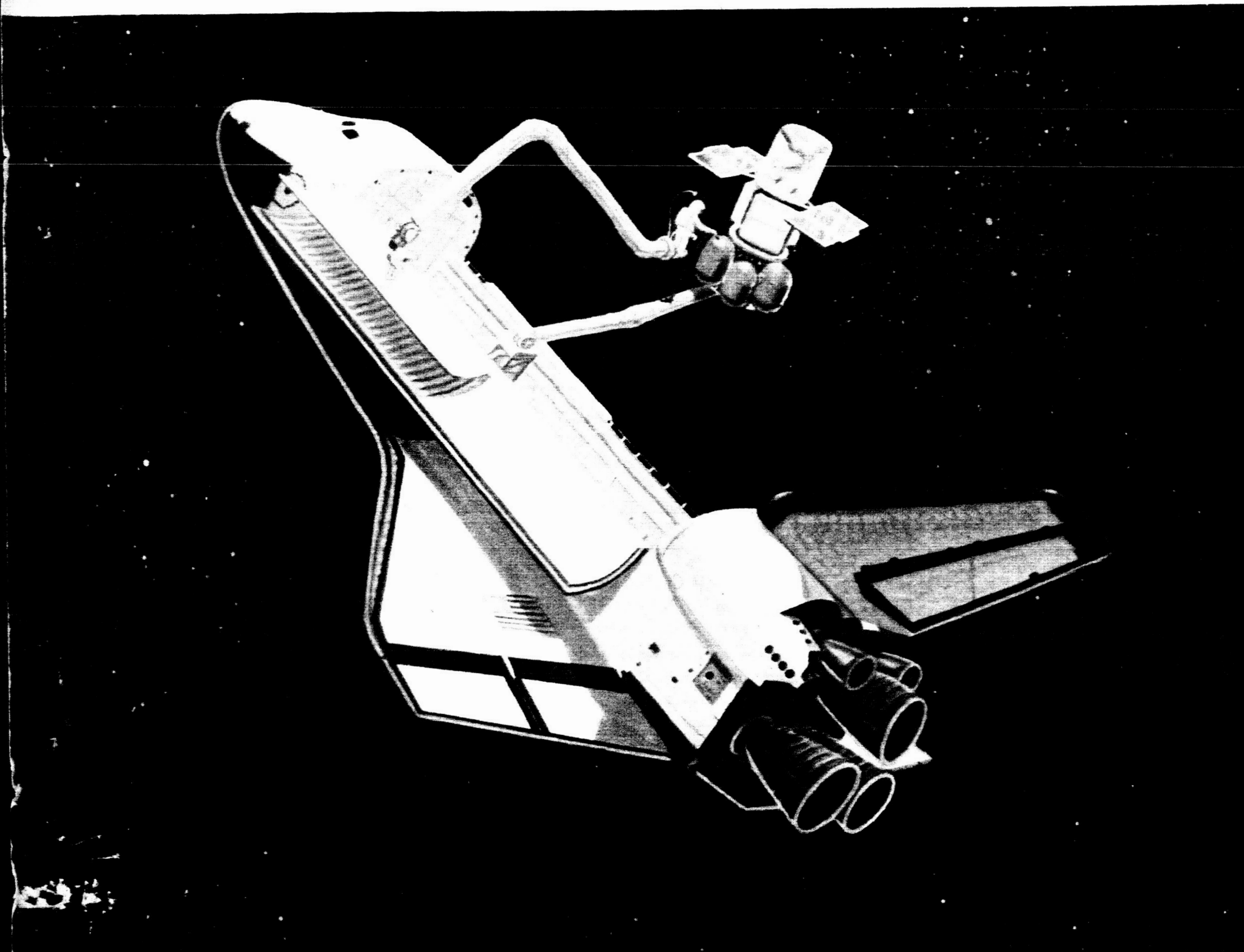
NASA Technical Memorandum 58249

Research and Technology
Annual Report 1982



NASA

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

NASA Technical Memorandum 58249

Research and Technology
Annual Report 1982

November 1982

Prepared by
Technical Planning Office
Program Planning Office
Lyndon B. Johnson Space Center
Houston, Texas

Preface

This report is prepared on an annual basis for the purposes of highlighting the fiscal year research and technology (R&T) activities. Its intent is to better inform the R&T Program Managers of significant accomplishments that promise practical and beneficial program application. The report is not inclusive of all R&T activities. This document will be updated in November of each year.

The JSC Annual R&T Report is compiled by the Technical Planning Office, Office of the Center Director. The personnel listed below have coordinated the technical inputs for their respective sections of the report. Detailed questions may be directed to them or to the technical monitors listed in the significant Task indices.

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Summary

Advanced Programs

The foremost 1980's goal of the Johnson Space Center in support of the Office of Space Flight is to complete the transition of the Space Transportation System (STS) from the test phase into routine user-oriented operation. This activity includes the development and integration of systems necessary to support the Shuttle, its companion upper stage vehicles, and any ancillary devices required to enhance orbital utility of the STS.

As shown in figure 1, the permanently manned Space Station in Earth orbit is the most important new dimension to be added to the STS system by the end of the decade. JSC has recently established a program office to work with NASA headquarters toward early initiation and development of the Space Station.

