS.

22. Cullingford, Hatice S. (JSC); W. M. Moses; T. D. Rogers; and H. Chowdhury (TAMU): Performance Characterization of Water Recovery and Water Quality from Chemical/Organic Waste Products. Presented at the 19th ICES Conference, July 24-27, 1989, San Diego, California.

Water reclamation subsystems currently being evaluated for the Space Station Freedom are designed primarily to reclaim water from waste streams containing low to moderate levels of organics/inorganics, including chemical additives to control microorganism proliferation. Wastes containing high organic content (solids), especially those containing chemical and bioprocess fluids, present potential risks for compromising operational integrity of these subsystems. Looking beyond near-term needs to reclaim water from primarily crew-derived waste streams, refurbishment and process characterization of a waste water management system capable of processing wastes containing high concentrations of organic/inorganic materials has been initiated. The process combines low temperature/pressure to vaporize water with high temperature catalytic oxidation to decompose volatile organics.

23. Cullingford, Hatice S. (JSC); Steven H. Schwartzkopf; and Mel W. Oleson (BAC): Plant Feeder Experiment (PFX) to Support CELSS Research: Study Results. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

This presentation will describe the results of a study to design a closed-loop fluid handling system capable of monitoring, controlling, and supplying nutrient solution to higher plants for Controlled Ecological Life Support System (CELSS) research applications. The hardware should be flight tested as the PFX. When flown, the PFX will provide data on the availability of nutrient elements to plant roots and on the mechanisms for recycling water in a micro-gravity (micro-g) environment. The design configuration has been specifically selected to evaluate: (1) the capability for monitoring fluid composition under micro-g conditions, (2) the capability for controlling the concentrations of different elements in solution under micro-g conditions, (3) the effectiveness of three different nutrient solution delivery system designs, and (4) the capability for condensing and recycling water vapor. The system hardware will fit into two middeck lockers on the United States Space Shuttle.

24. Cyr, Kimberly; and Wendell W. Mendell (JSC): Infrared Scanning Radiometer: Lunar Surface Thermal Data. Presented at the Division for Planetary Sciences/ASS Meeting, October 31, 1989, Providence, Rhode Island.

The Infrared Scanning Radiometer (ISR) was an Apollo 17 lunar orbital experiment used to investigate thermophysical properties of the lunar surface. While in orbit the ISR scanned the lunar surface from horizon to horizon, in particular mapping surface nighttime temperatures.

These temperature data are currently being reexamined using modern imaging data reduction techniques. Specifically, a Vax-11 mainframe and a compatible graphics package are being used to generate isothermal contour maps and cooling curves of portions of the lunar surface. Of particular interest are data from the far side of the moon and the identification of cold anomalies, whose origins are not well understood.

25. Duggin M. J.; S. A. Israel (SUNY); V. S. Whitehead (JSC); J. S. Myers (SUNY); and D. R. Robertson (LESC): Use of Polorization Methods in Earth Resources Investigations. *Proceedings of the SPIE 33 Annual Symposium on Optical and Optoelectronic Applied Science and Engineering*, August 1989.

26. Duke, Michael B. (JSC): Human Exploration of the Moon and Mars. Presented at the Canadian Space Institute Symposium, November 8, 1989, Ottawa, Canada.
    NASA has been studying alternative approaches to the human exploration of the Moon and Mars for several years. The "case study" process used has focused on developing coherent strategies by which both objectives may be accomplished within reasonable cost and schedule assumptions. On July 20th President George Bush presented a vision of the direction of a U. S. space program which completes the Space Station Freedom Program in the decade of the 1990's, then goes on to a permanent lunar outpost in the early years of the 21st century, followed by manned missions to Mars. The National Space Council is coordinating a study to develop feasible alternatives for the nation. The NASA studies, therefore, are directly relevant and will form the basis for NASA's recommendation to the Space Council.
    Detailed investigation will attempt to relate thermal attributes of surface elements to basic surface composition (e.g. soil or rocks, rock size, surface density) which will in turn indicate differing levels of surface weathering and thus relative surface age. In this way thermophysical data should provide insight into lunar feature age classification. This work has been partially supported by the NASA Planetary Astronomy Program.

27. Duke Michael B. (JSC): Initial Definition of a Self-Sufficient Lunar Outpost. Presented at the AIAA/JPL 2nd International Conference on Solar System Exploration, August 22-24, 1989, Pasadena, California.
    A lunar outpost concept is advanced which emphasizes the development of self-sufficiency in order to reduce or eliminate dependency on the Earth for resupply and to sharply reduce the need for importing materials for expansion of the base. Such an outpost could serve as the inhabited element of a lunar base established for scientific or commercial purposes; however, the outpost might simply serve as a test bed for studying the problems of extended human habitation on other planets.

28. Duke, Michael B. (JSC): Lunar and Mars Human Exploration Initiative. Presented at the American Concrete Institute National Meeting, San Diego, California.
    On July 20th, President Bush presented a vision of a renewed U. S. program of human exploration. The speech emphasized settling of space, going to the Moon "to stay," and sending humans to Mars. The National Space Council was directed to prepare a plan for implementing this initiative, and NASA has been assisting in the development of the plan.
    Many different views currently exist as to how a program should be structured. Some of its elements are clear - a new heavy lift launch capability to low Earth orbit, timely development of the Space Station Freedom and its appropriate augmentation to support the exploration initiative, and development of reusable space transportation vehicles to carry humans and cargos beyond Earth orbit.

29. Galindo, Charles (LESC); Donald L. Henniger; and Douglas Ming (JSC): Use of Lunar Simulants in Experimental Procedures; A Prerequisite for Establishing a Lunar Base. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.
    Now, as throughout history, human inhabitation of isolated areas is a gradual

process that begins with importation of required consumables. As the lunar base expands, the cost and time required for such importation will become infeasible. Therefore, it is to our advantage to study the moon as a life-giving body rather than barren and uninhabitable as it has always been thought to be.

30. Galindo, Charles (LESC); Donald L. Henniger; and Douglas Ming (JSC): The Use of Lunar Simulants in Plant Growth Experiments. Presented at the ASA-CSSA-SSA, October 15, 1989, Las Vegas, Nevada.

The use of lunar resources has the potential to provide substantial benefits to future activities on the Moon (e.g., lunar base agriculture) by saving the high transportation costs from Earth and to help attain self-sufficiency as a first step in planetary exploration. The lunar samples returned during the Apollo missions are a national treasure, and there is not enough material available on Earth to adequately test the potential of plant growth in lunar materials. However, the published information that is available on the mineralogical, chemical, and physical properties of lunar materials is such that terrestrial analogs may be designed and tested in plant growth systems. Several lunar "soil" simulants have been prepared from synthetically produced glass and terrestrial lithic fragments that are similar in chemical composition and mineralogy to Apollo 11 mare "soils." The glass was produced under anaerobic conditions by a commercial company to simulate the reduced environment at the lunar surface. A Minnesota basalt was used to simulate the lithic fragment of the simulant. Simulant starting materials have been ground and sized to best fit the modal particle-size distribution of the Apollo 11 "soils." Several properties of lunar materials are unique to the lunar surface and are very difficult to simulate on the Earth (e.g., solar wind implanted gases and agglutinates which are constructional particles welded together by a glassy matrix and formed by micrometeorite impacts at the lunar surface). However, current studies are underway to simulate these complex features.

31. Giardino, J. R. (TAMU); R. J. Mohler (LESC); M. R. Helfert; and Mary L. Cleave (JSC): Analysis of Shoreline Erosion Using Ground Surveys, Aerial Photography, and Space Shuttle Photography: South Padre Island, Texas. Presented at the Geological Society of America, November 6-9, 1989, St. Louis, Missouri.

The Gulf Coast of Texas has long been acknowledged as a rapidly eroding shoreline. Early predictions suggested that Padre Island would be eroded in a short time interval. In an attempt to answer the question of how fast the retreat was occurring, South Padre Island has been monitored for 9 years. The Gulf shoreline of South Padre Island, from Mansfield Cut to the Brazos Santiago Pass has been monitored from 1980 to 1989 using ground surveys every 6 months, aerial photography, and Space Shuttle photography. During this time interval the area has been struck by two major hurricanes: one directly, Hurricane Allen (1980) and one indirectly, Hurricane Gilbert (1988).

The Space Shuttle photography provided a synoptic view of overall sediment transport patterns and spatial patterns of change. From this study it is suggested that the Gulf Coast of South Padre Island continues to erode rapidly.

32. Gibson, Everett K. (JSC); and Roberta Bustin (AC): Hydrogen Abundances in Lunar Soils. *Proceedings of the 20th Lunar and Planetary Science Conference*, March 13-17, 1989, Houston, Texas.

Using a vacuum pyrolysis technique, hydrogen abundances were determined for 267 different samples of bulk lunar soils, grain-size separates, mineral separates, and soils from core tubes. Hydrogen concentrations varied from 2.2 to 72.0µg/g with an average of 31.8µg/g for the 126 bulk soils (both surface and core samples). The sub-20 micron particle sizes were enriched by approximately a

factor of three over the bulk soil. Both surface and volume correlated components were evident. Agglutinates and breccias, both composite particles, were enriched in hydrogen, but hydrogen concentrations in lunar basalts were extremely low (all less than 4.0 µg/g). In most of the cores studied, hydrogen abundance correlated very well with the maturity indicator Is/FeO.

33. Gibson, Everett K. (JSC); Christopher Hartmetz (NRC); and Richard Socki (LESC): Total Carbon and Sulfur Abundances in Antarctic Carbonaceous Chondrites, etc. Presented at the 52nd Annual Meteoritical Society Meeting, July 31 - August 4, 1989, Vienna, Austria.

Total carbon and sulfur abundances have been determined in 43 Antarctic meteorites and one terrestrial alteration product found on an H5 chondrite using published techniques. Comparison of the carbon abundances form Antarctic meteorites and falls indicate that within each group, Antarctic meteorites have generally lower carbon contents. A study of the interior and exterior of Antarctic meteorites indicates carbon is leached to the meteorite's surface. Carbonate weathering products have been observed on the surfaces of these meteorites. Perhaps once the carbon reaches the surface, wind removes the carbonate or carbonaceous material. It is also possible that falls are contaminated during storage by atmospheric carbon.

34. Gooding, James L. (JSC): Carbonates on Mars: Possible First Evidence from Carbonate Minerals in SNC Meteorites. *Proceedings of the Fourth International Conference on Mars*, pp. 115-116. Presented at the Fourth International Conference on Mars, January 10-13, 1989, Tucson, Arizona.

Carbonate minerals have become crucial players in models that purport to explain the decline and fall of an ancient, thick $CO_2$-rich atmosphere on Mars. Although production of carbonates through chemical weathering on Mars is plausible, there remains a disturbing lack of evidence for Martian carbonates.

The most exciting evidence that is relevant to Martian atmospheric evolution and climate change consists of the traces of Ca-carbonate that occur in the meteorites Nakhla (a nakhlite) and Elephant Moraine, Antarctica A79001 (EETA79001; a shergottite). If SNC meteorites are, in fact, Martian rocks, then the first direct evidence for Martian carbonates is already in hand.

35. Gooding, James L. (JSC); Michael H. Carr (USGS); and Christopher P. McKay (ARC): The Case for Planetary Sample Return Missions. *EOS*, Vol. 70, No. 31, pp. 745, 754-5, August 1, 1989.

Principal science goals for exploration of Mars are to establish the chemical, isotopic, and physical state of Martian material, the nature of major surface-forming processes and their time scales, and the past and present biological potential of the planet. Many of those goals can only be met by detailed analyses of atmospheric gases and carefully selected samples of fresh rocks, weathered rocks, soils, sediments, and ices. The high fidelity mineral separations, complex chemical treatments, and ultrasensitive instrument systems required for key measurements, as well as the need to adapt analytical strategies to unanticipated results, point to Earth-based laboratory analyses on returned Martian samples as the best means for meeting the stated objectives.

36. Gooding, James L. (JSC): Differential Scanning Calorimetry (DSC) and Evolved Gas Analysis (EGA) Applied to Planetary Surface Exploration. *Proceedings of the 18th North American Thermal Analysis Society Conference (NATAS)*, pp. 222-228, 1989. Presented at the 18th Annual Conference of NATAS, September 24-27, 1989, San Diego California.

The National Academy of Sciences recommended development of flight instruments that would identify the phase composition (mineralogy), volatile-compound contents (including water concentration), and oxidation state of iron in planetary surface materials.

Studies now in progress will define DSC/EGA experiments that could be flown in the late 1990's to Mars, its moons, or comets or asteroids to measure the water contents of the surface materials and identify their volatile-bearing mineral constituents. Such experiments would be useful both in dedicated surface missions and in missions designed to return planetary samples to Earth. in the case of Mars, establishing the abundance of soil water would be desirable in advance of human exploration.

37. Gooding, James L. (JSC): The "Sample Experiment" on the Mars Rover/ Sample Return Mission. *AIAA Paper No. 89-0423*, 1989. Presented at the AIAA Aerospace Sciences meeting, January 9-12, 1989, Reno, Nevada.

The Sample Experiment denotes the set of all operations that include collection, analysis, packaging, and environmental control of atmospheric and geologic samples of Mars. Various functions may be distributed among surface roving vehicles, stationary landers, and spacecraft but the Sample Experiment remains an integrated mission activity that extends from Mars landing through delivery of the sample payload to the receiving facility on Earth. Technological challenges not faced in previous planetary missions include development of robotic systems to manipulate and characterize samples and to reliably seal them in containers with minimal contamination or degradation.

38. Gooding, James L. (JSC); and Douglas B. Nash (JPL): Vacuum-Weathered Sulfur: Calorimetric Evidence for Unusual Phase Composition. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 760-761, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

Vacuum-weathered sulfur, produced by differential sublimation of ordinary sulfur under high vacuum, has been proposed as a candidate surface material on the Jovian moon, Io. To further establish the physical nature of vacuum-weathered sulfur, samples were analyzed by differential scanning calorimetry weather sulfur, samples were analyzed by differential scanning calorimetry (DSC). The vacuum-weathered material is distinguished by two major attributes: (1) it shows only weak and irreproducible lambda transitions in the liquid during first heating and no lambda transition during second heating; and (2) a smaller proportion exists in monoclinic form.

39. Gooding, James L. (JSC): Wanted: Geologists on Mars. *Houston Geological Society Bulletin*, Vol. 32, No. 4, pp. 15-17, December 1989.

All of the rocky planets in the inner solar system have experienced impact cratering and volcanism, but only Earth and Mars show unmistakable evidence for water-driven erosion and deposition. Although current conditions do not permit rainfall, photogeologic evidence abundantly indicates that liquid water played a major role during early Mars history. Proven reservoirs of Martian water include the permanent north-polar ice cap and atmospheric water vapor, which often forms ice-crystal clouds at virtually all latitudes. Additional tests for soil water and sub-surface ice are needed.

40. Hartmetz, Christopher; and E. K. Gibson (JSC): *In Situ* Determination of Volatiles in CM2 Chondrites. Presented at the 52nd Annual Meteoritical Society Meeting, July 31-August 4, 1989, Vienna, Austria.

Five carbonaceous chondrites, Allende (CV3), Coolidge (CV4), Felix (CO3), Murchison (CM2), and Orgueil (C11), have been examined for *in situ* volatiles at the 30-50 micrometer scale using a laser microprobe mass spectrometer. As expected the highest amount of volatiles were released from Orgueil and Murchison. The ratios of total volatiles released from Murchison, Coolidge, Felix, and Allende compared to Orgueil (Orgueil = 1) are 0.9:0.54:0.49:0.37, respectively. The evolutionary processes of aqueos alteration of Orgueil and Murchison, terrestrial weathering of Coolidge, and thermal metamorphism of Allende are reflected in the observed volatile inventories of these meteorites.

41.  Helfert, Michael R.; Mary Cleave (JSC); Lori Koepsell; John R. Giardino (TAMU); and Robert Mohler (LESC): Analysis of Shoreline Erosion Using Ground Surveys, Aerial Photography, and Space Shuttle Photograpy: South Padre Island, Texas. *Proceedings of the Annual Meeting of the Geological Society of America,* Abstract 22709, Vol. 21, no. 6, 1989. Presented at the 1989 Geological Society of America, November 6-9, 1989, St. Louis, Missouri.

The Gulf Coast of Texas has long been acknowledged as a rapidly eroding shoreline. Early predictions suggested that Padre island would be eroded in a short time interval In an attempt to answer the question of how fast the retreat was occurring, South Padre Island has been monitored for 9 years. The Gulf shoreline of South Padre Island, from the Mansfield Cut to the Brazos Santiago Pass, has been monitored from 1980 to 1989 using ground surveys every 6 months, aerial photography, and Space Shuttle photography. During this time interval the area has been struck by two major hurricanes: one directly, Hurricane Allen (1980); and one indirectly, Hurricane Gilbert (1988). Analysis of these data suggest that the middle section of the island has been retreating at an average of ~4 m year-1, the northern portion of the island has been relatively stable, and the southern portion near the Brazos Santiago Pass has experienced shoreline advancement of ~3 m year-1. Much of the erosion in the middle section appears to coincide with existing wash over channels that are reactivated during hurricanes. It is thought that reduced sediment supply and changing vectorial geometry of the island are the causes of change. The high-altitude aerial photography provided a useful base for measurement, the Space Shuttle photography provided a synoptic view of overall sediment transport patterns and spatial patterns of change. From this study it is suggested that the Gulf Coast of South Padre Island continues to erode rapidly.

42.  Helfert, Michael R. (JSC): Atmospheric Lamina in Earth Limb. *Science,* Vol. 243, No. 4892, p. 704, February 1989.

The astronaut photograph of a 10 October 1984 atmospheric limb is one of 40,000 Earth-looking photographs taken by NASA astronauts since 1981. This particular photograph of a Pacific Ocean sunrise to the north of Hawaii was taken by Captain Bob Crippen, STS-17 Mission Commander. At this time the Space Shuttle Challenger was at 123 nm altitude at

(S17-34-035)37.ON 174.1E at 16:44:26GMT (Orbit 85)
(S17-34-036)38:3N 175.5E at 16:44:53GMT (Orbit 85)

The actual terminator was 1200 miles to the southeast of the Orbiter at the time of exposure. The camera used here was a NASA-modified Hasselblad equipped with a 100 mm lens. The film used for this photograph was 70-mm Kodak Ektachrome 5017 ASA 64 Natural Color. Film and hardcopy products of this photograph, like all Earth photography taken by NASA astronauts from the Mercury through the Space Shuttle programs (1961-1988), are available from the

EROS Data Center, Sioux Falls, South Dakota. The EROS Data Center also does geographic searches for user-requested Earth photography from space using NASA-designed electronic databases.

43. Helfert, Michael R.; and Kamlesh P. Lulla (JSC): Changes in the Global Tropical Environment Recorded by Space Shuttle Discovery (STS-26). *Geocarto International*, Vol. 4, No. 2, pp. 55-63, Summer 1989.

The NASA Space Shuttle Earth Observations Office (SSEOO) trains astronauts in informed acquisition of Earth photography during their Space Shuttle missions. Following the Challenger accident (STS-25), there was a 32-month standdown between the 24th Space Shuttle flight (STS-61C, January 1986) and the 26th flight (STS-26, September-October 1988). Noticeable global tropical environmental changes were expected with the resumption of Space Shuttle missions in late 1988. This expectation was based upon trends in tropical environmental phenomena seen during the first 24 Space Shuttle missions (1981-86). Indeed, significant global tropical environmental changes were documented in 1505 large-format Earth photographs during the 4-day 1988 flight of Discovery, STS-26.

44. Helfert, Michael R.; and Kamlesh P. Lulla (JSC): Human-Directed Remote Sensing from Space. *Geocarto International*, Vol. 4, No. 1, 1989.

45. Helfert, Michael R.; and Kamlesh P. Lulla (JSC): Monitoring Tropical Environments with Space Shuttle Photography. *Geocarto International*, Vol. 4, No. 1, pp. 55-68.

46. Helfert, Michael R. (JSC): NASA Human-Directed Observations of the Earth from Space: An Introduction. *Geocarto International*, Special Issue, Vol. 5, No. 1, pp. 1-80, Spring 1989.

47. Helfert, Michael R. (JSC): Physical Environmental Considerations for Disaster Planning in the Sub-Himalayas and Bangladesh. *Proc. First Symp. Global Awareness for Preventable Problems: Exploring the Causes of Flood in Bangladesh*, January 14, 1989, pp. 3-14.

48. Helfert, Michael R.; and C. A. Wood (JSC): The NASA Space Shuttle Earth Observations Office. *Geocarto International*, Vol. 4, No. 1, pp. 15-24.

49. Helfert, Michael R. (JSC): The West African Sahel: Human Agency and Environmental Change. *Journal of Geography*, Vol. 76, No. 1, pp. 38-40, Winter 1989.

50. Henninger, Donald (JSC); C. Galindo (LESC); and D. W. Ming (JSC): Dissolution of Lunar Simulants. Presented at the American Society of Agronomy Annual Meetings, October 14-20, 1989, Las Vegas, Nevada.

Advanced mission scenarios under consideration by NASA include a manned lunar base. To reduce costly re-supply from Earth, a lunar base will have to make extensive use of the indigenous lunar regolith. One potential use of the lunar regolith is as a soil for plant growth. A 1 gram sample of each of three size fractions ( $>150$ $\mu$, $<38$ $\mu$) of a simulated lunar glass was subjected to 250 ml each of water and 0.05 $M$ HCL at 25°C and shaken. Aliquots taken at periodic intervals (1, 3, and 8 h; 1, 2, 4, 10, 20, and 90 d) were analyzed for the elements Na, Mg, Al, Si, K, ca, Tl, Cr, Mn, and Fe using an atomic absorption spectrophotometer. P was measured using a uv-visible spectrophotometer. The simulated lunar glass consisted of the six major elements Si (45.6 wt %), Fe (22.8), Al (10.2), Ca (8.6), Mg (5.8), and Ti (5.4); and the five minor elements Cr (0.2), Mn (0.2), P (0.1), Na (0.04), and K (0.03). The concentration of all the elements increased with time.

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After 90 d, the <38 μ fraction with water as the solvent had highest concentrations of Si (6.2 mg/1), Ca (2.9), and Mg (2.4). After 90 d, the <38 μ fraction with 0.05 M Hcl as the solvent had concentrations as follows: Fe (355.9 mg/1), Ca (124.7), Al (117.8), Si (79.3), Mg (73.4), Ti (16.9), Cr (3.3), Mn (2.8), Na (1.4), and K (0.6). High Fe and Cr concentrations pose potential problems for plant growth, however, Ca, Mg, Mn, and Fe concentrations in solution will be beneficial for plant growth.

51. Jackson, A. A. (LESC); and Herbert A. Zook (JSC): Resonance Trapping of Comet and Asteroid Dust Particles by the Earth and Mars. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 448-449, 1989.
    (Abstract too long).

52. Jackson, A. A. (LESC); and Hebert A. Zook (JSC): A Solar System Dust Rings the Earth as its Shepherd. *Nature*, Vol. 337, No. 6208, pp. 629-637, February 16, 1989.
    Bodies orbiting in the gravitational fields of galactic, solar or planetary systems often suffer dissipative forces, including tidal interactions and drag resulting from motion through a gas or from collisions with dust grains. In the early solar mebula, gas drag induces resonance trapping, which may be of importance in the early accretional growth of planets. By means of numerical integrations, we show that small dust grains can be temporarily captured into exterior orbit-orbit resonances with the Earth, lasting from less than 10,000 years to more than 10,000 years. Grains with radii of 30-100 μm, orbiting in planes less than 10° from the plane of the Solar System and with orbital eccentricities of less than 0.3, are captured most easily. We argue that there should be an approximately toroidal cloud of particles, derived mostly from the asteroid belt, trapped into a variety of these exterior resonances. The cloud is mostly beyond the Earth's orbit, but includes it.

53. Jones, John H. (JSC); and D. J. Malvin (University of Arizona): A Nonmetal Interaction Model for the Segregration of Trace Metals During Solidification of Fe-Ni-Si Fe-Ni-P, and Fe-Ni-Sp Alloys. *Metallurgical Transactions*, December 1989.
    As nonmetals are added to the Fe-Ni system, segregation coefficients (k) of trace constituents change dramatically. For example, as the S content of the metallic liquid increases from 0 to ~31 wt.%, the molar k(Ge) between solid and liquid metal increases from 0.6 to ~120. Little of this change can be ascribed to temperature. Also, these changes are not linear. In the case of the Fe-Ni-S system, the largest changes are seen between 20 and 30 wt.% S.

54. Jones, John H. (JSC): Ba and Th Partitioning Between Immiscible Silicate Melts: Etc. *Meteoritics*, December 1989. Presented at 52nd Annual Meteoritical Society Meeting, July 31, 1989, Vienna, Austria.

55. Jones, John H. (JSC): Boundary Conditions for the Archean Mantle. Presented at the Lunar Planetary Institute, January 11-13, 1989, Houston, Texas.

56. Jones, John H. (JSC): Experimental Constraints on the 205Pb-205Tl Chronology of Iron Meteorites. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

57. Jones, John H. (JSC): Geochemical Modeling of Igneous Fractional Crystallization. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

58. Jones, John H. (JSC): Siderophile Element Partitioning in the Fe-Ni-C System: Preliminary Results, Etc. *Meteoritics*, December 1989. Presented at the 52nd Annual Meteoritical Society Meeting, July 31, 1989, Vienna, Austria.

59. Jones, John H.; and T. Dickinson (JSC): The Role of Silicate Liquid Immiscibility in the Petrogenesis of Lunar Granites: New Evidence From Ba and Th Partitioning Experiments. Presented at the GSA National Meeting, August 1989, St. Louis, Missouri.

    Silicate liquid immiscibility (SLI) is proposed to be important in the petrogenesis of lunar granites. Fractional crystallization of major rock forming minerals does not affect inter-element ratios of Th, Ba, and REE. However, SLI and/or fractionation of whitlockite can affect Ba/La and Th/La ratios. It has been suggested that the dichotomy between BaD determined in lunar basalts and those measured in laboratory experiments is a function of the alkali/A1 ratio of the granitic melt.

60. Keith, J. E. (JSC); H. R. Heydegger; and K. E. Kavana (PU): Saturated $^{26}Al$ in Stony Meteorites. Presented at the Workshop on Cosmogenic Nuclide Production Rates, July 25-26, 1989, Vienna, Austria.

    We assembled a database in which over 300 meteorites appear and which contains information on the bulk chemical analyses of these meteorites and their $^{26}Al$ content. Most numerical information in the database is the average of several measurements.

    We regressed the $^{26}Al$ values on the chemical contents using the standard linear model with the pure constant set to zero. We used an iterative algorithm which systematically eliminates under- and super-saturated $^{26}Al$ values, by forcing the residuals to be normally distributed. As a result, we observed: (1) 10 supersaturated, (2) 128 saturated and 50 undersaturated, and (3) an expression for the saturated $^{26}Al$ content as a function of the chemical composition. We compared the residuals predicted by our expression to those predicted by the expressions of other workers (1,2,3,4), class by meteorite class. The ideal result is zero, which is not forced, since in no case is the pure constant set to zero. There is no bias in our prediction of saturated $^{26}Al$ content as a function of meteorite class, but there are biases in all previous predictive expressions.

61. Kessler, Donald J. (JSC): Orbital Debris Environment for Spacecraft Designed to Operate in Low Earth Orbit. TM-100 471, 1989.

    The orbital debris environment model contained in this report is intended to be used by the spacecraft community for the design and operation of spacecraft in low Earth orbit. This environment, when combined with material-dependent impact tests and spacecraft failure analysis, is intended to be used to evaluate spacecraft vulnerability, reliability, and shielding requirements. The environment represents a compromise between existing data to measure the environment, the uncertainty in both measurements and modeling, and the need to describe the environment so that various options concerning spacecraft design and operations can be easily evaluated.

62. Kessler, Donald J. (JSC); and Robert C. Reynolds (LESC): Orbital Debris and Meteoroids. Presented at the Southern California Chapter Society for Risk Analysis (SCSRA), May 12, 1989, Irvine, California.

    One of the hazards associated with space flight is the risk of colliding with other objects already in space. The consequences of such a collision can be severe since these other objects collide at very high velocities. Fortunately, the possibility of colliding with objects the size of another spacecraft, are remote. However, collisions with dust sized particles are frequent and cause visible holes

and pits in spacecraft surfaces; fortunately, these particles usually cause only minor damage. The frequency of collisions with objects between the sizes of 1 mm and 1 cm is large enough to be of concern, and energetic enough to be a hazard both to spacecraft and human activity in space.

63. Kessler, Donald J. (JSC): Projected Orbital Debris Environment. Presented at the Symposia on Space Nuclear Power Systems, January 9-12, 1989, Albuquerque, New Mexico.

The amount of man-made debris in orbit is now sufficient to create a flux in some regions of low Earth orbit which exceeds the flux of natural meteoroids. The primary source for this debris is from the fragmentation, or disintegration, of spacecraft. Future debris can be expected to result from random collisions between orbiting objects. This debris will require additional shielding for some spacecraft in order to maintain a certain reliability; however, if a very high reliability is required, the amount of shielding becomes excessive, and other techniques must be employed. Steps are being taken to minimize the accumulation of future debris. This paper will discuss the sources of orbital debris, the resulting environment, the alternatives to maintaining spacecraft reliability, and the actions currently being taken to reduce the future environment.

64. Klock, Wolfgang (JSC); K. Thomas (LESC); David McKay (JSC); and Michael Zolensky (JSC): Comparison of Olivine Compositions in IDPs and Chondrite Matrices. *Abstracts of the 52nd Annual Meeting of the Meteoritical Society*, July 31 - August 4, 1989, Vienna, Austria.

65. Klock, Wolfgang (JSC); K. Thomas (LESC); and David McKay (JSC): Identification of Possible Solar Nebula Condensates in Interplanetary Dust Particles and Meteorities. *Lunar and Planetary Science*, pp. 522-523, 1989.

66. Klock, Wolfgang; K. Thomas; and David S. McKay (JSC): Unusual Mineral Chemistry of Extraterrestrial Dust Particles. *Proceedings of the 19th Lunar and Planetary Science Conference*, pp. 613-614, 1989.

67. Klock, Wolfgang (JSC); K. L. Thomas (LESC); D. S. McKay (JSC); and H. Palme (Max-Planck-Institut Chemie): Unusual Olivine and Pyroxene Composition in Interplanetary Dust and Unequilibrated Ordinary Chondrites. *Nature*, Vol. 339, No. 6220, pp. 126-128, 1989.

Chondritic porous interplanetary dust particles (IDPs) collected in the stratosphere are considered to be micrometeoritic material different from any class of meteorites because of their fine-grained textures and high porosities. Several authors have suggested that chondritic porous IDPs might be cometary dust. Here we report the presence, in both a number of IDPs and in meteorite matrices, of olivine and orthopyroxene grains, low in FeO, but containing up to 5 wt% MnO. The majority of olivines and pyroxenes in meteorites contain less than 0.5 wt% MnO. The presence of these low-iron manganese-enriched (LIME) olivines and pyroxenes in IDPs and meteorites may indicate a link between the origin and history of IDPs and the matrix material of primitive meteorites. The origin of the LIME silicates could be explained by condensation from a gas of solar composition. Forsterite is the first major silicate phase to condense from a solar nebula gas, and Mn, which is not stable as a metal under solar nebula conditions, would condense at ~1, 100 K as $Mn_2SiO_4$ in solid solution with forsterite.

68. Lauer, H. V., Jr. (LESC); R. V. Morris; J. Gooding (JSC); and R. Singer (US): Origins of the Mars-Like Spectral and Magnetic Properties of a Hawaiian Palagonite Soil. American Geophysical Union, 1989.

A palagonitic soil (HW1) from Mauna Kea, Hawaii, has Mars-like spectral and magnetic properties; the reflectivity spectra of <20 and 500-1000 nm size separates of bulk soil resemble spectra for Martian bright and dark regions, respectively. The soil contains separate populations of black and orange tephra particles which are, respectively, relatively unaltered fragments of tachylite (partially devitrified basalt glass) and extensively palagonitized fragments of sideromelane (clear, brown basalt glass). Although both types of particles contain plagioclase and olivine microphenocrysts, their iron-oxide is associated with the black particles and is mostly responsible for the magnetic nature of the bulk soil (saturation magnetization $J_s$ = 0.98 Am2/kg).

69. Lee, J. K.; and K. Lulla (JSC): 1989 Data Structure Characterization of TM and MSS Systems Using Principal Component Analysis. *Geocarto International Journal of Remote Sensing*, Vol. 5, No. 2, pp. 43-57, 1989.

70. Lindstrom, D. J.; M. M. Lindstrom; M. E. Zolensky; David S. McKay (JSC); and Susan J. Wentworth (LESC): INAA of Glass Spheres from Ancient Apollo 16 Regolith Breccias. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 1195-1196, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

We are developing techniques for analyzing individual lunar glasses for minor and trace elements by means of INAA with procedures similar to those currently being developed for interplanetary dust particles. It should be possible to analyze very small glasses (i.e., as small as 10-20 um) with these techniques, which would be advantageous because many lunar glasses are found in these small size ranges. In addition, the nondestructive nature of INAA permits further studies of the glasses, including scanning electron microscopy studies of surface morphologies and electron microprobe major element analysis. Trace element data for lunar glasses, and for volcanic glasses in particular, would be of great importance in understanding the sources of the glasses and the systematics of lunar volcanism. Trace element data would also be useful in determining the origins of glasses with unusual major element compositions.

71. Lindstrom D.; David S. McKay (JSC); R. Martinez; and Susan J. Wentworth (LESC): In Search of Ancient Lunar Pyroclastics. Presented at the workshop on Lunar Volcanic Glasses: Scientific and Resource Potential, October 10-11, 1989, Houston, Texas.

During previous studies of glasses in thin sections of Apollo 16 regolith breccias, we found trace amounts of glass clasts with mare affinities in some of the ancient (~4 Gy) regolith breccias. The ancient Apollo 16 regolith breccias also contain some unusual highlands glasses with very high Mg' values (atomic Mg/Mg + Fe . 0.90), which we termed ultra Mg' glasses. The origin of these ultra Mg' glasses is uncertain. Some of them have compositions similar to the proposed lunar komatites, suggesting that the glasses may have a pyroclastic origin. Trace element data for ancient mare glasses would be very important in understanding the systematics of the earliest mare volcanism, and the identification and characterization of lunar komatitic glasses with high Mg' values would be of great benefit in deciphering the history of the moon as a whole. Therefore, we have undertaken a search for individual mare and ultra Mg' glass spheres in ancient regolith breccias in order to characterize their trace element compositions by

means of INAA, using methods similar to those previously tested on individual highland impact glass particles from Apollo 16 regolith breccias.