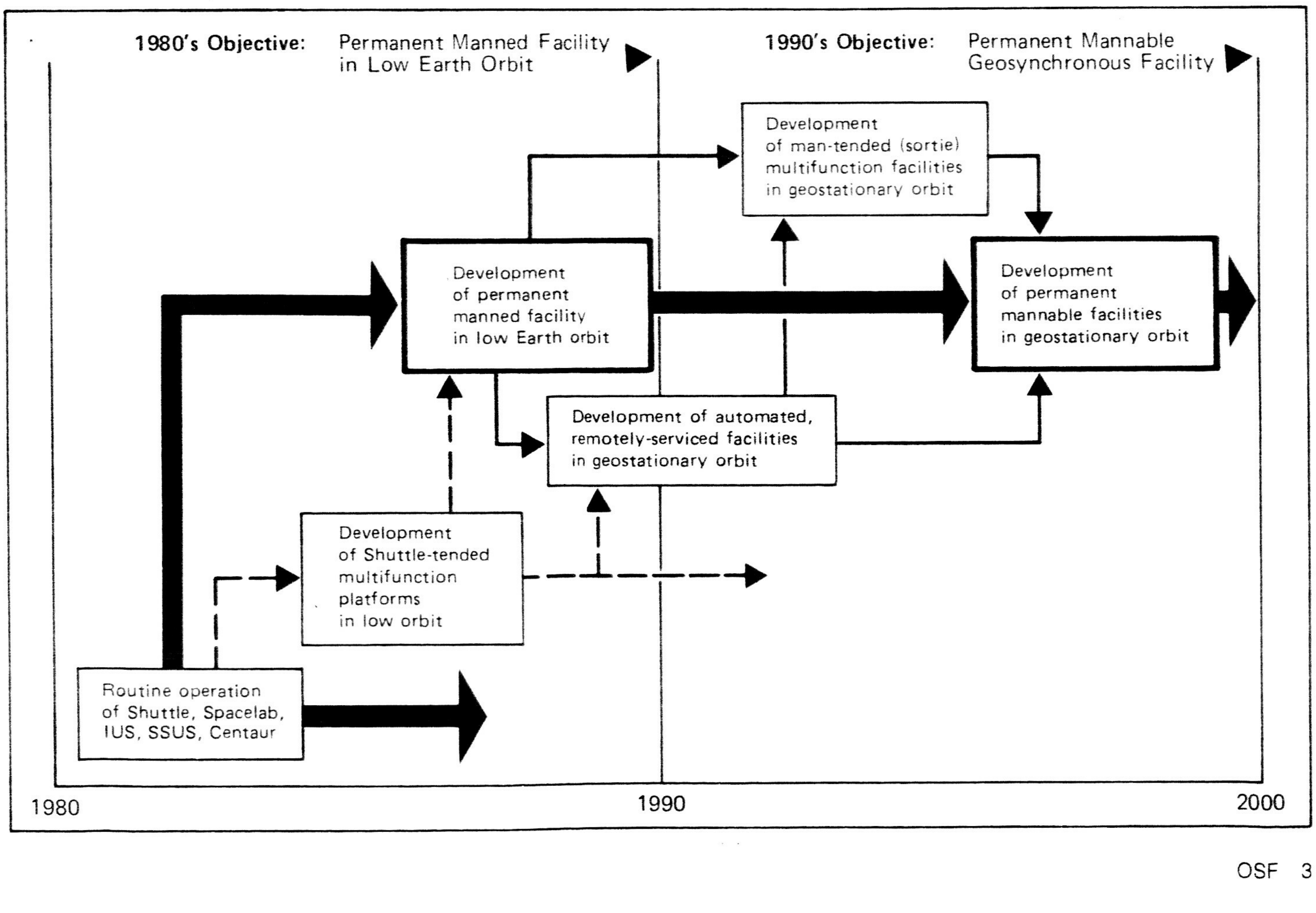
Virtually all of OSF-funded and in-house research activities at JSC continue to be directed toward the increased Shuttle utilization and/or the manned orbital Space Station.

Space Shuttle Utilization

The first operational flight of the Space Shuttle in November, 1982 opens the new era of routine in-situ satellite applications. For the first time space systems may be serviced, repaired, or returned to Earth as the need arises. JSC continues a major activity in the investigation of procedures and systems that will enhance and upgrade the utility of the STS for the performance of these tasks.

Reported in this document are research projects related to the Proximity Operations Vehicle (POV) and the Laser Advanced Rendezvous and Docking System. These projects have recently been proposed for an STS servicing demonstration. Operating together, the flight would demonstrate the capability of the POV while

Figure 1.— OSF long-range goals.



calibrating and functionally evaluating the laser docking system. Figure 2 presents a collage of potential uses for the POV.

Another utility demonstration, which has been extensively studied inhouse, involves the demonstration of refueling of satellite propulsion systems. The need for this capability was identified in the Satellite Services System Analysis Study (reported last year). The proposed demonstration involves the transfer of hydrazine propellant from a servicing system into flight type propulsion module. Both the propulsion module and servicing system would be carried to orbit and back in the Space Shuttle payload bay. Onorbit operations would include extravehicular activities to connect transfer lines, transfer of propellants, and line disconnects. The purpose of the flight test would be to demonstrate the capability to service propulsion systems of the class used on Landsat D. Figure 3 depicts an operational servicing mission.

Also reported this year is an activity aimed at increasing the utility of the astronaut through introduction of a spacesuit that will decrease the requirement for prolonged denitrogenation before extravehicular activities (EVA). The 4-psia EVA system in use today requires 3 hours of oxygen prebreathe to avoid the nitrogen-induced "bends". The zero-prebreathe system will operate at higher pressures and thus obviate the necessity for the extended denitrogenation process.

Another area of study to increase capability of the flight personnel is the Onboard Remote Terminal. This area promises to reduce training time for ground and flight crews and increase flexibility when new opportunities or changes in flight plans occur during the STS mission.