72. Lindstrom, David J. (LESC); M. E. Zolensky (JSC); and Richard Lindstrom (NIST): Procedures for Instrumental Neutron Activation Analysis of Individual Cosmic Dust Particles. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

    Previous trace element analyses of two interplanetary dust particles (IDPs) by instrumental neutron activation analysis (INAA) were clearly very difficult analyses to perform, but details of the procedures have not been published. The two particles analyzed were approximately chondritic in composition, but until more particles are analyzed for trace elements, how typical these two particles are will remain unknown. We are developing techniques which we hope will allow routine nondestructive trace element analysis of IDPs.

73. Lindstrom, Marilyn M. (JSC); Ursula B. Marvin; Beth B. Helmberg (HU); and David W. Mittlefehldt (LESC): Apollo 15 KREEP - Poor Impact Melts. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 77-90, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

74. Lindstrom, Marilyn M. (JSC); John W. Shervais; and Scott K. Vetter (USC): Chemical Differences Between Small Subsamples of Apollo 15 Olivine-Normative Basalts. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 109-126, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

    Nine samples of Apollo 15 mare basalt have been analyzed to assess chemical and petrological variations within the mare basalt suite at this site. All nine (15536, 15537, 15538, 15546, 15547, 15548, 15598, 15605, and 15636) are low-silica olivine normative basalts (ONBs) which correlate with the ONB suite as defined in previous studies. Partial analyses have been published for two of these samples, but the other seven have not been analyzed previously. Five of these samples are part of a concurrent study by Schuraytz and Ryder (1988).

75. Lindstrom, Marilyn M. (JSC); Bill Moss (AU); and David W. Mittlefehldt (LESC): Geochemistry of 15205 KREEP Basalt Clasts. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 578-579. Presented at the 20th Lunar and Planetary Conference, March 13-17, 1989, Houston, Texas.

    In an attempt to further characterize KREEP basalts and evaluate their petrogenesis we are collaborating with J. Shervais on a study of clasts from breccia 15205 which was identified as a regolith breccia containing abundant KREEP basalt clasts. Shervais' companion abstract describes the petrology of these clasts. Our samples range in size from 7 to 79 mg. We analyzed 13 basalts, a green glass fragment (16G) and a matrix sample (142M) by INAA. Twelve clasts are moderately coarse-grained, although there is some variation in texture, and one clast (135) is fine-grained. The five largest samples were ground and split before analysis and analyzed for major elements by fused bead electron microprobe analysis. Partial INAA results for the compositional extremes and unusual samples are presented in this presentation.

76. Lindstrom, Marilyn M. (JSC); Ursula B. Marvin; Beth B. Holmberg (HSCA); and David W. Mittlefehldt (LESC): Geochemistry and Petrology of Recrystallized Gabbroic Breccias From the Apollo 15 Site. *Proceedings of the 20th Lunar and Planetary*

*Science Conference*, pp. 576-577, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

KREEP basalt is an ubiquitous component of Apollo 15 soils and regolith breccias which, due to its igneous nature, provides our best opportunity to study the petrogenesis of this enigmatic rock type. However, most fragments are small, the largest being rake samples 15386, and relatively few chemical analyses have been reported to date.

77. Lindstrom, Marilyn M. (JSC): Lunar Meteorites: Newly Discovered Moon Rocks Which Have Been Here All Along. Presented at the 1989 Geological Society of America, November 6-9, 1989, St. Louis, Missouri.

Recent studies of Antarctic meteorites have shown that some lunar rocks have been here on Earth for 75,000-170,000 years, but that we didn't recognize them as lunar until after the Apollo Program showed us what lunar samples were like. Eight meteorites of undoubted lunar origin have been identified among the more than 10,000 meteorites collected in Antarctic during the past 20 years by U. S. and Japanese expeditions.

78. Lindstrom, Marilyn M. (JSC); Odette B. James; and James J. McGee (USGS): Studies of the Distribution of Rare-Earth Elements in the Minerals of Lunar Ferroan Anorthosites. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 452-453, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

79. Lulla, Kamlesh P.; and Michael Helfert (JSC): Analysis of Seasonal Characteristics of Sambhar Salt Lake, India, from Digitized Space Shuttle Photography. *Geocarto International*, 1989.

Sambhar Salt Lake is the largest salt lake (230 sq km) in India, situated in the northwest near Jaipur. During 1981-83 Space Shuttle photographs of this ephemeral lake reveal that water levels and lake basin land-use information can be extracted by both the digital and manual analysis techniques. This type of information is beneficial in cartographic updates in establishing seasonal hydrologic profiles and as baseline and extreme event documentation for mesoscale climate and climatic impact assessment modeling. This paper extends the digitization and mensuration techniques originally developed to derive numerical information from space photography and applied to other regions (e.g., Lake Chad, Africa; Great Salt Lake, USA).

80. Lulla, Kamlesh P. (JSC); K. Turcotte, W. Kramber, and G. Venugopal (BSU): Analysis of Regional Scale Vegetation Dynamics of Mexico Using Stratified AVHRR NDVI Data. Presented at the American Society for Photogrammetry and Remote Sensing, May 1989, Falls Church, Virginia.

Many studies have shown that a good relationship exists between AVHRR Normalized Difference Vegetation Index (NDVI) measurements, and both regional-scale patterns of vegetation seasonality and productivity. Most studies used known samples of vegetation types. While this is a satisfactory approach, an alternative is to stratify AVHRR-derived NDVI data with a conventional vegetation map. The purpose of this research is to examine the relationship between AVHRR NDVI measurements, patterns of vegetation seasonality and productivity by analyzing 1 year of AVHRR NDVI data that was stratified using a small-scale vegetation map of Mexico. Thus, rather than samples, the entire areal extent of vegetation types was used to generate statistics. Preliminary results suggest that there is a good relationship between AVHRR NDVI measurements and regional-scale vegetation dynamics of Mexico.

81.  Lulla, Kamlesh P.; and Michael R. Helfert (JSC): 1989 Space Shuttle Earth
     Observations: Column Introduction. *Geocarto International Journal of Remote
     Sensing*, Vol. 4, No. 2, pp. 49-54.

82.  Lulla, Kamlesh P.; Michael R. Helfert; D. Amsbury; and J. Bremmer (JSC): 1989
     Space Shuttle Earth Observations: Medium Format Cameras Used by NASA
     Astronauts. *Geocarto International Journal of Remote Sensing*, Vol. 4, No. 3,
     pp. 59-62.

83.  Lulla, Kamlesh P.; and Michael R. Helfert (JSC): 1989 Space Shuttle Handheld Pho-
     tography: A Unique Source of Data for Geography and Earth Science Educators.
     *Geocarto International*, pp. 179-189, Hong Kong.

84.  Lulla, Kamlesh P. and Jim Merchant (JSC): 1989 Vegetation Remote Sensing in
     Chapter on Remote Sensing. *Geography in America*, pp. 688-721.

85.  Lulla, Kamlesh P. (JSC): 1989 Biogeography. *Geography in America*, pp. 123-156.

86.  Lulla, Kamlesh P.; and Michael R. Helfert (JSC): Surface Water Problems of Soviet
     Central Asia as Seen From Low Earth Orbit. Presented at the Annual Meeting,
     Association of American Geographers, April 1989, Baltimore, Maryland.
         The two primary large water bodies of Soviet Central Asia, the Aral' and the
     Caspian Seas, have undergone large areal fluctuations over geologic time. A.
     decrease in the area of both water bodies has been ascribed to changes of
     climate and man-modification of the source streams of both inland seas.
         This reduction of the large surface water resources of Soviet Central Asia can
     be tracked to overextension of irrigated areas in the drainage basins of the Syr'
     Dar'ya and Amu Dar'ya Rivers flowing from the Pamir Mountains to the Aral' Sea;
     and the combination of industrial, urban, and agricultural diversions of water along
     the course of the Volga River, the major source of fresh water for the Caspian.
         This study uses digitized, rectified, classified, and mensurated space photog-
     raphy taken from high-latitude Space Shuttle missions to estimate the areal
     change of these large water bodies since 1983.

87.  Martinez, Rene R. (LESC); and Graham Ryder (LPI): Zoned and Exsolved Complex
     Pyroxenes in Evolved Highlands Rocks From the Apennine Front. Presented at
     the 52nd Annual Meteoritical Society Meeting, July 17, 1989, Vienna, Austria.
         Three cataclastic coarse fines samples from Station 7 on the Apennine Front
     have mineral compositions and assemblages similar to those of the quartz-
     monozodiorite (QMD) clasts in a Station 6a boulder, including iron-rich pyroxenes
     and silica-potash feldspar intergrowths. The original grain size appears to have
     been more than 1 mm.
         Fe-augite and Fepigeonite coexist in complex intergrowths that also charac-
     terize QMD, and some evolved rocks of the Palisades sill. All pyroxenes have
     exsolved, with lamellae less than 10 microns thick. The exsolution in almost all
     instances occurs in only one direction in any subgrain. In one preserved patch in
     15434, 12, the lamellae do not maintain a constant direction across the aggregate,
     but rather the aggregate is a series of subgrains.

88.  Marvin, Ursula B.; Beth B. Holmberg (HU); and Marilyn M. Lindstrom (JSC): Grano-
     blastic Lunar "Dunites" Revisited. *Meteoritics*, Vol. 24, p. 299. Presented at the
     52nd Annual Meteoritical Society Meeting, July 31 - August 4, 1989, Vienna,
     Austria.

Clasts consisting almost entirely of polygonal olivine grains are rare constitu-
ents of lunar highland samples. We have analyzed three such clasts in Apollo 15
breccias 15295 and 15445 and have concluded that they are rock fragments from
a deep-seated source in the lunar crust.

89. McKay, David S.; D. D. Bogard; and R. V. Morris (JSC): Apollo 15 Regolith Brec-
cias: Window to a KREEP Regolith. *Proceedings of the 19th Lunar and Planetary
Science Conference*, pp. 19-41, 1989.

We made multidisciplinary studies of 28 regolith breccias returned from the
Apollo 15 site. Measured densities of a subset of them range from 1.98 $g/cm^3$ to
2.94 $g/cm^3$, which slightly overlaps the most dense Apollo 15 core soil sample
(1.35-2.15 $g/cm^3$). The maximum measured porosity in these regolith breccias is
37%.

90. McKay, David S. (JSC); W. Klock (NRC); K. Thomas (LESC); and M. Zolensky
(JSC): Comparison of Olivine Compositions in IDPs and Chondrite Matrices.
Presented at the 52nd Annual Meteoritical Society Meeting, July 31, 1989 -
August 4, 1989, Vienna, Austria.

Zolensky (1) showed that the bulk compositions of matrices and chondrule rims
in CM2 meteorites are essentially identical. It is not clear if chondrule rims are
the precursor material of CM2 matrix material. Comparing mineral compositions
in chondrule rims and matrices might help us to find genetic relationships
between chondrule rims and matrices.

91. McKay, David S. (JSC): Current Status of Technology to Extract Useful Materials
from Lunar and Martian Resources. *Proceedings of the AIAA 13th Annual
Technology Symposium*, pp. 3-9, May 18, 1989.

92. McKay David S.; and Judy Alton (JSC): Description and Analyses of Core Samples:
The Lunar Experience. *Proceedings of the Workshop on Analysis of Returned
Comet Nucleus Samples*. Presented at the Workshop on Analysis of Returned
Comet Nucleus Samples, January 16-18, 1989, Milpetas, California.

Cores provide the best way to sample a planetary regolith in three dimensions.
Depth information will be absolutely vital for proper interpretation of the regolith of
a comet. Such information has made major contributions to our understanding of
the history and evolution of the lunar regolith. A large number of core samples
were taken during the Apollo missions. The experience gained in taking, describ-
ing, and analyzing those cores constitutes a valuable resource which can be used
in planning for core-sample collection on a comet and for subsequent analysis
and interpretation. Many lessons were learned on hardware design, laboratory
handling, data collecting and reporting, and scientific problems which could and
could not be profitably addressed with cores.

93. McKay, David S. (JSC); W. Klock (NRC); and K. L. Thomas (LESC): Identification of
Possible Solar Nebular Condensates in Interplanetary Dust Particles and
Meteorites. *Proceedings of the 20th Lunar and Planetary Science Conference*.
Presented at the 20th Lunar and Planetary Science Conference, March 13-17,
1989, Houston, Texas.

One of the most important aspects in planetary sciences is the history of our
solar system, prior to and during the formation of the sun and planets. Information
about this time period comes mainly from the study of meteorites. Meteorites can
be classified in many different groups based on chemical and mineralogical char-
acteristics. Meteorites of the same group are believed to come from the same
kind of parent body. Probable parent bodies are planets and asteroids. But

meteorites comprise only a minor fraction of the extraterrestrial component falling onto Earth. The major component are micrometeorites or cosmic dust particles smaller than about 0.03 mm in size. The main sources of these cosmic dust particles are believed to be comets and asteroids. Material derived from comets was probably not affected by planetary processes such as internal heating, melting, and differentiation of the plant (or parent body) into core and mantle. Furthermore, cometary material is less likely to be affected by aqueous alteration compared to asteroidal material. Cometary material is, therefore, ideal if we want to study and understand preplanetary or solar nebula processes.

94. McKay, David S. (JSC); and S. J. Wentworth (LESC): Impact Glasses in Apollo 14 Regolith Breccias and the Origin of Soils. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 673-674, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.
    Apollo 14 soils and regolith contain a variety of both impact and volcanic glasses. Delano (1988) has documented the mare glass population and has shown that different regolith breccias contain different populations of mare glass types which he suggests may correlate with relative closure times for the breccias. Simon, et al. (1989) has analyzed a number of both volcanic and impact glasses from Apollo 14 regolith breccias and concluded that the regolith breccias, except for 14315, resemble the soils in glass types and bulk compositions, but the relative proportions of glass types differ and may also reflect earlier closure times of the breccias compared to the continuous exposure time for the soils.

95. McKay, David S. (JSC): The Lunar Regolith. Presented at the First Annual Invitational Symposium, October 24-26, 1989, Tucson, Arizona.
    A presidential decision has been made to go back to the Moon, and to establish a lunar outpost in order to explore and to learn how to live and work in space. This lunar outpost would provide the experience and technology required to send people to Mars to establish a human outpost. A part of the activity contemplated for the lunar outpost is the extraction of oxygen from lunar materials for use mainly as a propellant. Other uses for lunar material are also contemplated.

96. McKay, David S.; and Douglas W. Ming (JSC): Mineralogical and Chemical Properties of the Lunar Regolith. *Lunar Base Agriculture: Soils for Plant Growth.* D. W. Ming and D. L. Hennsinger, editors, p. 255, 1989.

97. McKay, David S.; and D. Ming (JSC): Mineralogical and Chemical Properties of the Lunar Regolith. *Lunar Base Agriculture: Soils for Plant Growth,* pp. 45-68, 1989.
    Lunar regolith is the layer of loose, incoherent rock material that nearly everywhere forms the surface of the Moon. The finer-grained (<1 mm) part of the lunar regolith has been loosely called "soil" and, in most locations, is the result of numerous and repeated bombardment by mostly small meteorites. Unlike terrestrial soils, the regolith lacks the influence of organic matter and the Moon is thought to be completely lacking in water. The regolith holds the most promise as a source of raw materials for use at lunar bases as well as materials for use in building large infrastructures in space. Lunar regolith may also provide rocket propellants and life support consumables, including oxygen, hydrogen, and manufactured water.
    No doubt, the regolith will play an important role in the development of lunar-base agriculture. The regolith may (1) act as a 'soil' and provide a soild-support substrate for plant growth, (2) be a source for essential, plant-growth elements, and (3) provide a source of oxygen and hydrogen, which may be used to

manufacture water - possibly the most important component of an agricultural system.

It has been almost 20 years since the first Apollo mission returned samples from the Moon in 1969. Since that time, lunar materials have been thoroughly studied and a wealth of information has been published on their physical, chemical, and mineralogical properties. The study of nonterrestrial surface materials and how they may react as a soil and/or a source of plant nutrients opens up a whole new frontier for researchers in the agricultural community. Because the Moon may be the first stepping stone for the presence of humans away from the Earth, the following paper has been prepared to acquaint agricultural scientists with the mineralogical and chemical properties of the lunar regolith.

98. McKay, David S. (JSC): Project Pathfinder and the Utilization of Lunar and Martian Resources. Presented at the 39th Annual North Central Regional AIChE Student Conference, Michigan Technological University, April 7-8, 1989, Houghton, Michigan.

A major objective of the recently started NASA Pathfinder program is to develop the advanced technology necessary for possible future NASA missions including lunar base and Mars expeditions. One subtopic of the Pathfinder program is the Resource Processing Pilot Plant (RPPP). The intent in this subtopic is to develop technology which will allow utilization of local resources on the moon or on Mars. For every ton of material which can be produced from local materials, one less ton has to be transported up from earth with the associated high costs of space transportation.

99. McKay, David S.; and Douglas W. Ming (JSC): Properties of Lunar Regolith. *Proceedings of International Working Meeting on Soil Micromorphology*, 1989. Presented at the International Working Meeting on Soil Micromorphology, July 10-15, 1989, San Antonio, Texas.

The lunar regolith consists of the fragmental, unconsolidated mantle which overlies more consolidated or crystalline rocks at the surface of the moon. The thickness of the regolith ranges from a few meters in some areas overlying mare basalt flows to tens of meters over much of the highland terrain. The lunar regolith has primarily been formed by repeated impact of meteorites which have ground and pulverized underlying coherent rock and have gardened the unconsolidated debris. One of the most important properties of lunar regolith is its maturity, which is a function of its integrated exposure time within the first few millimeters of the lunar surface. Maturity affects grain size; the most mature samples are the finest grained (mean grain size ~ 45 microns). Mature soils also have abundant agglutinates (up to 50 percent by volume) which are constructional particles made of lithic, mineral, and glass fragments welded together by a glassy matrix containing extremely fine-grained metallic iron and formed in micrometeorite impacts at the lunar surface. The agglutinates, the grain size parameters, and implanted solar wind abundances, and the variation of these parameters with depth can all be used to reconstruct the local geologic history and the variation in external environment or 'climate' over geologic time. Meter deep regolith profiles at a given locality typically show little change over time scales of a few million years, but usually change in a major way over time scales on the order of a hundred million years. Detailed data on the composition and micromorphologicproperties of lunar regolith may also be used to estimate its ability to support crop growth at a future lunar base.

100. McKay, Gordon (JSC): Analysis of Rare Earth Elements by Electron Microprobe. Presented at the 1989 Microbeam Analytical Society Conference, July 1989. Ashville, North Carolina.

Geochemists commonly use abundances of Rare Earth Elements (REE) to determine evolutionary histories of suites of rocks. This approach requires knowledge of REE concentrations in the constituent minerals of the rocks. These concentrations are sometimes measured by bulk analytical techniques, such as neutron activation analysis of mineral separates. However, bulk techniques provide no information concerning zoning within the minerals. Moreover, results are often adversely affected by impurities in the mineral separates. Hence, it is often desirable to measure REE abundances in minerals with an in situ technique.

101. McKay, Gordon (JSC); R. O. Colson (WU); and L. A. Taylor (UT): Charge Balancing of Trivalent Trace Elements in Olivine and Low-Ca Pyroxene: A Test Using Experimental Partitioning Data. *Geochimica et Cosmochimica Acta*, June 1989.

Charge-balancing substitution mechanisms have been determined for the incorporation of the trivalent cations A1 and Sc in low-Ca pyroxene and A1, Sc, Yb, and Cr in olivine. In low-Ca pyroxene, the substitution mechanism was determined by evaluating covariations of trivalent trace cations with Si, Mg, Fe, and Ca. In olivine, substitution mechanisms were determined by comparison of the observed compositional dependence of partitioning to the compositional dependence theoretically expected for each substitution reaction.

102. McKay, Gordon (JSC); M. Miyanoto; and H. Takeda (University of Tokyo): Cooling History of Angrite LEW 86010. Presented at the 52nd Annual Meteoritical Society Meeting, July 31-August 4, 1989, Vienna, Austria.

Antarctic angrite LEW 86010 has many chemical and mineralogical characteristics which suggest it is closely related to Angra dos Reis (ADOR). However, despite their similarities, these meteorites have had very different thermal histories. Olivines and pyroxenes in ADOR are nearly homogeneous, suggesting very slow cooling or extensive subsolidus equilibration. In contrast, LEW 86010 pyroxenes are extensively zoned in both major and trace elements. On the other hand, olivines in LEW 86010 are nearly homogeneous, suggesting that cooling of this sample was slow enough to homogenize olivines, but too fast to homogenize pyroxenes.

103. McKay, Gordon (JSC); L. Le; and J. Wagstaff (LESC): Is Unique Achondrite LEW 86010 a Crystallized Melt. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

Antarctic meteorite LEW 86010 has many chemical and mineralogical characteristics which suggest it is closely related to Angra dos Reis (ADOR). Unlike ADOR, however, it has undergone little subsolidus recrystallization, and thus its minerals might closely reflect the composition of the melt from which they crystallized. Experiments indicate that the composition of LEW 86010 is close to multiple liquidus saturation with plagioclase, fassaite, and olivine, suggesting the possibility that this sample is an isochemically crystallized melt. In this case, the composition of the parent melt would simply be the bulk composition of the rock, a conclusion of obvious importance for petrogenetic modelling. However, there is evidence that the melt with which the LEW 86010 pyroxene and plagioclase core last equilibrated did not have the composition of the bulk meteorite.

104. McKay, Gordon A. (JSC); R. O. Colson (WU); and L. A. Taylor (UT): Partitioning Data Pertaining to Fe-Mg Ordering Around Trace Cations in Olivine and Low-Ca Pyroxene. *Mineralogy and Petrology*, May 1989.

We have used trace element partitioning data available in the literature to investigate nonideality of the cations of Yb, Sm, Gd, Ca, Mn, Sc, Ni, and A1 in silicate melt, olivine, and low-Ca pyroxene. Results are consistent with ordering of Mg and Fe around trace cations in olivine and pyroxene. On the basis of these data, we suggest there is an increasing tendency for Fe to congregate in the vicinity of the trace cation as the size of the trace cation increases. These results are important both in achieving a better understanding of trace element behavior in crystals and in constraining the temperature and compositional dependence of trace element partitioning.

105. McKay, Gordon A. (JSC): Partitioning of Rare Earth Elements Between Major Silicate Minerals and Basaltic Melts. *Reviews in Mineralogy*, December 1989. Presented at the Mineralogical Society of America Short Course on Rare Earth Element Geochemistry, December 1989.

A major geochemical application of rare earth elements (REE) is in the mathematical modelling of igneous petrogenetic processes, the fundamentals of which are discussed by Hansen elsewhere in this volume. An essential conceptual tool in such modelling is the mineral/melt partition coefficient, generally defined as the concentration of an element in a mineral divided by its concentration in the melt in equilibrium with that mineral. More formally, the partition coefficient of element $E$ between a solid mineral $S$ and the molten silicate liquid in equilibrium with that mineral is defined as $D_{E,SIL}C(E_s) = C(E_s)/C(E_L)$, where $C(E_s)$ is the concentration of element $E$ in mineral $S$ and $C(E_L)$ is its concentration in the coexisting liquid. Thus, because the concentration of $E$ in the solid is normalized to its concentration in the liquid, it is generally assumed that D will be independent of the concentration of $E$.

106. McKay, Gordon A. (JSC); L. Le; and J. Wagstaff (LESC): Redox Conditions for LEW 86010. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

107. Mendell, Wendell W. (JSC): A Strategy for Investment in Space Resource Utilization. *Acta Astronautica*, 1989, Paris Cedex, France.

During the first quarter of the next century, space transportation systems will be capable of routine flights of humans and cargo to the Moon. The general acceptance of permanent human presence in space, as exemplified by at least two manned stations in LEO at that time, will lead to one or more staffed outposts on the Moon. Whether such outposts evolve into sustained, growing settlements will depend, in part, on whether the economic context attracts substantial private investment. A planetary surface provides a material and gravitational environment distinct from that of an orbiting space station and thus provides a setting familiar to non-aerospace sectors of terrestrial industry. Examination of current trends in terms of historical processes which operate on new frontiers suggests that the limited markets and unfamiliar technologies associated with space commercialization today may change dramatically in 20 years when lunar resources are accessible.

108. Meyer, Charles (JSC); Ian Williams; and Bill Compston (ANU): 207Pb/206Pb Ages of Zircon-Containing Rock Fragments Indicate Continuous Magmatism in the Lunar Crust from 4350 to 3900 Million Years. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

Zircons are found intergrown with other minerals in clasts within lunar breccia. The textures indicate that ages determined for certain of the zircons are also the ages of the rock fragments. The wide range of composition of attached plagioclase and pyroxene indicate that the zircons formed in a wide variety of plutonic lunar samples.

The wide spectrum of ages for zircon-containing lunar rock fragments is further evidence that serial magmatism occurred within the lunar crust during the time interval 4350 to 3900 Ma. No zircons have been found older than 4371 + -8 Ma, which may be within the period of crystallization of the last differentiates from an early lunar magma ocean.

109. Meyer, Charles (JSC); W. Compston; and I. S. Williams (ANU): The Problem of Lunar Initial Pb. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

The initial Pb isotopic compositions of many lunar igneous rocks are not well known for several reasons: their extremely small Pb contents, the mobile nature of Pb during thermal events, and the lack of precise model-independent age determinations. We applied the ion probe to the problem during U-Pb age determinations on lunar zircon. In principle, the precision for U-Pb ages by ion probe for old zircons can be as high as a few million years, but this cannot be realized without knowledge of the initial Pb composition. There were internal indications of a high-*mu* initial Pb at 4.35 Ga from our first lunar zircon measurements, but the particular zircons (rounded grains in breccia) could not be related to adjacent Pb-bearing minerals. Similar indications from later measurements on euhedral zircons within lunar granophyres led us to ion-probe analysis of the cogenetic Pb-bearing K-feldspars in these rocks using available polished thin sections.

110. Ming, Douglas W. (JSC); and Lisa K. Tuck (UHCL): Clay Liner Materials Amended with Zeolites to Adsorb Heavy Metals. Presented at the Soil Survey and Land Resource Workshop, February 10, 1989, College Station, Texas.

The treatment and disposal of hazardous materials from industrial and municipal wastes is a growing worldwide problem. Residues from materials that cannot be treated and/or reused are confined in hazardous waste landfills. The most commonly used material for liners in hazardous waste landfills is clay. Clay materials used in liners have the ability to adsorb various ions and molecules released from the waste materials and slow down their movement into the underlying materials. The addition of a material(s) to the liner that would increase the potential adsorption capacity for ions and molecules released in landfills would be desirable. A group of materials that may increase the adsorption capacity of landfill liners are zeolites. Zeolites are minerals that have a framework structure containing tunnels filled with water and exchangeable atoms of sodium, potassium, calcium, and magnesium. One of their more notable features is the ability to exchange some of their exchangeable atoms without a major structure change. Thus, they can adsorb other exchangeable atoms such as cadmium or lead in their framework while releasing other less objectionable atoms such as sodium and calcium.

111. Ming, Douglas W.; and Gary E. Lofgren (JSC): Crystal Morphologies of Minerals Formed by Hydrothermal Alteration of Synthetic Lunar Basaltic Glass. *Soil Micromorphology Workshop*, 1989.

If zeolites and other ion-exchange minerals existed on the lunar surface, they would have a variety of potential applications in life support systems at lunar bases. In this study we have synthesized under mild hydrothermal conditions

zeolites (analcime, ZK-19, sodalite hydrate, zeolite $P_t$, zeolite A), phyllosilicates (smectite), feldspars (anorthite), feldspathoids (cancrinite), tobermorite (double-chained silicate), calcite, and several unnamed synthetic minerals with no known natural analogs (e.g., $CaO.Al_2O_3.2SiO_2$) from basaltic glass with chemical compositions similar to lunar basaltic glasses. Basaltic glass in the presence of $Na_2CO_3$, NaOH and $NA_2Sio_3.5H_2O$ solutions favored the formation of synthetic analcime. Zeolite ZK-19 (phillipsite-type) formed from basaltic glass altered by $K_2CO_3$ and KOH solutions at 250° C.

112. Ming, Douglas W. (JSC): Human Exploration of the Inner Solar System. Presented at the Worcester Polytechnic Institute Chemical Engineering Department Space Forum Meeting, January 23, 1989, Worcester, Massachusetts.

NASA is considering a step into a new frontier--extending permanent human presence beyond Earth orbit into our solar system. As part of the planning process, a number of missions are now being evaluated as case studies or scenarios, including (1) the human exploration of Mars and its satellite, Phobos; (2) the establishment of a lunar science outpost; and (3) the evolutionary expansion of humans in our inner solar system. Evolutionary expansion will be a step-by-step program to open the inner solar system for exploration, space science research, in situ resource development, and permanent human presence. The first step will probably be the shortest--the establishment of lunar bases. A number of reasons to revisit the Moon have been suggested, including (1) scientific research, (2) utilization of lunar resources, and (3) attainment of self-sufficiency in the lunar environment as a first step in planetary exploration.

113. Ming, Douglas W. (JSC); and Lisa K. Tuck (UHCL): Ion Exchange Selectivities for Cadmium and Lead in Clay Liner Materials Amended with Clinoptilolite. Presented at the American Society of Agronomy Annual Meeting, October 15-20, 1989, La Vegas, Nevada.

Clay liner materials amended with the natural zeolite clinoptilolite have been shown to increase the adsorption capacity of the liner for the heavy metals Cd and Pb. No studies have been performed, however, to determine the selectivity of these materials for $Cd^{2+}$ and $Pb^{2+}$ versus the alkali and alkaline earth cations (i.e., $K^+$, $Na^+$, $Mg^{2+}$, and $Ca^{2+}$). In this study, clay liner materials and clinoptilolite were each saturated separately with Cd and Pb. The clay liner materials were then amended with varying percentages of clinoptilolite for total sample weights of 0.1 g, 1.0 g, and 2.0 g and brought to equilibrium with solutions of $KCL$, NaCl, $MgCl_2$, or $CaCl_2$. Ion exchange selectivities for $Cd^{2+}$ and $Pb^{2+}$ versus $K^+$, $Na^+$, $Mg^{2+}$, and $Ca^{2+}$, were determined using the Vanselow selectivity coefficient. All samples (i.e., clay liner materials, clay liner materials amended with clinoptilolite and clinoptilolite) showed a preference for $K^+$ over $Pb^{2+}$, but $Pb^{2+}$ was much more selective than $Mg^{2+}$, $Ca^{2+}$, and $Na^+$. Potassium and $Na^+$ were more selective on zeolite and clay sites than $Cd^{2+}$; however, $Cd^{2+}$ was more selective than $Ca^{2+}$ and $Mg^{2+}$.

114. Ming, Douglas W. (JSC): Manufactured Soils for Plant Growth at a Lunar Base. Presented at the American Society of Agronomy, October 15-20, 1989, Madison, Wisconsin. Lunar Base Agriculture: Soils for Plant Growth, August 1989.

The newly created Office of Exploration at NASA Headquarters is considering several missions that the Agency may undertake as a part of the human exploration of our inner solar system. These scenarios include: (1) expeditions to establish the first human presence on another planet (e.g., Mars); (2) lunar outposts to conduct extraterrestrial science; and (3) evolutionary expansion to establish self-sufficient human presence beyond low Earth orbit. Evolutionary

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expansion is a step-by-step program away from low Earth orbit. The first step will probably be the establishment of a lunar outpost that will lead to a self-sufficient lunar base. A self-sufficient lunar base will require the utilization of *in situ* resources for construction materials, propellants, life-support systems, etc.

115. Ming, Douglas W. (JSC); C. Galindo (LESC); and D. Henninger (JSC): Methods for Determining Cation Exchange Capacities and Compositions of Exchangeable Cations for Several Natural Zeolites. Presented at the American Society of Agronomy Annual Meetings, October 15-20, 1989, Las Vegas, Nevada.

Because of their unique cation-exchange properties, natural zeolites are being considered for a variety of agricultural and environmental applications (e.g., zeoponics, clay-liner amendments, heavy metal contaminated soils). Standard methods do not exist for determining cation exchange capacities (CECs) and compositions of exchangeable cations (e.g., Na, K, Mg, Ca) for natural zeolites. The objective of this study was to design and test methods to determine CECs and composition of native exchangeable cations for selected zeolites. Based on ion-exchange selectivities and ion-sieving properties, methods were developed to determine CECs for the sedimentary zeolites clinoptilolite and chabazite. The best methods for determining CECs for clinoptilolite and chabazite were $K^+$/$Cs^+$ and $K^+$/$Rb^+$ exchanges, respectively. Six sedimentary clinoptilolites were examined, CECs ranged from 120 to 185 $cmol_c kg^{-1}$, depending on the purity of the zeolite deposit. CECs of three sedimentary chabazites were determined, ranging from 180 to 240 $cmol_c kg^{-1}$. The composition of native exchangeable cations on clinoptilolite and chabazite were determined on dialyzed samples using the replacement cations $Cs^+$ and $Rb^+$, respectively.

116. Ming, Douglas W.; and David S. McKay (JSC): Resource Processing Pilot Plant. Presented at the Pathfinder: Technology for the 21st Century, June 6-8, 1989, Hampton, Virginia.

Project Pathfinder is a NASA program that has been initiated to develop the advanced technology necessary for possible future NASA missions including lunar bases and the exploration of Mars and its moons. One subtopic of the Pathfinder program is the Resource Processing Pilot Plant (RPPP). The RPPP element will develop the technology which will allow utilization of local resources on the Moon or on Mars and its moons. For every ton of material which can be produced from local materials, one less ton has to be transported up from Earth with the associated high costs of space transportation.

117. Ming, Douglas W.; D. L. Henninger (JSC); and C. Galindo, Jr. (LESC): Solid-support Substrates for Plant Growth at a Lunar Base. Presented at the CELSS Principal Investigators Meeting, February 5-8, 1989, Orlando, Florida.

A variety of *in situ* materials could be used as solid-support substrates for plant growth at planetary bases (primarily lunar bases) including: (1) native lunar "soils"; (2) sized lunar regolith amended with synthetic materials (e.g., zeolites, smectites) that provide nutrient and water retention; (3) synthetic, inorganic, highly-reactive substrates (e.g., zeoponics); and (4) sized lunar materials or industrial by-products used as inert, solid-support substrates in nutriculture systems. Research at NASA JSC is being conducted in several areas of plant growth in solid-support substrates including: (1) behavior of lunar materials as "soils"; (2) zeoponic systems for plant growth; and (3) production of lunar simulants to use in plant growth experiments.

118. Ming, Douglas W. (JSC): Zeolites in Space. Presented at the Worcester Polytechnic Institute Chemical Engineering Department Graduate Seminar, January 23, 1989, Worcester, Massachusetts.

    Maintaining colonies on the Moon or Mars will require the utilization of lunar or Martian resources to reduce the number of launches to transport goods from the Earth. It may be possible to alter *in situ* materials to produce minerals or other materials that can be used for applications in life support systems at a planetary base. For example, the mild hydrothermal alteration of basaltic glasses should produce special purpose minerals (e.g., zeolites, smectites, and tobermorites) which in turn may be used in life support, construction, waste, and chemical processes.