Space Station

JSC continues to vigorously support the development of a permanently manned low-Earth-orbit facility as the agency focus for the 1980's. JSC also supports the concurrent development of a space-based orbital transfer vehicle as a necessary companion element of the Space Transportation System. The Space Station is intended to provide a permanent orbital facility for servicing of satellites, space basing of

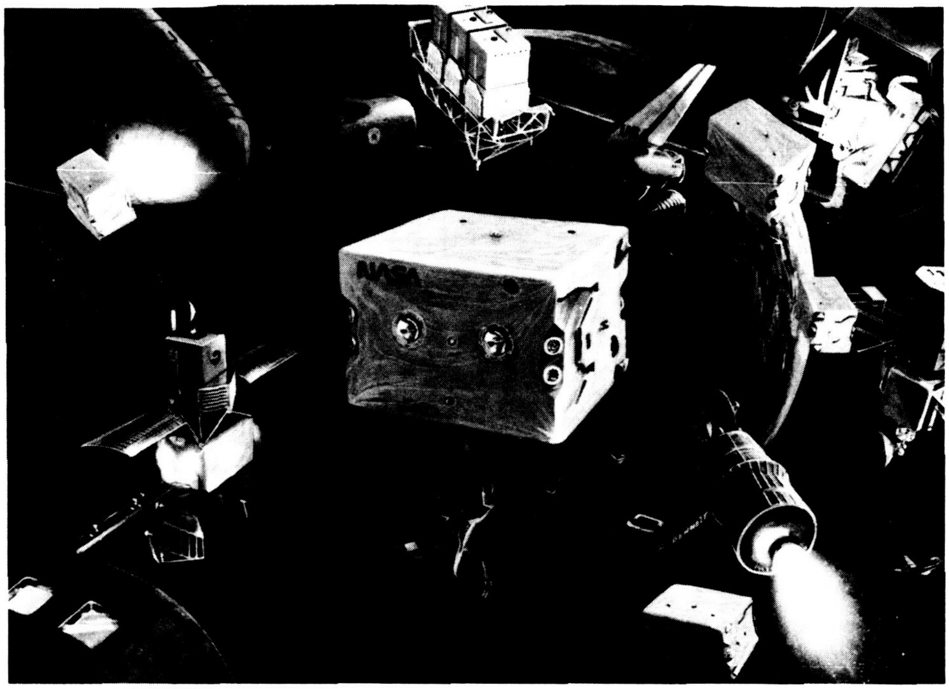
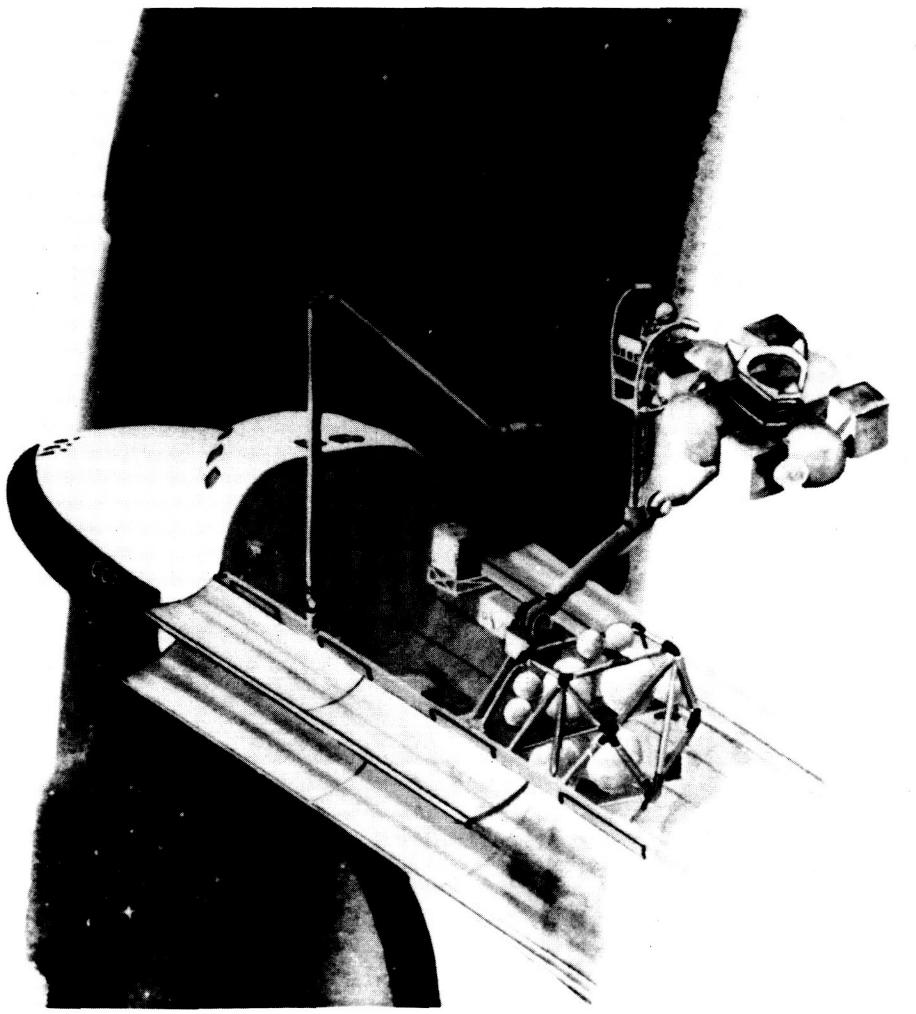


Figure 2.— Potential uses for the POV.

Figure 3.— Fluid transfer.



reusable upper stages, assembly of large payloads and stages, and for conducting long-duration manned science and application endeavors.