119. Ming, Douglas W.; Frederick A. Mumpton (JSC): Zeolites in Soils. *Minerals in Soil Environments*, August 1989. Presented at the American Society of Agronomy, October 15-20, 1989, Madison Wisconsin. .

    In the last 25 years, zeolite minerals have been recognized with increasing regularity as common constituents of Cenozoic volcanogenic sedimentary rocks and altered pyroclastic rocks Their occurrence in soils, however, is not as well known and has received little attention by geologists and soil scientists. In the course of this investigation, about four dozen papers were encountered that describe members of this group of hydrated aluminosilicates of alkali and alkaline earth cations in soils ranging from Mollisols of Texas to cold, arid soils of Antarctica. Most of these reports discuss residual zeolite phases that remain during weathering of parent rocks which are themselves rich in zeolites (generally of volcanic origin); but several occurrences have been reported where zeolites have crystallized *in situ* from strongly alkaline soil solutions.

120. Ming, Douglas W.; Donald L. Henninger (JSC); and Charlie Galindo (LESC): Zeoponic Systems for Plant Growth in CELSS. Presented at the CELSS Principal Investigators Meeting, February 5-8, 1989, Orlando, Florida.

    The term "zeoponics" was first used to describe an artificial soil that consisted of zeolites, peat, and vermiculite used by Bulgarian researchers. Zeolites are hydrated aluminosilicates of alkali and alkaline-earth cations (e.g., $K^+$, $Na^+$, $Ca^{2+}$, $Mg^{2+}$) that possess infinite, three-dimensional crystal structures (i.e., tektosilicates). Zeolites have the ability to exchange most of their constituent exchange cations as well as hydrate/dehydrate without major change of the structural framework. Natural zeolites may have cation exchange capacities (CECs) of 200 to 300 $cmol_c$ $kg^{-1}$, whereas some synthetic zeolites may have CECs as high as 600 $cmol_c$ $kg^{-1}$. Because zeolites have extremely high CECs, they are very attractive media for plant growth.

121. Mittlefehldt, David W. (LESC); and Marilyn M. Lindstrom (JSC): Eucrites: Antarctica Versus the Rest of the World. Presented at the Workshop on Differences Between Antarctic and Non-Antarctic Meteorites, July 27-28, 1989, Vienna, Austria.

    Antarctic eucrites provide a valuable source of material from the HED parent body for petrologic and geochemical interpretations of petrogenesis on asteroids. We have previously noted that many basaltic clast samples of the LEW853xx polymict eucrites have unusual REE patterns that show positive Ce anomalies and suggested the possibility that the anomalies result from weathering processes.

    The REE data for Antarctic eucrites and non-Antarctic eucrites show distinct differences. The Ce/La ratios for non-Antarctic eucrites are generally more nearly chondritic than those of Antarctic eucrites; 76% of the 51 analyzed non-Antarctic eucrites are within the range 0.91.1x CI. In contrast, only 40% of the 76 analyzed

Antarctic eucrites are within the same range. Most of the samples with higher than normal Ce/La have low La concentrations. This suggests that the anomalous Ce/La ratios are predominantly due to low La in the samples and not high Ce.

122. Mohler, Robert R. J. (LESC); Michael R. Helfert (JSC); and John R. Giardino (TAMU): The Decrease of Lake Chad as Documented During Twenty Years of Manned Space Flight. *Geocarto International* (1), Volume 4, No. 1, March 1989.
Space photography has been successfully used to extend the space remote sensing database for environmental monitoring by a decade. In this study of Lake Chad, space photographs were digitized and registered to a topographic base map before water classifications were performed. From 1966 to 1985 we observed over a 21,000 square kilometer decrease in lake surface area.

123. Mohler, Robert R. J. (LESC); Michael R. Helfert; and Kamlesh P. Lulla (JSC): Detection of Change in Lacustrine and Deltaic Environments Using Space Photographs. Presented at the 1989 AAG Annual Meeting, March 19-22, 1989, Baltimore, Maryland.
Earth-viewing photographs have been acquired by astronauts over inaccessible or remote areas for over 25 years. Such photography serves as additional base-lines when monitoring Earth processes through time. We present a computer-based methodology which incorporates this photography for quantifying areal change. Study sites include Great Salt Lake, Utah; Lake Chad, Africa; and the Omo Delta, Ethopia. Our measurements of Great Salt Lake (original test case), in which we document a 46 percent increase in surface area between 1974 and 1985, are not significantly different from USGS-calculated estimates at the 0.05 level. In extending the methodology to Lake Chad, we recorded a 93 percent decrease in lake area from 1966 to 1984; we also recorded a dramatic increase in the progradation of the Omo Delta during this time frame. This methodology is now felt sufficiently mature to allow assessment of areal change over time of selected sites in regions of no, little, or low-quality ground truth.

124. Mohler, Robert R. J. (LESC); and D. L. Amsbury (JSC): Extension of a Drought Monitoring and Vegetation Classification Methodology to the Western Sahel. *Geocarto International*, Vol. 3, No. 4, December 1988, pp. 29-36, Hong Kong.
Biomass of growing vegetation over large semiarid regions can be estimated by digital manipulation of data from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA polar-orbiting satellites. Successful techniques which have been employed include the Normalized Difference Vegetation Index and CAUSE. We have extended to the African Sahel a methodology which incorporates both the Normalized Difference and CAUSE procedures for the monitoring of vegetation during drought conditions. Preliminary analysis of color infrared photographs taken on Space Shuttle missions indicates that such photographs can be digitized, registered to maps and other images, and utilized to fill temporal gaps in the historical record of data from unmanned satellites.

125. Mohler, Robert R. J. (LESC): Space Photography: An Alternative Data Set for Monitoring Earth Systems. Presented at the Texas A&M University College of Geosciences Student Symposium, March 4-5, 1989, College Station, Texas.
With the degradation of the biosphere, primarily through the activities of man, members of the scientific community have become acutely aware of the need of monitoring the Earth using space-based remote sensing sytems. Essential in the monitoring of global sytems and environmental change is the establishment of a baseline data set for the regions of interest. The current baseline year for civilian

satellite data is 1972. For several environmental sites this base year can be extended through use of space photography from manned orbital systems.

Space photographs of Great Salt Lake, Utah, have been analyzed as a test case to determine the suitability of the photos for both quantifying environmental change and extending the remote sensing length-of-record for detecting such change.

126. Morgan, T. H.; Herbert A. Zook; and A. E. Potter (JSC): Production of Sodium Vapor from Exposed Regolith in the Inner Solar System. *Proceedings of the 19th Lunar and Planetary Science Conference*, pp. 297-304, 1989.

We have calculated the likely supply of sodium to the lunar exosphere by impact vaporization, by charged particle sputtering, and by photon stimulated desorption. These were each compared to the supply of sodium needed to maintain the observed sodium exosphere about the Moon. The two processes, already known to act on the lunar regolith, impact vaporization and charged particle sputtering, and appear to be sufficient to explain the observed column density of sodium in the lunar atmosphere. Photon-stimulated desorption, given the estimates for the yield of sodium due to this process available in the literature, would produce 100 to 1000 times more sodium than is observed. If impact vaporization is the main source of sodium to the atmosphere of Mercury, then sodium photo-ions in the exosphere of Mercury are efficiently recycled to the planet.

127. Morris, Richard V. (JSC); and H. V. Lauer, Jr. (LESC): Effect of Matrix Properties on the Reflectivity of Dispersed Nanocrystalline Hematite: Implications for Martian Spectral Data. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

128. Morris, Richard V. (JSC); D. G. Agresti; T. D. Shelfer; and T. J. Wdowiak (University of Alabama): Mossbauer Backscatter Spectrometer: A New Approach for Mineralogical Analysis on Planetary Surfaces. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

129. Morris, Richard V. (JSC); and D. G. Schulze (PU): Reflectivity Spectrum (350-2200 nm) of Ferrihydrite. Presented at the Fourth International Conference on Mars, January 10-13, 1989, Tucson, Arizona.

130. Morris, Richard V. (JSC): Reflectivity Spectra (350-2200nm) of SNC Meteorites. *Proceedings of the 20th Lunar and Planetary Science Conference II*, pp. 719-720, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

131. Morris, Richard V. (JSC); and H. V. Lauer, Jr. (LESC): Superparamagnetic Hematite as an Optically and Magnetically Important Component of the Martian Surface. Presented at the Fourth International Conference on Mars, January 10-13, 1989, Tucson, Arizona.

The positions and shapes of spectral features and the magnetic properties for unsupported sp-Hm are equivalent to those for sp-Hm supported on silica gel. It appears that even in the superparamagnetic (nanocrystalline) size range, sp-Hm, sp-Mh, and ferrihydrite can be distinguished from one another if enough different types of data are available. The fact that the properties of sp-Hm are not strongly dependent on the nature of the support material reinforces our previous conclusion that sp-Hm is an optically and magnetically important constituent of Martian surface materials.

132. Nellis, Duane M.; R. Lougeay; and K. Lulla (JSC): Current Trends in Remote Sensing Education. Special Monograph in Advances in Remote Sensing. *Geocarto Publication*, p. 196. Hong Kong.

133. Nellis, Duane M.; R. Lougeay; and K. Lulla (JSC): Interfacing Remote Sensing Research and Instruction: Current Trends in Remote Sensing Education. *Geocarto Publication*, pp. 1-5, Hong Hong.

134. Nelson, Dennis O.; W. C. Phinney; L. E. Nyquist; and D. A. Morrison (JSC): Trace Element and Sr Isotopic Compositions of Granitoids of the Kapuskasing Structural Zone: Implications for AFC Evolution of the Matachewan Dikes. *Geological Society of American Abstracts with Programs*, Vol. 21, No. 6, p. A189, 1989. Presented at the 1989 Geological Society of America, November 6-9, 1989, St. Louis, Missouri.

Trace element models suggest that AFC, involving tonalitic assimilants, was important in producing variations in trace element ratios of the 2.45 Ga Matachewan dikes. We have analyzed granitoids (tonalities to granites) from the Archean lower crust now exposed in the Kapuskasing Structural Zone (KSZ) of the Superior Province for their trace element and Sr isotopic compositions. Compositions vary markedly, ranging from granitoids enriched in incompatible elements, particularly La and Th, having high $(La/Sm)n$, $(La/Yb)n$ and $Th/Ta$, and low CaO and MgO contents (type 1) to less evolved granitoids (type 2). AFC trajectories $(Ma/Mc = 0.5)$ involving type 1 pass through the dike data, those involving type 2 do not.

135. Nyquist, L. E.; D. D. Bogard (JSC); H. Wiesmann; B. M. Bansal; and C.-Y. Shih (LESC): $^{147}Sm$-$^{143}Nd$ Age and Initial $^{146}SM/^{144}Sm$ Ratio of a Eucrite Clast in the Bholghati Howardite. *Meteoritics*, Vol. 24, p. 311, 1989.

Analyses of the Bholghati eucrite clast (whole rock, 2.65-2.85 $g/cm^3$ plagioclase, 3.4-3.55 $g/cm^3$ pyroxene, 2.85-3.4 $g/cm^3$ mixed phases, and leachates (phosphates) from, respectively, the 2.85-3.4, 3.4-3.55 and 3.55-3.7 $g/cm^3$ separates) yield an isochron corresponding to an age of 4.53 ± 0.03 Ga and initial $^{143}Nd/^{144}Nd$ = 0.505962 ± 48 normalized to $^{146}Nd/^{144}Nd$ = 0.72414 (equivalent to $^{148}Nd/^{144}Nd$ = 0.24308). Some phases severely disturbed in the Rb-Sr system of the clast ( > 3.7 g/cm3 ilmenite, 3.55-3.7 g/cm3 pyroxene (1) are also slightly disturbed in the Sm-Nd system. The initial $^{143}Nd/^{144}Nd$ value is ~0.5 ε-unit higher than the CHUR value (3) and is compatible with evolution in an LREE depleted source.

136. Phinney, W. C.; and Donald A. Morrison (JSC): Calcic Anorthosites: Distribution Coefficients and Parent Melts. Presented at the1989 Geological Society of America, November 6-9, 1989, St. Louis, Missouri.

Calcic anorthosites are a major part of the lunar crust and knowledge of their parent melts is mandatory for understanding lunar evolution. Because plagioclase is commonly the only cumulate phase in anorthosites, parent melt compositions must be estimated by use of distribution coefficients (KDs) for the minor and trace components in plagioclase. Attempts at experimental determination of usable KDs have been fraught with many problems including dependence of KDs on bulk melt composition, accurate analysis of minor components in the small crystals of experimental charges, kinetic effects, and oxygen fugacity variations. Anorthosites with homogeneous calcic plagioclase megacrysts are common in the Earth's Archean crust. Identical homogeneous megacrysts in many Precambrian basalts allow determination of apparent KDs between crysts and matrices. These

KDs can be tested for matches between terrestrial occurrences of anorthosite and coeval basalts.

137.  Phinney, W. C.; and D. A. Morrison (JSC):  REE Distribution Coefficients for Plagioclase:  Implications for Anorthosite Melts.  Presented at the 20th Lunar and Planetary Sciences Conference, March 13-17, 1989, Houston, Texas.

The composition and fractionation trends of melts parental to calcic anorthosites is a longstanding problem on Earth and a more recent one on the Moon. Over the past few years we have attempted to determine the nature of these melts by combining analyses of trace elements in terrestrial occurrences of plagioclase megacrysts with published distribution coefficients for these elements between plagioclase and basaltic melt.  Two major problems complicated this task:  (1) alteration of plagioclase made separation of clean aliquots for analysis nearly impossible and (2) several sets of distribution coefficients with widely differing values exist for basalts.

138.  Reynolds, Robert C.; and Andrew E. Potter (LESC):  *Orbital Debris Research at NASA Johnson Space Center 1986-1988.*  NASA TM 102155, September 1989.

139.  Reynolds, Robert C.; Chris Largent (LESC); and Faith Vilas (JSC):  Optical/IR Observations of Orbital Debris from Orbiting Platforms:  Lighting Conditions and Look Directions.  Presented at the Third Annual RADC Electro-Optical Space Surveillance Conference, November 14-16, 1989, Abilene, Texas.

Mission orbits of inclination 28.5°, 57°, and 67° and altitude 300 and 500 km have been examined for two conditions:  (1) Sun-Earth-spacecraft angle, which can be related to the ability to see debris under good lighting conditions against a dark background, and (2) $\beta$ angle (the complement of the angle between the orbit angular momentum vector and the line from the Earth to the Sun), which determines the angle out of the orbital plane that such debris will be seen.  Four Sun positions, Celestial Longitude 0°, 30°, 60° and 90° are examined for each orbit. Sun position in the other quadrants leads to geometries simple related to these cases.

Two conclusions may be drawn from the cases examined:  (1) there is adequate observation time for the low $\beta$ in-plane debris searches in all cases, and (2) for those cases where there are suitable observation conditions available through the entire orbit, $\beta$ is large enough to support direct cross-range observation of debris.  Both cases are shown in the attached Figure, where it can be seen that the low $\beta$-angle interval centered on Right Ascension of Ascending Node (RAAN) of 75° and 205° lead to observation times of about 27 minutes per rev, and for the shaded high $\beta$-angle cases centered on RAAN of 180°, there is a significant range of RAAN values for direct cross-range measurements.

140.  Saski, Y.; S. Allen; K. Mizuo; V. Whitehead; and K. Wilk (JSC):  Optimized Variational Analysis Scheme of Single Doppler Radar Wind Data.  *Proceedings of the American Meteorological Society Annual Meeting,* 1989.

141.  Score, Roberta (LESC); Marilyn Lindstrom (JSC); and Brian Mason (SI):  Collection, Classification and Description of MAC88104 and MAC88105 - Two Fragments of a Lunar Meteorite.  *Meteoritics,* Vol. 24, No. 324, 1989.

Antarctic meteorites MAC88104 (61 g) and MAC88105 (662 g) were collected as paired specimens in the eastern quarter of the MacAlpine Hills blue ice basin. They were found in an area that has a large concentration of terrestrial rocks of various types and a few meteorites.  They were collected by the 1988 ANSMET

field team consisting of W. Cassidy, D. Blewett, M. Grady, R. Harvey, R. Korotev, S. Sandford, J. Schutt, and R. Score.

MAC88104 and MAC88105 are polymict breccias. Both hand-specimen and thin-section examination confirm the suspected pairing of these fragments. Each has thin grey-green fusion crust covering 25-33% of the surface. The other exterior surfaces are dark grey, weathered, and have numerous clasts and holes where clasts were plucked out by weathering. The interior is blue grey and mostly fine-grained, but glassy in some areas. Veins of dark glass surround some clasts, but do not transect any clasts. The meteorite contains abundant, angular feldspathic clasts and fine-grained grey, black and beige clasts. The largest clast exposed (1.5 x 1 cm) is fine-grained and anorthositic, with scattered mafic minerals. Another clast is medium-grained and more mafic.

142. See, Thomas H.; D. W. Mittlefehldt (LESC); and F. Horz (JSC): Analysis of Aeroballistically Dispersed Glass Samples From Wabar Crater, Saudi Arabia. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 980-981, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

Our investigation of the 6,400 year old Wabar impact structure of south-central Saudi Arabia has continued with analyses of some newly acquired melt samples. In our initial study we confirmed the observations of Spencer that two distinct impact melts (i.e., black and white) coexist at the 90 m diameter Wabar Crater. In addition, both melts were shown to be part of the crater's main melt-volume and exhibit unusually high levels of meteoritic contamination (i.e., ~4.5% and ~0.5% for the black and white melts, respectively) when compared to most terrestrial impact melts. These observations indicate a substantially heterogeneous, if not bimodal, dissemination of the projectile throughout the target volume melted during the Wabar impact.