A Space Station Program Office was recently formed to focus JSC managerial, technical, and budgetary efforts related to Space Station and to develop the plans and documentation necessary to support early agency initiation.

The current Space Station related activity at JSC involves a contingent of approximately 100 program office and directorate specialists. The Space Station is currently targeted as a new initiative in 1986 with initial operational capability in 1990. Figures 4 and 5 depict potential interim and growth configurations of a Space Station as previously defined by in-house studies.

The evolutionary buildup of the Space Station will dictate flexibility of design not previously attempted for space systems. Hardware and software for the avionics systems threaten to be very costly unless this evolution can be understood and accommodated in the initial design. Activities are currently underway to design and activate an avionics system test bed to gain early insight into this problem. Also underway is a project by which the Space Shuttle Remote Manipulator System can be used as a test article to investigate the feasibility of onorbit flexible control for large systems such as the Space Station. A third project aimed at understanding Space Station-related activities is the Space Construction Experiment Definition Study. The goal of this activity is to define a Space Shuttle-based flight experiment to derive fundamental data relative to large space structures and their construction in space.

Regenerable concepts that recover oxygen and water from metabolic wastes are being developed for extended-duration Orbiter and Space Station applications. The Advanced Life Support Laboratory has been established at JSC for evaluation of the regenerable concepts. The test program plan includes both unmanned laboratory testing and long-duration manned chamber evaluation testing of regenerative environmental control and life support subsystems.

Testing of a process that recovers potable water from urine, using a vapor compression and distillation technique, has been completed. A competitive system using a hollow fiber membrane is also under evaluation for water recovery. Electrochemical and catalytic processes that accomplish the removal of carbon dioxide and makeup of oxygen in a cabin atmosphere are now undergoing individual tests, then grouping of processes will be evaluated for system-level effects.

A 20-foot-diameter vacuum chamber has been modified to accommodate the installation of the regenerative life support subsystems. A system configuration for air and water recovery that includes many of the processes baselined for the Space Station will be built and subjected to extensive unmanned and manned testing.

Figure 4.— Space Station interim configuration.

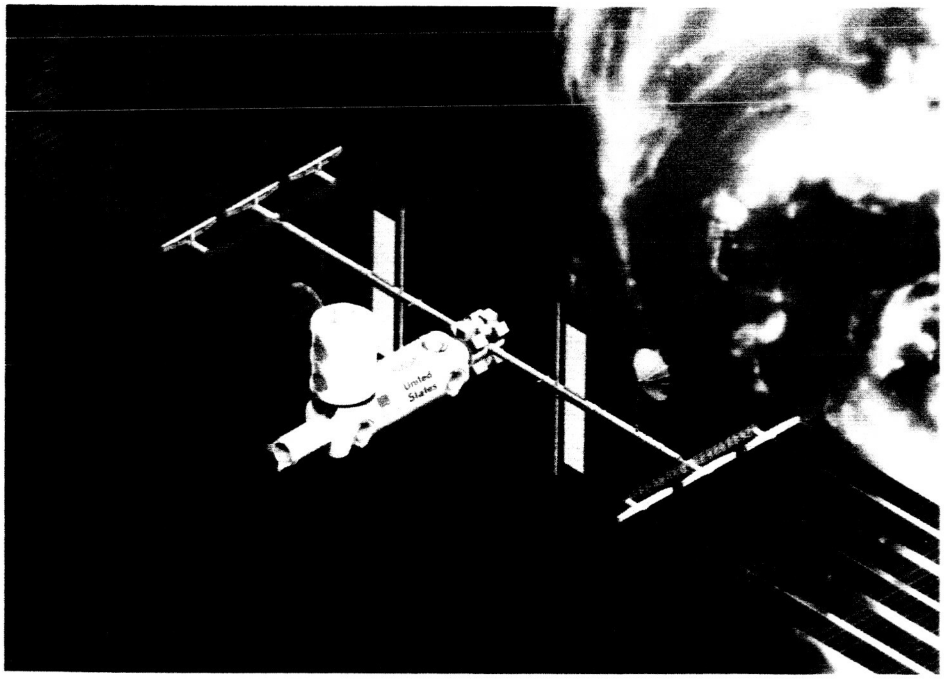
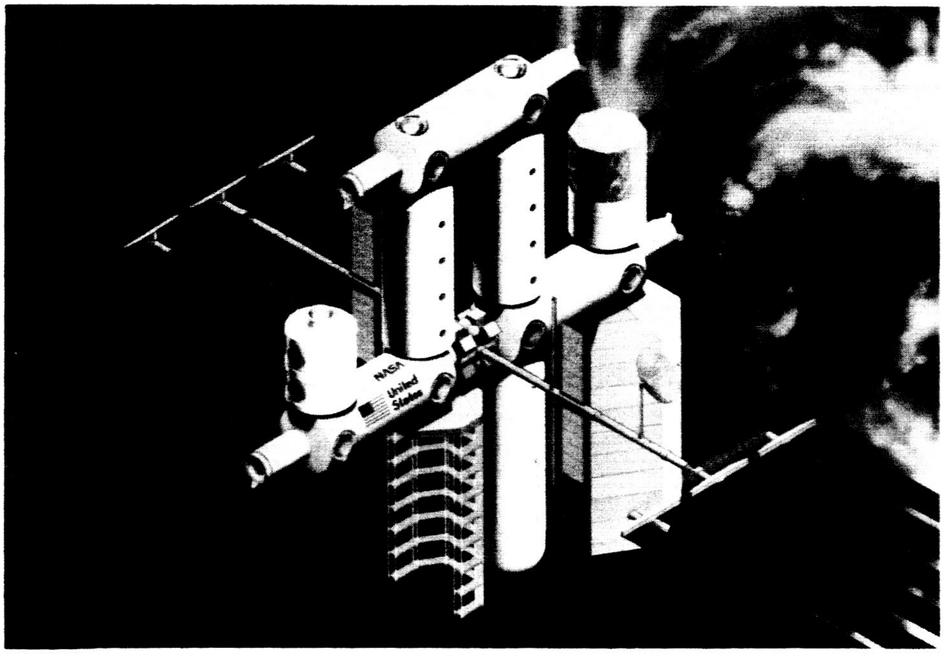


Figure 5.— Space Station growth configuration.



Orbital Debris Studies

In the past, spacecraft designers have been concerned with shielding their systems against a relatively low level of natural meteoroids. The meteoroid flux has been well-understood, and in most cases offered little design penalty. However, the next generation of space hardware may utilize lightweight materials such as graphite resins and metal matrix composites which could be more susceptible to collision damage. Further complicating the design issue is the steadily increasing flux of man-made objects in Earth orbit. The source of small man-made objects is the breaking of large satellites either by explosion or collision. These breakups account for most of the objects cataloged by North American Air Defense Command (NORAD), and for an even larger number of uncataloged objects.

To address the problem of orbital debris, JSC conducted a 3-day workshop, July 27-29, 1982. The workshop addressed the three major areas of Environment Definition, Spacecraft Hazards, and Space Object Management. The workshop concluded that the debris population is only accurately measured by NORAD for satellites larger than 1-meter in diameter. Below this size, the NORAD radar and optical systems begin to miss objects. Below 4-cm in diameter, the environment is totally unmeasured. The workshop put the highest priority on obtaining new data to define the environment of smaller sizes. Ground-based and satellite instruments are feasible approaches to collecting these data. Additional data could come from ground simulations of satellite fragmentation by the explosion and hypervelocity collisions. It was recommended that low-cost techniques to control the environment be encouraged and continued. Also, NASA should continue as lead agency in conducting future research.

JSC is planning to expand its Orbital Debris Program to include ground experiments and an in situ experiment concept to improve knowledge of the current, small particle environment. Figure 6 portrays a potential orbital detection system utilizing the multimission spacecraft. The Center has built a small, light gas gun to study the effects of hypervelocity impacts into composite material. Additional resources will concentrate on some of the unique problems of geosynchronous orbit.

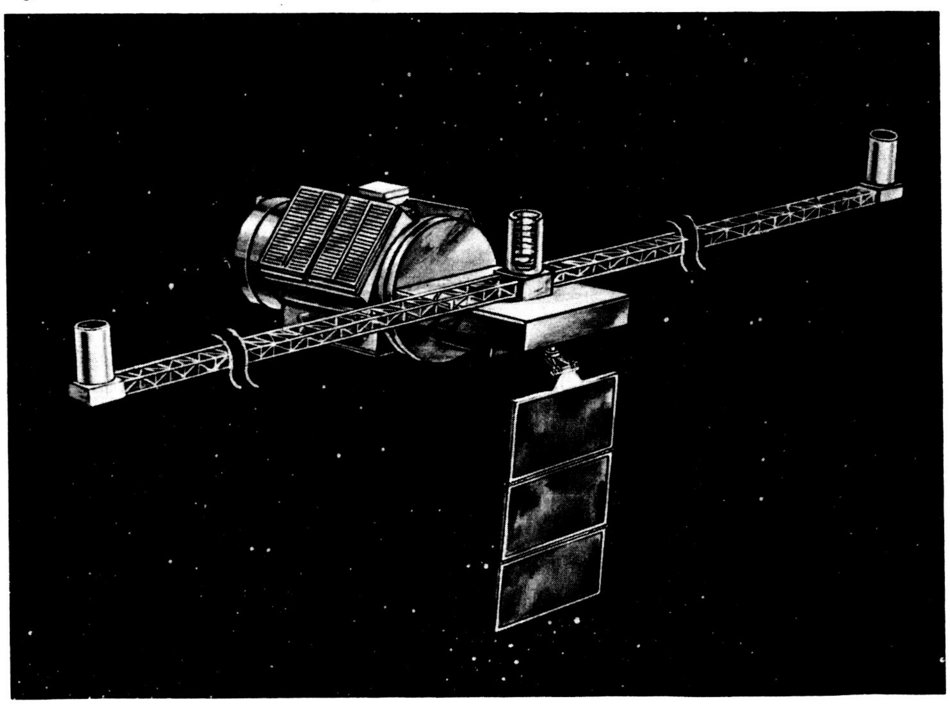
Research Spinoff to Ongoing Programs

During the past year two important steps have occurred toward increasing the STS satellite servicing capability.

1. The Shuttle Program has initiated development of the Manipulator Foot Restraint (MFR) which is the initial portion of an Open Cherry Picker. The MFR is a piece of generic equipment which will facilitate positioning of an astronaut to accomplish servicing and inspection activities within the reach envelope of the remote manipulator system (RMS). In addition, being able to provide optimum positioning of the astronaut for accomplishment of required tasks, the MFR will simplify training and reduce requirements for unique equipment development.

2. The Manned Maneuvering Unit has been scheduled for use in servicing and repair of the Solar Maximum Mission spacecraft. The Manned Maneuvering Unit will be used to attach a remote manipulator grappling fixture to the spacecraft (see fig. 7) to allow the vehicle to be maneuvered onto a holding fixture for the EVA repair activities.

Figure 6.- Orbital debris detection experiment.