143. See, Thomas H. (LESC); F. Horz; D. Blanchard; and A. J. Murali (JSC): Heterogeneous Dissemination of Projectile Materials in the Impact Melts From Wabar Crater, Saudi Arabia. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 697-709, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

We confirmed the initial observations of Spencer (1933a,b) that two distinct impact melts coexist at the 90-m-diameter Wabar crater, Saudi Arabia. A dark or "black" melt contains on the order of 4% meteoritic contamination, while the transparent or "white" melt contains <1%. The Fe/Ni ratios in both varieties exhibit considerable scatter on electron-microprobe scales, akin to those reported by others for metal spherules in the black melt. If the meteoritic component is subtracted, both melts are chemically very similar. Clasts engulfed by the Wabar melts were also investigated, as they represent the progenitor lithologies from which the melts formed. Bulk compositions for these clasts reveal subtle differences in modal feldspar content within the quartz-rich Wabar target. Both melts require that a minimum of two target lithologies be present in the Wabar melt zone. The distinctly bimodal dissemination of projectile remnants in the melts is not well understood, primarily because the target stratigraphy at Wabar is not known in detail. It is suggested, however, that the crater size may play an important role in the degree of melt homogenization.

144. Stansbery, E. G. (JSC); H. R. Henderson; and D. J. Maglieri (EE): Sonic Boom Measurements From Very High Altitude and Mach Numbers on Space Shuttle Orbiter Reentry. Presented at the 118th Meeting of the Acoustical Society of America, November 27 - December 1, 1989, St. Louis, Missouri.

STS-Orbiter reentry sonic boom measurements are presented with partic-
ular emphasis on those acquired at very high altitude and Mach numbers.
Included are the Orbiter physical characteristics and reentry parameters along
with a discussion of the nature of its sonic-boom characteristics as compared to
previous experience with aircraft. The applicability of existing sonic-boom theory,
used for aircraft, to the STS-Orbiter is shown. Previous STS reentry boom
measurements, along with recently acquired measurements from the STS-26 and
STS-27 reentry, are presented and discussed. The results indicate that there are
no significant differences in sonic-boom signature characteristics from STS-
Orbiter and other aircraft. N-wave type signatures are observed on STS-Orbiter
up to Mach 23 and altitude of 250,000 feet having an overpressure of about 0.1
psf and a period of about 3.0 seconds. It is also shown that Orbiter reentry
maneuvering conditions do not produce focus booms. Although STS-Orbiter
signatures are predictable up to Mach 6 and an altitude of 130,000 feet, sonic-
boom theory improvements are required for Mach numbers greater than 6.0.

145. Stansbery, E. G. ; and John F. Stanley (JSC): Sonic Boom Measurements from Very
High Altitude and Mach Numbers on STS-26 Reentry. Presented at the AIAA 27th
Aerospace Science Meeting, January 9-12, 1989, Reno, Nevada.
Data from the Space Shuttle Sonic Boom Measurement Program recorded
during the descent and landing of STS-26 on the morning of October 3, 1988,
along with model predictions are presented. The intensity and shape of the
pressure signature that reaches the ground is the result of three groups of
parameters: (1) vehicle parameters, including the Space Shuttle shape, lift, and
drag; (2) flight path parameters, including altitude, speed, angle of attack, roll
angle, flight-path curvature, and accelerations; and (3) atmospheric parameters
such as air turbulence, winds, and temperature variations.

146. Takeda, H.; M. Miyamoto: H. Mori; S. Wentworth; and David McKay (JSC):
Comparison of Y86032-Type Lunar Meteorites to Feldspathic Fragmental Breccia
67016. Proceedings of the 20th Lunar and Planetary Science Conference, March
13-17, 1989, Houston, Texas.

147. Thomas, K.; W. Klock; and David McKay (JSC): Compositional Comparison of
IDP Glasses and UOC Chondrule Glasses. Presented at the 52nd Annual Meeting
of the Meteoritical Society, July 31 - August 4, 1989, Vienna, Austria.

148. Warren, J. L. (LESC); Herbert A. Zook (JSC); J. H. Allton (LESC); U. S. Clanton
(U. S. Department of Energy); C. B. Dardano; J. A. Holder; R. R. Marlow (LESC);
R. A. Schultz (GSFC); L. A. Watts; and S. J. Wentworth (LESC): The Detection
and Observation of Meteoroid and Space Debris Impact Features on the Solar
Max Satellite. Proceedings of the 19th Lunar and Planetary Science Conference,
pp. 641-657, 1989.
The Solar Maximum spacecraft had spent 4.15 years in space before it
was captured for repair on board Challenger, the 11th Space Shuttle flight. This
long duration, combined with the approximately 3 m2 of surface area exposed to
space on the recovered parts, meant that valuable new data about impacts by
meteoroids and space debris could be obtained. We optically examined the
spacecraft parts for the presence of impact-generated features. Of 82 hollow
double-walled aluminum thermal control louvers (totaling about 1 m2), 44
contained a total of 65 holes through the first wall, and these were further
searched for impact craters larger than 40 μm in diameter. The outer surface of
22 different multilayer thermal blankets, totaling 1.84 m2 in area, were also
scanned to the 40 μm threshold. A total of 1,908 impact sites were found: 65

holes and 611 craters in the louvers, and 427 holes and 805 craters in the first layer of the thermal blankets. These impact features are curated at the NASA JSC, and most are still available for further work.

149. Wentworth, Susan J. (LESC); and J.L. Gooding (JSC): Calcium Carbonate and Silicate 'Rust' in the Nakhla Meteorite. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 1193-1194, 1989. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.
  We have successfully used scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS) to discover secondary minerals of aqueous origin in shergottite and nakhlite meteorites. Our goal is to identify secondary minerals of preterrestrial origin as an approach to understanding aqueous geochemistry on the parent planet of the shergottite, nakhite, and chassignite (SNC) meteorites. Recent SEM/EDS work has shown that Nakhla contains common chlorides and traces of Casulfate, Mg-sulfate, and Ca-carbonate minerals. Chlorides and sulfates are found in both exterior and interior samples, while calcium carbonate has been found only in interior samples. We report here further evidence that at least the Ca-carbonate has a preterrestrial origin and that it is associated with the iddingsite-like material first reported by Bunch and Reid.

150. Wentworth, S.; D. Lindstrom; M. Zolensky; M. Lindstrom; David McKay (JSC): INAA of Glass Spheres from Ancient Apollo 16 Regolith Breccias. *Proceedings of the 20th Lunar and Planetary Science Conference*, pp. 1195-1196, 1989.

151. Wentworth, S.; David McKay; and H. Takeda (JSC): Glasses in Lunar Meteorite Y82193: Comparisons to Apollo 16 Feldspathic Fragmental and Regolith Breccias. Presented at the 52nd Annual Meeting of the Meteoritical Society, July 31 - August 4, 1990, Vienna, Austria.

152. Whitehead, V.; M. Helfert; K. Lulla; C. Wood; D. Amsbury; R. Gibson; G. Gardner; M. Mullane; J. Ross; B. Shepherd; J. Bremmer (JSC); and C. Wash (U. S. Navy). Earth Observatons During Space Shuttle Flight STS-27. *Geocarto International* Vol 3, 1989.

153. Whitehead, V. S. (JSC); and Kinsell L. Coulson (UC): Remote Sensing in Polarized Light Observed from the Space Shuttle. *Geocarto International*, 1989.

154. Whitehead, V. S. (JSC);and Kinsell Coulson (UC): The Space Shuttle as a Polarization Observation Platform. Presented at the SPIE 33rd Annual Symposium on Optical and Optoelectronic Applied Science, August 6 - 11, 1989, San Diego, California.
  To date polarization observations have been acquired from four Shuttle missions. These observations, consisting of some 400 pairs of polarized images of Earth, demonstrate both the sensing and the complexity involved in doing so. Following the acquisition and preliminary analysis of the data, a workshop on Remote Sensing in Polarized Light was convened at the NASA JSC to consider follow-on options. A three-phase program was recommended by the workshop members with all phases using the Space Shuttle as the observation platform. The Shuttle has some constraints in supporting observations of the type required to obtain a better understanding of the complexities in applying polarization in remote sensing. However, it has many attributes, foremost being the human presence which provides the real time feedback required to get the most information out of any given scene. A description of these constraints and attributes will be provided along with the recommendations resulting from the

workshop and descriptions of the past and future observing procedures used from Shuttle.

155. Whitehead, V. S. and M. R. Helfert (JSC): Earth Observations During Space Shuttle Flight STS-27: A High-Latitude Space Shuttle Earth Observation Opportunity. *Geocarto International*, Vol. 4, No. 3, pp. 63-76.

156. Yang, S. Vincent; Jerry Wagstaff (LESC); and Gordon McKay (JSC): A Case Study of Temperature-Related Peak Shift in WDS Microprobe Analysis. *Microbeam Analysis*, pp. 247-248, 1989. Presented at the 1989 MAS Conference, July 16-21, 1989, Ashville, North Carolina.

Minor changes in room temperature can cause significant peak drift during quantitative electron microprobe analysis. Some quantitative data acquired by a CAMECA MBX electron microprobe are reported in this study. A spectrometer verification (insuring that one element is aligned with an absolute reference position on each spectrometer) before each analysis helped correct the peak-drift problem.

A CAMECA MBX electron microprobe at NASA JSC was programmed to perform 200 analyses of a Kaersutite standard using three wavelength dispersive x-ray spectrometers. All data discussed in this report were acquired using the CAMECA MBX fully automated scanning electron microprobe at NASA/JSC.

157. Zolensky, Michael (JSC): Yamato-86720: A CI Chondrite Intermediate Between Types 1 and 2. Presented at the 14th Symposium of Antarctic Meteorites, National Institute of Polar Research, June 6-8, 1989, Tokyo, Japan.

Yamato 86720 (Y-86720) is a CI chondrite (by oxygen isotopic composition which is mineralogically and petrologically unlike previously described CI chondrites, but with similarities to Y-82162 and Belgica-7904 (B-7904). We report here results of a characterization of Y-86720 by petrographic and electron beam techniques, and then attempt to place this unique meteorite within petrologic context with the other CI chondrites.

158. Zolensky, Michael E. (JSC); D. W. Mittlefehldt (LESC); M. E. Lipschutz; X. Xiao (PU); R. N. Clayton; T. K. Mayeda (UC); and R. A. Barrett (LESC): The Composition of EET 83334: A Progress Report. Presented at the 52nd Annual Meteoritical Society Meeting, July 31 - August 4, 1989, Vienna, Austria.

We report here preliminary results from a consortium study of the bulk mineralogical, trace element, and oxygen isotopic composition of EET 83334. The data are used to place this meteorite within proper petrological context. As previously revealed, EET 83334 contains abundant rounded to irregularly shaped rimmed aggregates (<1 mm) of coarse- to fine-grained Fe-Mg phyllosilicates and, sometimes, Ca-carbonates, dispersed within a matrix of Fe-Mg phyllosilicates, magnetite, Ca-carbonates, pyrrhotite, and pentlandite. Rare grains of magnetite-rimmed kamacite, chromite, and Ca-phosphate are also present. The bulk Fe-Si-Mg-S composition of the matrix and aggregate rim material of EET 83334 is similar only to that for previously analyzed CM matrices. The oxygen isotopic composition of a whole rock sample of EET 83334 is $\delta^{18}O = +5.90\%°$ and $\delta^{17}O = +0.79\%°$, relative to SMOW, and falls along the CM matrix line. The results of analyses for major and minor elements by INAA and RNAA are presented in a CI-normalized plot.

159. Zolensky, Michael E. (JSC); and R. A. Barrett (LESC): CI1, CI2, and CM2 Clasts in the Bholghati Howardite and the AL Rais Chondrite. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

The presence in meteorites of clasts of greatly differing classes or types from the host are of great interest to meteoriticists and dynamicists because they indicate that representatives of these different materials were at one time in orbital proximity. This report is the first description of Cl1 and CM2 clasts in the Bolghati Howardite, and a probable Cl2 clast in the A1 Rais chondrite. All reported analyses were performed by quantitative SEM-EDX techniques developed in our laboratory.

160. Zolensky, Michael E. (JSC); and Ruth A. Barrett (LESC): The Chondritic Source of Silicate Ablation Spheres: A Reappraisal. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

We have performed chemical analyses of the fusion crusts of 16 C, H, L and LL chondrites, in order to determine their relationship to silicate ablation spheres encountered in Earth's atmosphere, hydrosphere and lithosphere. On the basis of major element compositions, we conclude that the bulk of observed silicate ablation spheres could have been produced from C and H chondrites. A smaller, but still significant proportion of observed ablation spheres could also have been produced from L and LL chondrites. We therefore suggest that the bulk of observed silicate spheres could have resulted from the atmospheric ablation of chondrites in the proportions provided by modern fall observations. It is therefore not necessary for a significant fraction of silicate ablation spheres to have been provided by friable material which does not survive atmospheric entry to produce meteorites, as has been previously suggested. In addition, since fusion crust is so similar between C, H, L and LL chondrites, it will generally be impossible to distinguish the precursor chondrite group for any particular silicate ablation sphere on the basis of only major element composition.

161. Zolensky, Michael E. (JSC): Interplanetary Dust Particles Recovered From Antarctic Ice. Workshop on Meteorite Stranding Surface, 1989.

The discovery of large quantities of meteorites in blue ice regions of Antarctica, and the resultant explosive development of meteorite studies have also sparked interest into the recovery and study of interplanetary dust particles (IDPs) from the ice. There are several reasons for this development. Modern laboratory studies of IDPs, as permitted by advances in microanalytical techniques, began to mature just as the first large concentrations of meteorites were discovered in Antarctica. Just as the ice prevents certain types of terrestrial contamination and alteration from harming meteorites, so the IDPs are also preserved. In addition, the steady stream of meteoriticists visiting the Antarctic to collect meteorites inevitably included some whose cosmopolitan interests included the study of IDPs.

162. Zolensky, Michael E.; J. L. Gooding (JSC); and R. A. Barrett (LESC): Matrix and Rim Compositions Compared for 13 Carbonaceous Chondrite Meteorites and Clasts. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

An important goal in studies of carbonaceous chondrites is to understand the genetic relationships among the various materials that occur together in those breccias. Lately our work on these meteorites has concerned the bulk composition of the matrix and adjacent dark, compact rims on chondrules and aggregates. We have previously compared bulk-elemental compositions of matrices and rims in each of four chondrites: Allende (CV3), Murchison, Nogoya, and Bells (CM2). We report here the results for six more chondrites: Vigarano (CV3), EET 83389 (CM2), EET 83334 (probable CM1), Orgueil (Cl1), Ivuna (Cl1), Yamato 82162 (probable Cl2). We also report the results for CM2 and Cl1 clasts in the Bholghati howardite, and a probable Cl2 clast in the A1 Rais chondrite. All

analyses were performed using quantitative SEM-EDX procedures developed in our laboratory. The number of separate analyses for each meteorite ranged from 25-43 for matrix and 32-103 for rims. The small size of the clasts permitted fewer analyses.

163. Zolensky, Michael; M. Lindstrom (JSC); D. Lindstrom (LESC); and R. Lindstrom (NBS): The Measurement of Trace Elements in Interplanetary Dust and Cometary Particles by Ultra-High Sensitivity INAA. Presented at the Workshop on Analysis of Returned Comet Samples, January 16-18, 1989, Milpetas, California.

Today the major element chemistry of interplanetary dust particles (IDPs) is routinely determined in many laboratories. These and mineralogical studies have revealed the presence of at least two major types of IDPs: chondritic and refractory. Chemical and mineralogical databases for IDPs have expanded to the point where workers are beginning to suggest possible parent bodies for some samples, and also outline possible thermal-pressure-chemical histories. This work generally involves analogies to meteorites. However, these comparisons remain at a primitive state partly due to the lack of trace element information from IDPs.

164. Zolensky, Michael E. (JSC); and Gordon Wells (LPI): A New and Higher Estimate of the Global Frequency of Meteorite Falls. *Workshop on Meteorite Stranding Surfaces*, 1989.

Before we can properly evaluate the stranding rate of meteorites in Antarctica, we must firmly establish the global rate of meteorite falls. Previous estimates of this important value have relied upon (1) the recovery of meteorite falls in densely populated regions, (2) the worldwide recovery of meteorite falls, or (3) automatic camera networks set to photograph fireballs. Meteorite fall rates are shown as a plot of log N vs. log M, where N is the number of falls per year in 106 km2 with mass exceeding M grams. In this figure "MORP" is the Canadian Meteorite Observation and Recovery Program. The estimated meteorite fall rates shown are observed to differ by an order of magnitude.

165. Zolensky, Michael (JSC); R. A. Barrett (LESC); and M. Prinz (AMNH): Petrography, Mineralogy and Matrix Composition of Yamato-82162, a New C12 Chondrite. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

Yamato-82162, a newly recognized CI chondrite (as determined by oxygen isotopes), is now the subject of a consortium effort organized by Prof. Y. Ikeda. We have analyzed the major minerals in two thin sections using quantitative SEM-EDX techniques and TEM-EDX procedures on ultramicrotomed samples. In this presentation, results are compared to those of two similar studies.

166. Zolensky, Michael; S. L. Koontz; F. Horz (JSC); F. Cardenas; R. A. Barrett; W. Davidson; G. Haynes; and W. Carswell (LESC): The Utility of Silica Aerogel as a Cosmic Dust Capture Medium on the Space Station. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

To fulfill the dream of collecting interplanetary dust particles (Cosmic dust, IDPs), and perhaps interstellar dust particles, with their velocity and trajectory information intact, it is necessary to operate above the atmosphere (as much as is possible). This goal will be achievable using the Space Station Freedom as a permanent base. An integral part of the Space Station Cosmic Dust Collection Facility will be the particle deceleration/collection media. These materials must decelerate incoming particles with the minimum loss of the chemical, isotopic, and (although not generally) structural character.