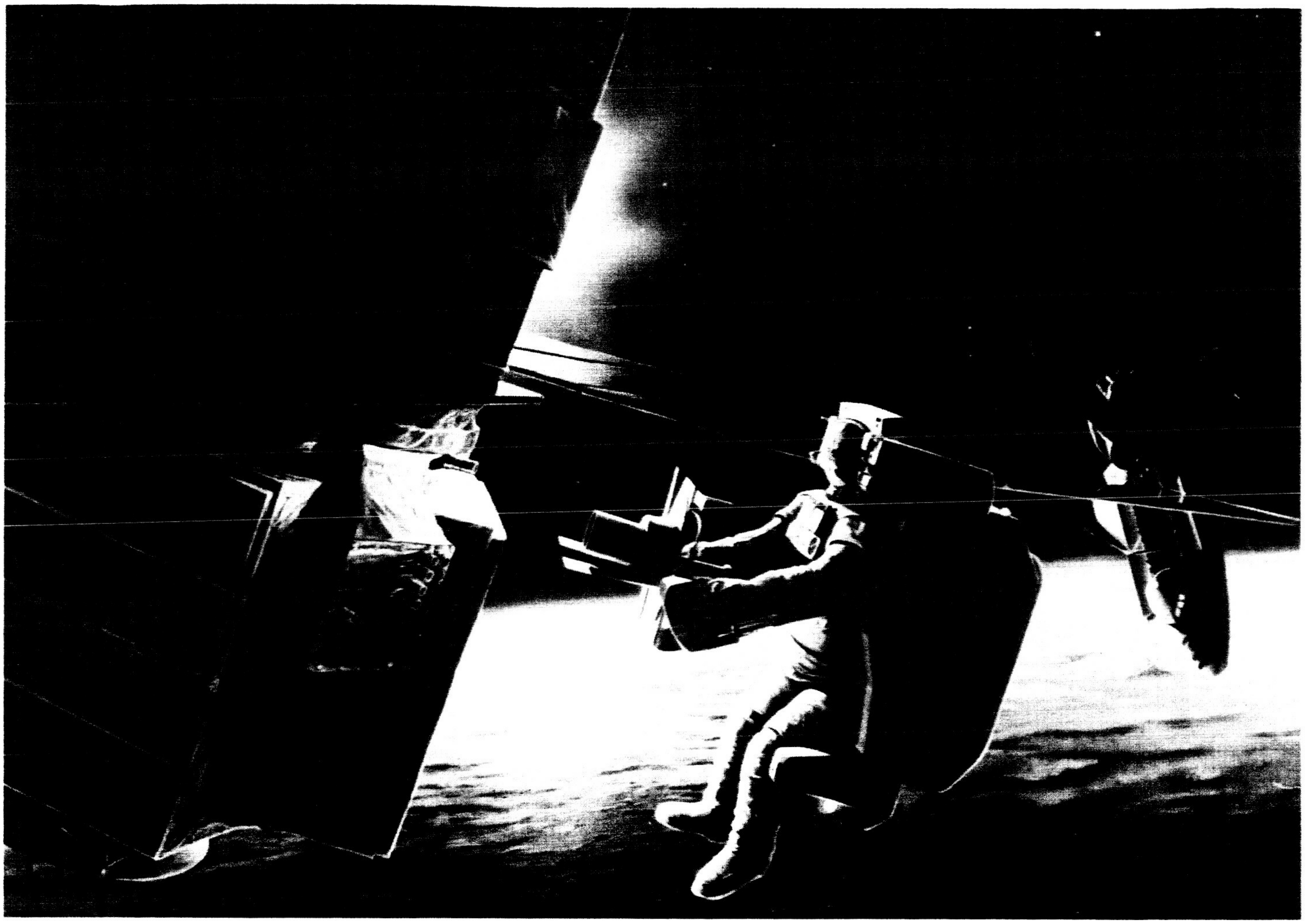


Figure 7.— The MMU being used in preparation for solar maximum mission satellite retrieval.