167. Zook, Herbert A. (JSC); Burton Cour-Palais (MDSSC); and J. Allton (LESC): On the Meteoroid Flux Striking the Solar Max Satelite. Presented at the 20th Lunar and Planetary Science Conference, March 13-17, 1989, Houston, Texas.

1. Bierschwale, John B.; Carlos E. Sampaio; Randy Smith; and Mark A. Stuart (LESC): Speech Versus Manual Control of Camera Functions During a Telerobotic Task. Presented at the 33rd Annual Conference of the Human Factors Society, October 16-20, 1989, Denver, Colorado.

   Voice input for control of camera functions was investigated in this study. Objectives were to (1) optimize the vocabulary used in a voice input system from a Human Factors perspective, (2) assess the feasibility of a voice-commanded camera control system, and (3) identify factors that differ between voice and manual control of camera functions. Each of eight subjects participated in a remote manipulation task that required extensive camera-aided viewing. Each subject was exposed to two conditions, voice and manual input, with a counter-balanced administration order. After testing, participants completed question-naires regarding mental and physical workload, strategies used, and preferences between the two modes of input. Task completion times and errors were also recorded. Voice input was found to be significantly slower than manual input for this task. However, in terms of accuracy and subject preference, there was no difference between modalities. Critical problems encountered with voice input were overshooting the desired position, and starting and stopping movements. This report contributes to a better understanding of the issues that will affect the design of an efficient human/telerobot interface.

2. Gillan, Douglas J. (LESC); Robert Lewis (RICE); and Marianne Rudisill (JSC): Models of User Interactions with Graphical Interfaces: I. Statistical Graphs. Presented at the 1989 Computer Human Interaction Conference, April 30-May 4, 1989, Austin, Texas.

   Three models of human interactions with computer-displayed statistical graphics were developed and tested in an experiment which examined users' speed and accuracy with identification and comparison questions with 17 graph types. The results indicated that response time and accuracy were influenced by the perceptual and informational complexity of the graph as well as the relation between the figure and axes, the physical elements of the graph (e.g., points, lines, and areas), the data-ink ratio, and data density. The discussion focussed on the development of a single integrated model of interactions with graphics.

3. Gillan, Douglas J. (LESC); Robert Lewis (Rice); and Marianne Rudisill (JSC): Process and Representation in Graphical Displays. Presented at the Space Opera-tions, Automation and Robotics Conference, July 27, 1989, Houston, Texas.

   This paper addresses two questions: (1) What is the cognitive representation of information from a data graph, and (2) What processing strategies do people apply to answer questions about data graphs? Research on representation has examined both the features present in a graphic display and the mental represen-tation of the graphic. The key features centered around the types and complexity of the physical components of a graph, the relation between the figure and its axes, and the amount of information in the graph. Physical and informational aspects of a graph are also important in the mental representation of the graph, with the research suggesting that the physical (or perceptual) features over-shadow the information to a large degree.

   Processing strategies also involve a perceptual-informational distinction. Research on how people process information from a graph to answer simple questions (e.g., determining the value of a variable, comparing several variables, and determining the mean of a set of variables) indicates that people switch between two strategies: (1) an arithmetic, look-up strategy in which they use a graph much like a table, looking up values and performing arithmetic calculations, and (2) a perceptual strategy in which they use the spatial characteristic of the

graph to make comparisons and estimations.  The user's choice of strategies optimizes the speed-accuracy trade-off.

4.   Goldsberry, B. S.; B. O. Lippert; and Sandra McKee (LESC); J. L. Lewis; and Frances Mount (JSC):  Using Computer Graphics to Design Space Station Freedom Viewing.  Presented at the 40th Congress of the International Astronautical Federation, October 7-14, 1989, Malaga, Spain.

An important aspect of Space Station Freedom planning at NASA is the placement of the viewing windows and cameras for optimal crewperson use during assembly and operation of the Space Station Freedom.

To evaluate the placement options, a three-dimensional graphics program called PLAID which was developed at JSC is being used.  The PLAID program determines the extent to which the viewing requirements for assembly and operation of the Space Station Freedom are being fulfilled under a variety of window and camera placement options in several modules.  These modules include the Habitation and Laboratory modules which are being built in the United States, the Japanese Experiment Module proposed by the National Aeronautics and Space Development Agency (NASDA), and the Columbus Module under development by the European Space Agency (ESA).

5.   Holden, Kritina; Susan Adam; Douglas J. Gillan (LESC); and Marianne Rudisill (JSC):  A Descriptive Model of Text Selection Performance with a Mouse. Presented at the 1989 Computer Human Interaction Conference, April 30-May 4, 1989, Austin, Texas.

Development of performance models of human-computer interactions requires an understanding of the component actions involved in using input control devices.  These models would serve as (1) prediction tools for new devices, and (2) a baseline for performance data collected in alternative environments, e.g., the space environment.  Subjects used a mouse to perform a text selection task, in which target selection was accomplished by (1) moving the cursor from a starting point to the target, and (2) "dragging" the cursor across the target while holding down the mouse button.  Target definition, size, screen location, and distance from the starting point were manipulated in an attempt to simulate a real-world editing task.  Selection responses were categorized as one of ten response types reflecting various deviations in selection performance.  Research on the use of computer control devices in both low gravity and microgravity indicates that the time to make a controlled movement is a function of the movement, distance, and the accuracy with which the movement must be made.

6.   Jensen, Dean G. (JSC); Susan C. Adam; and James H. Stramler (LESC):  Telepresence and Space Station Freedom Workstation Operations.  Presented at the 3rd Annual Space Operations, Automation, and Robotics Workshop (SOAR '89), July 25-27, 1989, Houston, Texas.

The Space Station Freedom workstation system is a distributed network of computer based workstations that provide the man-machine interfaces for control of space station systems.  This includes control of external manipulator, robotic, and free flyer devices by crewmembers in the Space Station's pressurized shirt-sleeve environment.  These remotely controlled devices help minimize the requirement for costly crew EVA time for such tasks as station assembly and payload support.  Direct window views may be used for controlling some of the systems, but many activities will be remote or require levels of detail not possible by direct observation.  Since controlling remote devices becomes more difficult when direct views are inadequate or unavailable, many performance enhancing techniques have been considered for representing information about remote

activities to the operator. This paper describes the telepresence techniques under consideration to support operations and training.

7.  Kidd, John (JSC): Weightless Environment Training Facility Diving Safety Program. Presented at the 1989 National Water Safety Congress, April 24-26, 1989, Clearwater, Florida.

    The weightless environment training facility (WETF) at JSC provides controlled neutral buoyancy in water to simulate the condition of zero gravity. The WETF is an essential tool in the design, testing, and development of spacecraft and crew equipment; in the evaluation of body restraints and handholds; in the development of crew procedures; and in the determination of extravehicular capabilities and workload limits. For the astronaut, it provides important preflight training in becoming familiar with planned crew activities and with the dynamics of body motion under weightless conditions.

    The WETF Diving Safety Program is divided into two parts which consist of diving requirements and test procedures. The diving requirements an individual must meet vary depending on whether the individual is a non-assigned diver, safety diver or a suited subject. The basic requirement an individual must have to dive in the WETF is a certificate showing that they have completed an approved scuba course and verification of an Air Force class III physical or equivalent and pass a written and scuba proficiency test. This checkout is performed by a NASA WETF training officer.

    Safety is the primary consideration during all WETF operations. All areas are designed and activities controlled to ensure maximum safety.

8.  Kwon, Hyuck M. (LESC): Imperfect Jamming State Information Generators for Coded FH/MFSK Under Partial-Band Noise Jamming. *IEEE Military Communications Conference Record*, Vol. 1, pp. 1.1.1 - 1.1.5, October 15-18, 1989, Boston, Massachusetts.

    Three imperfect jamming state information (JSI) generators for coded, memoryless, noncoherent, frequency-hopped MFSK (FJ/MFSK) systems under partial-band noise jamming (PBNJ) are introduced. These are then compared in the bit-energy-to-jamming-noise power spectral density ratio (Eb/NJ) required to achieve cutoff rates.

9.  Kwon, Hyuck M.; and Pil Joong Lee (LESC): Performance of Viterbi's Ratio Threshold Receiver Against Mixed Jamming. *IEEE Military Communications Conference Record*, Vol. 1, pp. 1.6.1 - 1.6.5, October 15-18, 1989, Boston, Massachusetts.

    A performance analysis is presented for a coded FH/MFSK system under a combination of tone jamming and full-band noise-jamming (FBNJ). A maximum likelihood metric former with Viterbi's ratio threshold techniques is assumed to support the decoder in the system. It is shown that the most efficient FBNJ portion of the total jamming power depends on M and the symbol energy-to-jamming power density ratio.

10. McKee, Sandra D. (LESC); and Frances E. Mount (JSC): The Use of PLAID in the Space Station Freedom Viewing Analysis. Presented at the 3rd Annual Space Operation, Automation, and Robotics Workshop (SOAR '89), July 25-27, 1989, Houston, Texas.

    The Space Station Freedom Viewing Analysis is being performed under the auspices of the Man-Systems Working Group. This analysis involves identifying and evaluating window and camera locations in order to determine the extent to which direct and indirect viewing requirements are fulfilled, and satisfactory

viewing is available for Space Station Freedom assembly and operations. The viewing analysis employs PLAID, a three-dimensional graphics program developed at JSC, to simulate the assembly of the Freedom as well as to examine operations on the Station as it evolves. PLAID is used as a tool to analyze general out-of-the-window viewing conditions for all Space Station components. Additionally, PLAID provides the ability to integrate an anthropometrically modeled person with the Station's interior architecture. Views generated on PLAID will be displayed and accompanied by the rationale of their usefulness in this analysis.

11. Mount, Frances E. (JSC): Crew Quarters for Space Station. Presented at the Human Factors Society Meeting, October 16-20, 1989, Denver, Colorado.

The only long-term U.S. manned space mission completed has been Skylab, which has similarities as well as differences to the proposed Space Station. With the exception of Skylab missions, there has been a dearth of experience on which to base the design of the Space Station Crew Quarters. Shuttle missions commonly do not have sleep compartments, only 'sleeping arrangements'. There are provisions made for each crewmember to have a sleep restraint and a sleep liner, which is attached to a bulkhead or a locker. When the Shuttle flights began to have more than one working shift, crew quarters became necessary due to noise and other disturbances caused by crew task-related activities. Shuttle missions that have planned work shifts have incorporated sleep compartments. To assist in gaining more information and insight for the design of the crew quarters for the Space Station a survey was given to current crewmembers with flight experience. The results from this survey were compiled and integrated with information from the literature covering space experience, privacy, and human factors issues.

12. Probe, John D. (LESC): Quantitative Assessment of Human Motion Using Video Motion Analysis. *Proceedings of SOAR '89*, July 25-27, 1989.

A rapidly growing field of biomechanical study is the measurement and analysis of human movement. Previously, video has been commonly used to qualitatively analyze motion. However, recent advances in video technology now permit video to compete with other photogrammetric methods as an accurate, convenient, and cost effective method of obtaining quantitative data.

The Ariel Performance Analysis System is one such video based motion analysis system utilized by the Anthropometric and Biomechanics Laboratory at NASA JSC. Developed by Dr. Gideon Ariel, the system integrates state-of-the-art computer and video processing hardware to support full three-dimensional kinematic analysis.

The Ariel system has proven to be an effective means of quantifying and documenting human motion. Consequently, the data can be more completely and accurately compared to mathematical models to meet the ultimate goal of enhancing astronaut performance.

13. Rudisill, Marianne (JSC); and Douglas J. Gillan (LESC): Human-Computer Interaction Laboratory, NASA, Johnson Space Center. Presented at the Computer Human Interaction Conference, April 30-May 4, 1989, Austin, Texas.

The Human-Computer Interaction Laboratory (HCIL) was established in 1984 at the NASA JSC in Houston, Texas, to: (1) perform applied research examining user interaction with complex computer systems; (2) apply the results of this research to the design of spacecraft computer-based workstations and HCIs; and (3) serve as a resource in the discipline of human-computer interaction to support ongoing programs. The HCIL is one of five R&D laboratories within the Crew Interface Analysis Section of the Man-Systems Division in the Space & Life Sciences Directorate.

14. Rudisill, Marianne (JSC): Human Factors Design in Special-Purpose Workstations for Space Station. Presented at the 32nd Annual Meeting of Human Factors Society , October 24-28, 1989, Anaheim, California.

    The Space Station Program will provide information systems to several users involved in such diverse tasks as commanding and monitoring the Station's systems, conducting space- and ground-based science and payload operations, and developing station software. The Human-Computer Interaction Laboratory (HCIL) in the Man-Systems Division at JSC was tasked with developing a Human-Computer Interface Guide early in program design. This document, primarily for use by space station software applications developers, is intended to provide a general model and specific guidance for the design of a standard, station-wide HCI. The development of the guide and supporting prototypes will be described.

15. Shepherd, C. K. (LESC): Combining a Speech Recognizer and a Bench-Model Helmet-Mounted Display to Perform an Extravehicular Construction Task. Presented at the 33rd Annual Meeting of the Human Factors Society, October 16-20, 1989, Denver, Colorado.

    Fourteen subjects constructed an electronic circuit using instructions displayed on a helmet-mounted display (HMD). Speech commands were used to page through the instruction file. The human-machine interface of the HMD-based information system was examined. All of the subjects successfully completed the circuit. Ten reported that their eyes did not feel more fatigued than when they had begun. The interface with the voice recognizer was examined. Subjects had an 88% overall accuracy. The most common type of interface error that occurred was insertion (when a command was recognized but was not spoken). The subjects averaged one insertion error for every $4\frac{1}{2}$ seconds of conversational speech. An analysis of the errors revealed that confidence scores of insertion errors followed a different pattern from those of correct recognitions. However, amplitude levels of correct recognitions and those of insertion errors formed the same normal distribution curve. Several possible solutions to reduce the incidence of these errors are presented.

16. Shepherd, C. K. (LESC): HMD for the MMU - Video Presentation. Presented at the Human Factors Society 33rd Annual Meeting, October 17, 1989, Denver, Colorado.

    A bench-model of the Space Station extravehicular Mobility Unit (EMU) Helmet-Mounted Display (HMD) was attached to a Manned Maneuvering Unit (MMU) simulator to examine how an HMD/MMU Information Display could enhance the performance of an MMU pilot. The information display was designed with input from NASA-JSC Crew and Thermal Systems Division, Training Division, the Human-Computer Interaction Laboratory, and the Astronaut Office. Performance was examined by comparing the time and propellant used to complete a simulation scenario when the HMD was on and when it was off, and through questionnaires. Although objective data was inconclusive, subjective data indicated that several aspects of the display were very useful. Comments from Captain Bruce McCandless of the Astronaut Office are featured in the video.

17. Smith, K. U. (UW); T. J. Smith (USBM); S. T. Smith (HU); R. L. Smith; and M. A. Stuart (LESC): Interactive Performance In Space — The Role of Perturbed Sensory Feedback. Presented at the 1989 International Conference of Human-Computer Interaction, September 18-22, 1989, Boston, Massachusetts.

    NASA is currently working on Space Station Freedom which will be a permanently manned orbiting space laboratory to be assembled in the mid 1990s. Teleoperated robots (telerobots), devices with mechanical arms for grasping and

manipulation, are envisioned to be integral parts of the Space Station. These devices which have some of the same capabilities as an astronaut in space suit, will be used for station assembly, maintenance, and satellite repair. The ability of a human to quickly and accurately manipulate objects in space using these tele-robotic devices, will result in increased Space Station productivity, safety, and flexibility while lowering the overall cost of operations. The objective of the work described in this paper is to develop the idea of perturbed sensory feedback as a decisive concept in the ability to do useful work with man-in-the-loop space tele-robotics. Perturbed sensory feedback is defined here as a disturbance or recep-tor stimulation during behavioral activity. The crucial problem is that sensory information is subject to perturbations that could radically deteriorate its use-fulness to the human operator. The result of sensory information feedback per-turbations varies from minor annoyances which cause an increase in the astro-naut operator's mental workload to accommodate the perturbation, to total disorientation of the operator, thus forcing system performance to zero. Each of these modalities of feedback and the type and effect of perturbations will be discussed in this paper.

18. Smith, Randy L.; and M. A. Stuart (LESC): The Effects of Spatially Displaced Visual Feedback on Remote Manipulator Performance. Presented at the Human Factors Society 33rd Annual Meeting, October 16-20, 1989, Denver, Colorado.
    The objective of this investigation was to quantify whether different types of spatially displaced visual feedback adversely affect operation of a camera-viewed remote manipulation task. Operators performed a remote manipulation task while exposed to the following different viewing conditions: direct view of the work site (baseline condition); "normal" (zero-degree displacement) camera view; reversed (180-degree displacement) camera view; inverted/reversed camera view; and inverted camera view. The task completion performance times were statistically analyzed with a repeated measures analysis of variance. It was determined that there was statistical significance ($p = 0.0024$) due to the main effect of the view-ing conditions. A Newman-Keuls pairwise comparison test was then administered to the data and it was revealed that the time for the inverted camera view condi-tion was significantly ($p$ 0.05) worse than all of the other viewing condition times. It was also determined that the time for the reverse viewing condition was signifi-cantly worse than the normal viewing condition time. A final result was that the normal viewing condition was significantly slower than the direct viewing condition. An important finding in this evaluation is concerned with the extent to which results from previously performed direct manipulation studies can be generalized to remote manipulation studies. This evaluation has demonstrated that generaliza-tions to remote manipulation applications based upon the results of direct manipu-lation studies are quite useful, but they should be made cautiously.

19. Smith, R. L.; M. A. Stuart; and D. J. Gillan (LESC): Telepresence for Space: The State of the Concept. *SOAR '89 Conference Proceedings*, CP-3059, July 1989. Presented at the 3rd Annual Space Operation, Automation, and Robotics Workshop (SOAR) Conference, July 25-27, 1989, Houston, Texas.
    The purpose of this paper is to examine the concept of telepresence critically. To accomplish this goal, the assumptions that underlie telepresence and its applications were examined and the issues raised by that examination discussed. Also, these assumptions and issues were used as a means of shifting the focus in telepresence from development to user-based research. The most basic assumption of telepresence is that the information being provided to the human must be displayed in a natural fashion, i.e., the information should be displayed to the same human sensory modalities and in the same fashion, as if the person

were actually at the remote site. Another assumption of functional telepresence is that the distant machine under the operator's control must resemble a human in dexterity.

20. Woolford, Barbara J. (JSC): Plaid as a Maintainability Tool. Presented at the AIAA/ NASA Maintainability of Aerospace Systems Conference, July 1989, Anaheim, California.

PLAID (not an acronym) is a computerized man-modeling software package with a number of capabilities. It can draw high fidelity three-dimensional pictures of spacecraft interiors and exteriors, equipment, and personnel. These images can be presented as single hard copies, or can be used to generate a videotape illustrating motion through the spacecraft. These capabilities have been utilized heavily in planning for crew safety and for crew operations, including maintenance.

1. Kusik, Edwin G. (JSC): Empowerment of Knowledge Workers Through the Synergism of Converging Information Technologies. Presented at the AIAA 14th Annual Technical Symposium, May 18, 1989, Houston, Texas.

2. Rockwell International Space Systems Group: *National Space Transportation System Model and Loads Analysis Configuration Management/Control*, NASA CR 185616, 1989.
     This report documents a formal configuration management/control system for the Shuttle/orbiter dynamic and quasi-static math models and forcing functions. The report also specifies standard and optional verification analyses, quasi-static load factors, and models/forcing functions to be used for loads analysis. It is intended that this report will serve as a working agreement between Rockwell International Corporation and NASA JSC. The techniques used to develop the coupled dynamic results will be approve by NASA JSC.

3. Speier, William M. (JSC): Power from the Space Shuttle. Presented at the Space Commercialization Symposium, March 5-10, 1989, Nashville, Tennessee.
     The Space Shuttle, a large, sophisticated payload carrier, has the capability to provide avionics and electrical power accommodations to a large, dedicated payload and/or to multiple, smaller payloads throughout the flight. Electrical power is one of the principal services provided to payloads by the Orbiter. The Shuttle Orbiter's electrical power distribution system (EPDS) is a multiple source system consisting of three independent fuel cell power plants which consume hydrogen and oxygen to generate electrical energy. Each of these fuel cells provide power to respective dc buses which can be cross-strapped as necessary to enhance reliability and load balance. Electrical power accommodations are available to payloads at numerous locations in the aft flight deck, middeck, and payload bay. Primary payload dc power, the Orbiter's most frequently used payload service, is available at a payload-dedicated standard interface panel (SIP) mounted adjacent to the payload on the starboard side of the Orbiter payload bay. Other dc and ac power sources can also be provided to payloads at this same interface. In the AFD, a limited amount of ac and dc electrical power can be provided. In the middeck, dc power can be provided to payloads from the middeck control panel utility outlets. Electrical power is available for payload use during all mission phases. However, when Orbiter demand is high, during descent and postlanding mission phases, payload power usage must be restricted.

1. Bhusan, B.; Bradshaw, R. L.; Kalthoff, C. H.; and Phelan, R. M. (IBM): Overview of Challengers Space Shuttle Tape-Data Recovery Study. Presented at the IEEE Intermag Symposium, Tokyo, Japan.

   Degraded magnetic tapes recovered from the challenger space shuttle, after being immersed in seawater for six weeks, could not be unwound without damaging the recording surface. The recording side cemented to the backside and during unwinding, the fragments from the recording side, mostly at tape edges transferred to the backside, and remained firmly adherent. Magnesium hydroxide was found to be substance adhering the recording surface to the backside, which is thought to have precipitated due to increased concentration of magnesium ions resulting from the corrosion of the magnesium alloy flanges of the reel assembly. In addition, we found that low-molecular weight degraded magnetic-coating binder was present on large areas of the backside of the tape. Matrix experiments showed that the presence of magnesium hydroxide was primarily responsible for the interlayer adhesion. We found that magnesium salts could be removed with a treatment of 0.5 molar nitric acid, and low-molecular weight binder could be dissolved with a methanol rinse. We devised a method to chemically treat the damaged reels. We first removed the eroded magnesium hub and placed the reel on a spring-loaded plastic ring.

2. Collazo, Fernando; Sumi Matsuura; and Elizabeth Schulte (RIC): Establishing a Standard User Interface for In-house Developed Software Tools. Presented at the Third Annual Rockwell International Software Engineering Symposium III, October 2-4, 1989, Dallas, Texas.

   The Standard User Interface (SUI) created by our department was targeted for software tools developed in-house, using Ada as the primary programming language. The interface was implemented on a local VAX cluster. The user interface, based on the concept that software tools are interactive, communicates with users by menu selection or command line inputs.

   The SUI increases productivity of: (1) the software developer through reuse of software interface services to drive the menu screen; and (2) the end user by providing a standard set of on-line functions for software tools. The user only has to learn one common interface for the software tools under the SUI.

   After developing a prototype of the defined SUI, an application was developed to drive it. The first, an elementary application, assisted the development team in creating enhancements to the SUI. The SUI has been and continues to be improved as new applications are developed for it.

3. Hoey, J.; and D. Zeilingold (JSC): A Representative Model for a Safing and Failure Detection Expert (SAFE) for the Space Shuttle. Presented at the Third Annual Rockwell International Software Engineering Symposium, October 2-4, 1989, Dallas, Texas.

   The Safing and Failure Detection Expert (SAFE) is a prototype for a malfunction detection, diagnosis, and safing system for the atmospheric revitalization subsystem (ARS) on board the orbiter. SAFE automatically takes care of all the phases of failure handling -- detection, diagnosis, testing procedures and recovery instructions. The system's knowledge was extracted from expert provided heuristics or documented procedures. The SAFE architecture allows it to correctly handle sensor failures and multiple malfunctions. Since SAFE is highly interactive, it was used as a testbed for evaluation of various advanced human-computer interface (HCI) techniques. It is expected that the use of such expert systems on board the next generation of space vehicles will increase their reliability and autonomy to levels not achievable before.

4. Mechelay, Joseph E.; and Ward, Robert J. (JSC): Flight Problem Evaluation for Space Shuttle Orbiters. Presented at the Tenth Aerospace Testing Seminar, Los Angeles, California.

The flight problems experienced with the reusable Space Shuttle Orbiter have decreased during subsequent flights of each vehicle. By comparison to first flights of previous vehicles, the problems encountered on the initial flight of each new vehicle entering the fleet decreased. This improvement in turn has reduced the turnaround time between flights significantly and thus greatly enhanced the increased Space Shuttle launch frequency. The reusable manned space vehicle concept necessitated the development of a flight problem recognition and resolution system which would enable a thorough and timely vehicle turnaround flow. Flight evaluation, testing, and repair of manned space craft to enhance reliability and to ensure mission success is a unique activity. Real-time recognition of the flight problem, prompt isolation of the cause, and timely implementation of the corrective action are the keys to maintaining an operational fleet. Examples of flight problems that have been encountered as well as the corrective actions implemented during the first 24 Space Shuttle missions are presented. The corrective actions taken to preclude problem recurrence include modifications of hardware designs, manufacturing processes, flight software, test methods, and operational procedures.

5. Nagle, Scott M; and Guy M. Sinclair (RIC): Space Shuttle Orbiter Update. Presented at the AIAA 25th Joint Propulsion Conference, July 10-12, 1989, Monterey, California.

The first flight of the National Space Transportation System (NSTS) took place with the launch of STS-1 on April 12, 1981. Between that time and the loss of STS-51L (Challenger) on January 28, 1986, a total of 24 flights were flown. As a result of these flights, 37 payloads were deployed, 9 retrieved, and 2 were repaired in orbit. A total of 327 experiments were completed and all primary mission objectives were accomplished. Because of the Challenger disaster, however, a complete review of all Space Shuttle program technical and managerial areas was undertaken. The resulting updates from this review were extensive. This paper presents an overview of the updates resulting from this review that pertain to the Space Shuttle program.

6. Saldana, Rudolph L. (JSC): Safeguarding the NSTS Spacecraft Hardware. Presented at the AIAA Society of Logistics Conference, Huntsville, Alabama.

Following the accident of the Space Shuttle Challenger, Mission 51-L, an appointed Presidential Commission investigating the accident reported their findings and recommendations which would contribute to a safe return to flight and a strengthened NASA organization. A synopsis of NASA's organization is presented , as well as a synopsis of NASA's goals and corrective actions in response to the specific hardware safeguard recommendations. The NSTS program's approach is focused on developing a comprehensive set of requirements for assuring that flight and ground systems retain their design performance, reliability, and safety. The requirements must provide: objectives and schedules consistent with NASA capabilities and resources, a constant awareness of the hardware status, and the constant presence of involved design engineers and Safety, Reliability, and Quality Assurance personnel. Finally, the requirements must delineate organizational responsibilities and reporting control requirements for the Space Shuttle Program activities.

1. Moon, Larry J. (JSC); and John H. Moore (RI): Space Shuttle Flight Software Life Cycle. Presented at the National Technical Association Symposium, April 7-8, 1989, Houston, Texas.

   This paper describes the process by which NASA designed, developed, and maintains the onboard flight software used to control the propulsion systems, the guidance, navigation and control system, the environmental control and life support system, and various other functions of the Space Shuttle. Even though the software is very mature, changes are constantly incorporated into the systems and code discrepancies must be weeded out to protect life, vehicle, and mission objectives. The discussion describes the capabilities of the current flight software system and the methodologies used to ensure an excellent standard of reliability and quality. The emphasis is on the ongoing activities of the NASA software community and the process of testing the flight software capabilities, resolving identified problems and concerns, and implementing procedures necessary for management to certify that the flight software system is ready for flight.

2. Morris, Keith E. (JSC): A Symbolic Analysis Approach as an Aid to White Box Verification Testing. Rockwell International Document STS 89-0420, Space Transportation Systems Division, Downey, California. Presented at the Third Rockwell Software Engineering Symposium (SES), October 2-4, 1989, Dallas, Texas .

   Many approaches have been used to solve the software program white box verification testing problem. The commonly accepted minimal test coverage criteria require that each program statement and control flow branch be exercised at least once during the testing process. Manually developed symbolic analysis has often been used to assist in the selection and generation of test cases to satisfy this condition. However, in Space Shuttle flight software applications, because the manual application of symbolic analysis can be extremely labor intensive and is itself error-prone, a systematic, step-by-step, mathematically based process was developed. This paper describes that systematic process and the notation employed, illustrates its application with a simple example, briefly describes some of the other benefits of symbolic analysis, and offers suggestions on its future automation.

3. O'Neill, Pat M.; and Jim Pollock (MDSSC): Analysis of Single Event Effects in Spacecraft Electronics Caused by Cosmic Radiation. Presented at the 14th Annual AIAA Technical Symposium, May 18, 1989, Houston, Texas.

   Newer microelectronic parts are smaller and require lower operating power. As a result they are more susceptible to cosmic radiation. When a heavy ion passes through a material it deposits energy and charge at a rate that depends on the square of the charge and the inverse of the square of the velocity of the ion. Therefore, an ion can penetrate the sensitive region of a microchip and deposit enough charge to change its operating characteristics. The result may be a single event upset (a bit flip) or a latchup (a low impedance path induced by a cosmic ray which can cause permanent damage due to excessive current). We have analyzed and developed techniques for determining the rate at which microchips operating in a spacecraft in Earth orbit will be affected by the cosmic radiation environment. We describe the cosmic ray environment, the physical mechanisms involved in upsets and latchups, and the testing methods used to predict the effects of cosmic rays on spacecraft electronics.

1.  Hawthorne, H.M. (SPAR):  Tribological Aspects of Ceramic Composites in Conform-
    ing Contacts. *28th Metallurgical Society Conference Proceedings*. Presented at
    the 28th Conference of the Metallurgical Society, August 20-24, 1989, Halifax,
    Canada.

    Ceramic composites sliding against either themselves or hard metals in con-
    tinuously conforming (thrust washer) contacts under high vacuum conditions
    exhibit stable, high friction coefficients with moderate wear rates. $TiB_2$ particle
    reinforced SiC, SiC whisker reinforced $A1_2O_3$ and $Si_3N_4$, and others, have coeffi-
    cients between 0.4 - 0.8, and wear rates between $10^{-4} - 10^{-2}$. As with polymer-
    based composite materials, trapped interfacial wear debris controls the behavior
    of these ceramic tri-bosystems but the frictional stability of the latter are more
    suited to some applications in this environment.

2.  Szirtes, Thomas (SPAR):  A Mathematical Model for the Determination of Dynamic
    Characteristics of Impacting Bodies.  Presented at the 23rd Aerospace Mechan-
    ism Symposium, May 3-5, 1989, Huntsville, Alabama.

    An efficient mathematical simulation model and associated algorithm were
    developed to determine the forces and relevant kinematic characteristics
    encountered during certain emergency and test conditions of the End-Effector of
    the Shuttle Remote Manipulator System - also known as the 'CANADARM'. The
    CANADARM is a 15.3 meter (603 in) long, 388.3 kg (856 lb), six jointed arm,
    designed and built by SPAR for the main purpose of placing and removing pay-
    loads to and from the cargo bay of the Shuttle Orbiter.

    This paper presented the general structure, flow diagram of the associated
    numerical algorithm, some representative results and conclusions obtained by
    employing the described method to the End Effector of the CANADARM.

1.   Robitaille, Richard A. (JSC): Shuttle Critical Function Audit Progress. Presented at
     the Local Society of Risk Analysis, January 19, 1989, Seal Beach, California.
         NASA has requested Rockwell to establish a program for Quantitative Risk
     Assessment in response to recommendation #6 of National Research Council
     Committee on Shuttle Criticality Review and Hazard Analysis Audit. The overall
     Rockwell task is to provide a Quantitative Risk Assessment (QRA) Pathfinder for
     the following Shuttle Systems:

     (1) the Orbiter Main Propulsion System,
     (2) the Shuttle System Main Engine (SSME),
     (3) the Orbiter Thrust Vector Control, and
     (4) the ET/Orbiter/SSME Pressurization System.***

***  The QRA will include an integrated dynamic fault tolerance reliability model; a
     system description diagram including system schematics and operational infor-
     mation; a top down fault tree model and failure development; a reliability data
     base to provide reliability data for model quantification; a configuration
     management system to maintain traceability; a Probabilistic Risk Assessment
     Analysis of the fault tolerance model; and development of software tools to
     support analysis and output data to users of the model.

1. Flores, B. M.; and M. H. Seiter (IBM): The Software Management and Test Support Facility for the NASA Space Shuttle Onboard Flight Software. Presented at the AIAA/NASA Symposium on the Maintainability of Aerospace Systems, July 26-27, 1989, Anaheim, California.

   The NASA Space Shuttle primary onboard software is developed in a full scale software management and test support facility. This facility provides a rich set of software management utilities and test support capabilities. A discussion of the basic design of this software management and test support facility is presented along with a review of the design lessons learned from building and maintaining it.

2. Gillespie, Horace; and Margaret Powers (IBM): Program Compliance Assurance and Status System (PCASS) Database Applications. Presented at Houston Area DB2 Exchange, August 1, 1989, Houston, Texas.

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# NASA
National Aeronautics and
Space Administration

# REPORT DOCUMENTATION PAGE

| 1. Report No. NASA TM 102173 | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|

| 4. Title and Subtitle The 1989 JSC Bibliography of Scientific and Technical Papers | 5. Report Date December 1990 |
|---|---|
| | 6. Performing Organization Code |

| 7. Author(s) Nancy Hutchins, Compiler | 8. Performing Organization Report No. S-621 |
|---|---|

| 9. Performing Organization Name and Address NASA Lyndon B. Johnson Space Center Houston, Texas 77058 | 10. Work Unit No. |
|---|---|
| | 11. Contract or Grant No. |

| 12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546 | 13. Type of Report and Period Covered Technical Memorandum |
|---|---|
| | 14. Sponsoring Agency Code |

15. Supplementary Notes
Compiled by Management Services Division
Documentation Management Branch
Lyndon B. Johnson Space Center

16. Abstract
This document is a compilation of Lyndon B. Johnson Space Center contributions to the scientific and technical literature in aerospace and life sciences made during calendar year 1989. Citations include NASA formal series reports, journal articles, conference and symposium presentations, papers published in proceedings or other collective works, and seminar and workshop results.

| 17. Key Words (Suggested by Author(s)) Bibliographies Conferences Documentation Reports | 18. Distribution Statement Unclassified - Unlimited Subject Category 82 |
|---|---|

| 19. Security Classification (of this report) Unclassified | 20. Security Classification (of this page) Unclassified | 21. No. of pages | 22. Price |
|---|---|---|---|

For sale by the National Technical Information Service, Springfield, VA 22161-2171

JSC Form 1424 (Rev. Aug 89) (Ethernet Jan 88)

*U.S.GOVERNMENT PRINTING OFFICE:1991-561-057/20087

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NHB/12/ Tech-1.6