Proximity Operations Vehicle

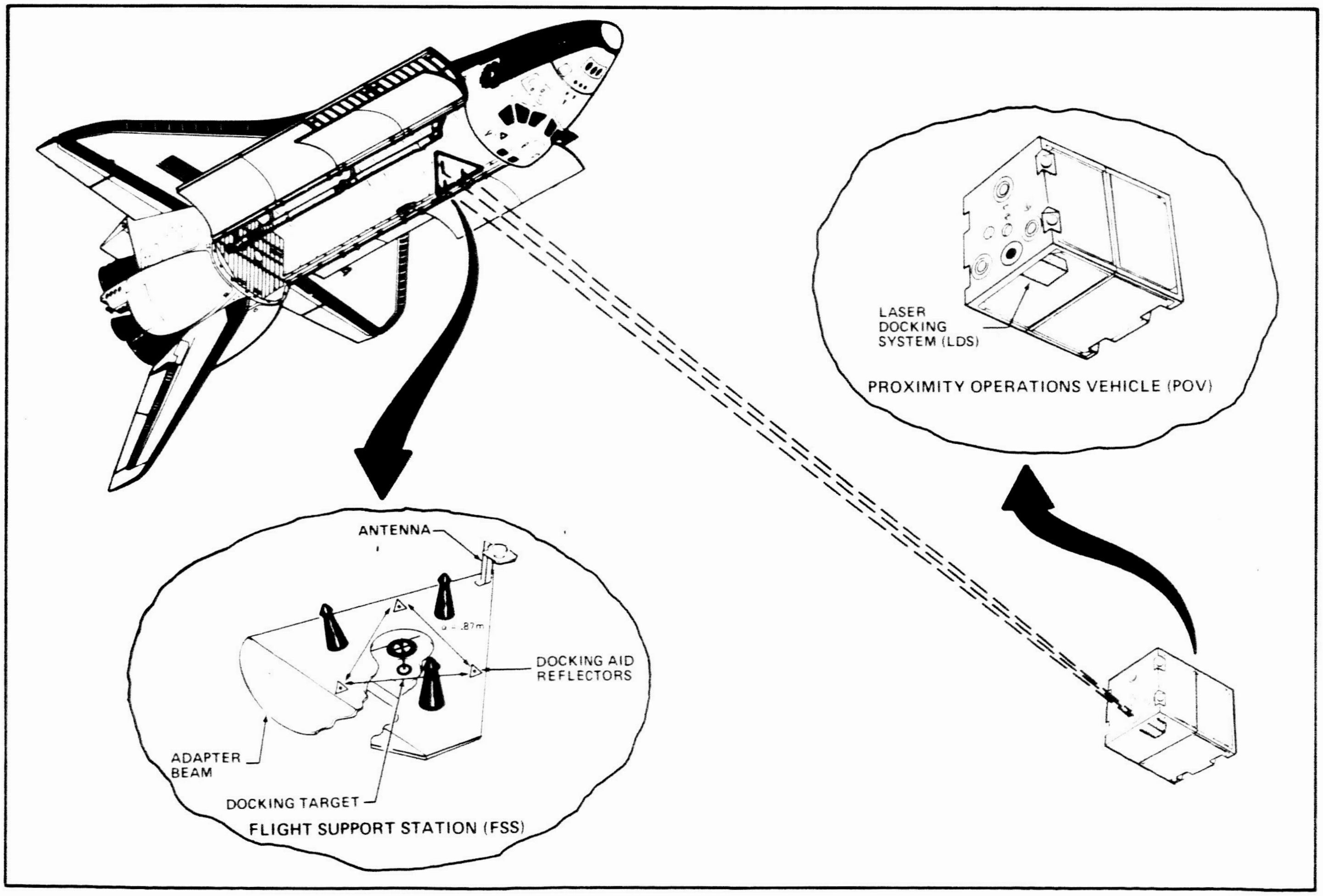
TM: Ronald H. Gerlach/EN5
Reference OSF 1

The Space Shuttle and Space Station will require vehicles to ferry objects, perform remote inspections, transport cargoes, and perform remote experiments. Another need will be that of close-in (proximity) support for object retrieval and satellite services assistance with a free-flying vehicle. These activities will require a remotely piloted vehicle which has the capabilities for control from the Shuttle or Space Station and has automatic systems for remote stationkeeping, automatic rendezvous, and automatic docking. The Proximity Operations Vehicle (POV) is under concept development at JSC to develop the systems procedures, and methods to accomplish these tasks.

Several ongoing studies at JSC have been exploring the subsystem requirements for a free-flier, the software and procedures requirements for automated rendezvous, docking, and stationkeeping, and the sensing systems for proximity operations. Under the Maneuverable Television (MTV) study, the electronic, propulsion, and mechanical system of the vehicle were fabricated and are being analyzed. Additionally, the flight control system (FCS) has been modeled in a computer program which also models the Shuttle Orbiter and a remote satellite for targets. The software and procedures for control of a remote vehicle are being investigated in another study, and the developed items will be utilized with the FCS program to analyze fuel usage and controlability. A Laser Docking System (LDS) engineering model has been fabricated to investigate the sensor requirements and demonstrate performance.

A full scale engineering model of a MTV has been fabricated and has been "flying" on the JSC precision air bearing table. This model incorporates representative subsystem for performance evaluations. The model has demonstrated numerous successful dockings using only manual flight control with visual feedback from the planned TV links. The FCS computer program has demonstrated that the planned manual systems are capable of controlling the vehicle within fuel constraints and has identified significant flight control characteristics. The software analysis has identified automatic control techniques and procedures. The Laser Docking System model has demonstrated the capability to locate, track, and analyze a target for proper automatic control. Figure 1 is an outline of a demonstration experiment from the automatic docking concept. During 1983, these various mechanical, electronic, and software systems will be integrated and analyzed to continue the end-to-end performance assessment.

Figure 1.- POV/LDS rendezvous and docking demonstration with Orbiter.



Advanced Rendezvous and Docking Sensor

TM: Harry O. Erwin/EE6
Reference OSF 2

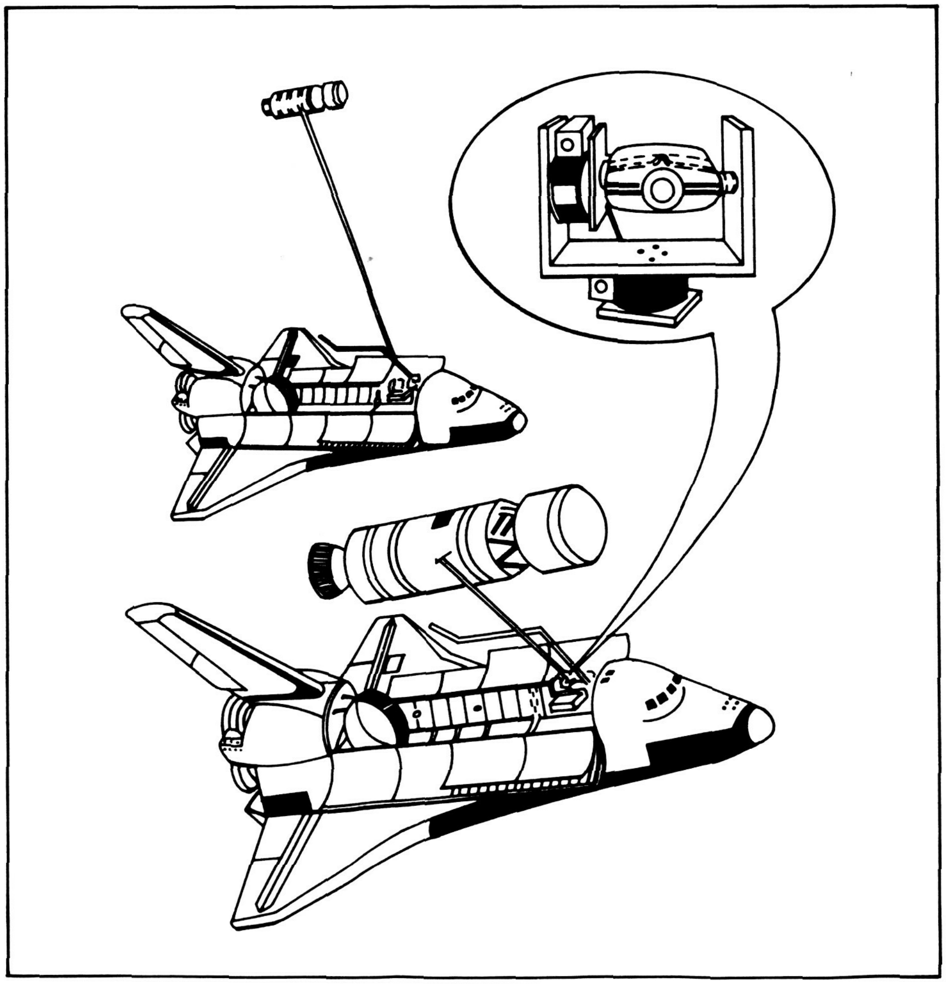
An automatic rendezvous and docking system has been established as a requirement for future space operations. A docking capability has existed in the previous manned spacecraft programs, but the capability was limited to impact docking (hard docking) under manual control using visual (out-the-window) cues. Sensor technology, together with microprocessor technology, is now sufficiently advanced to permit the development of a compact, lightweight system that can effect automatic terminal rendezvous and soft docking. 'Soft' docking refers to the condition in which relative translational and rotational velocity residuals and alignment errors are essentially zero. This project pursues the technological development of such a system.

The approach taken was to first establish a set of preliminary performance requirements for rendezvous, stationkeeping, and soft docking. A variety of sensor systems and techniques were surveyed and analyzed to determine their potential to satisfy the necessary performance (accuracy) requirements. Systems analyzed included radio frequency, conventional microwave radars, and laser radars. Conceptual designs of the most promising candidates were developed and subjected to further detailed analysis including an assessment of the technological readiness of the various system elements. The most promising system will be developed into a laboratory breadboard for test and evaluation. Additionally, there is an ongoing planning activity to configure a brassboard system for a flight demonstration program on a future Space Shuttle flight. This would in effect complete the predevelopment activity and demonstrate the system capability in a realistic space environment.

The initial design analysis phase of the program has been completed. The selected approach utilizes a continuous wave laser and tone ranging to three small retroreflectors. A modular design approach will permit the system to be configured to support rendezvous with minimum overall size and weight. Typical parameters which appear achievable are (1) 1-percent range accuracy with 0.01 m/sec range rate from 2 meters to several kilometers separation, (2) angle accuracy of 10 mrad with 0.1 mrad/sec angle rate, and (3) vehicle relative attitude accuracies of 30 mrad with 0.1 mrad/sec attitude rate.

A laboratory system has been assembled using readily available commercial components. The activity has been supported in part by the JSC Director's Discretionary Program. This system is being used for laboratory investigations and techniques development until a breadboard of the developmental system is available from the next phase of the program.

Figure 1.- Laser stationkeeping and docking sensor.



A laser sensor has also been proposed as a part of the Proximity Operations Vehicle (POV) demonstration experiment (see fig. 1). This Shuttle demonstration includes the activities that will reflect the operational aspects of orbital proximity operations. The experimental data acquired through the laboratory breadboard and Shuttle demonstration will be utilized to design and develop rendezvous and docking systems for the Space Station. The Orbiter demonstration and Space Station task areas will be completed during FY 1985-86. The key element of the Space Station and docking system will be the automatic acquisition, stationkeeping, and docking capability.

Zero Prebreathe Extravehicular Mobility Unit

TM: Joseph J. Kosmo/EC
Reference OSF 3

The current baseline in support of operational Shuttle extravehicular activities (EVA) requires that EVA be conducted at 4.1 psia from a 14.7-psia cabin. Space Transportation System crewmembers are required to prebreathe pure oxygen for 3 hours to denitrogenate prior to an EVA. This is necessary to preclude the "bends", a painful and potentially dangerous physiological condition resulting from bubble formation when dissolved nitrogen in body tissues is driven out of solution by exposure to reduced ambient pressure.

The prebreathe operations require crewman encumbering equipment, significant onboard vehicle expendable support, and extensive crew overhead activities.

As an outgrowth of an initial study on a zero prebreathe system, it was recognized that if higher extravehicular mobility unit (EMU) operational pressures were required to eliminate prebreathe operations, significant improvements would be required for space suit mobility. Contracted efforts, therefore were undertaken to investigate core technology concepts for higher operating pressure suit mobility systems.

This current effort is being based on proven advanced space suit mobility technology encompassing rolling convolute, multibearing, and toroidal joint systems.

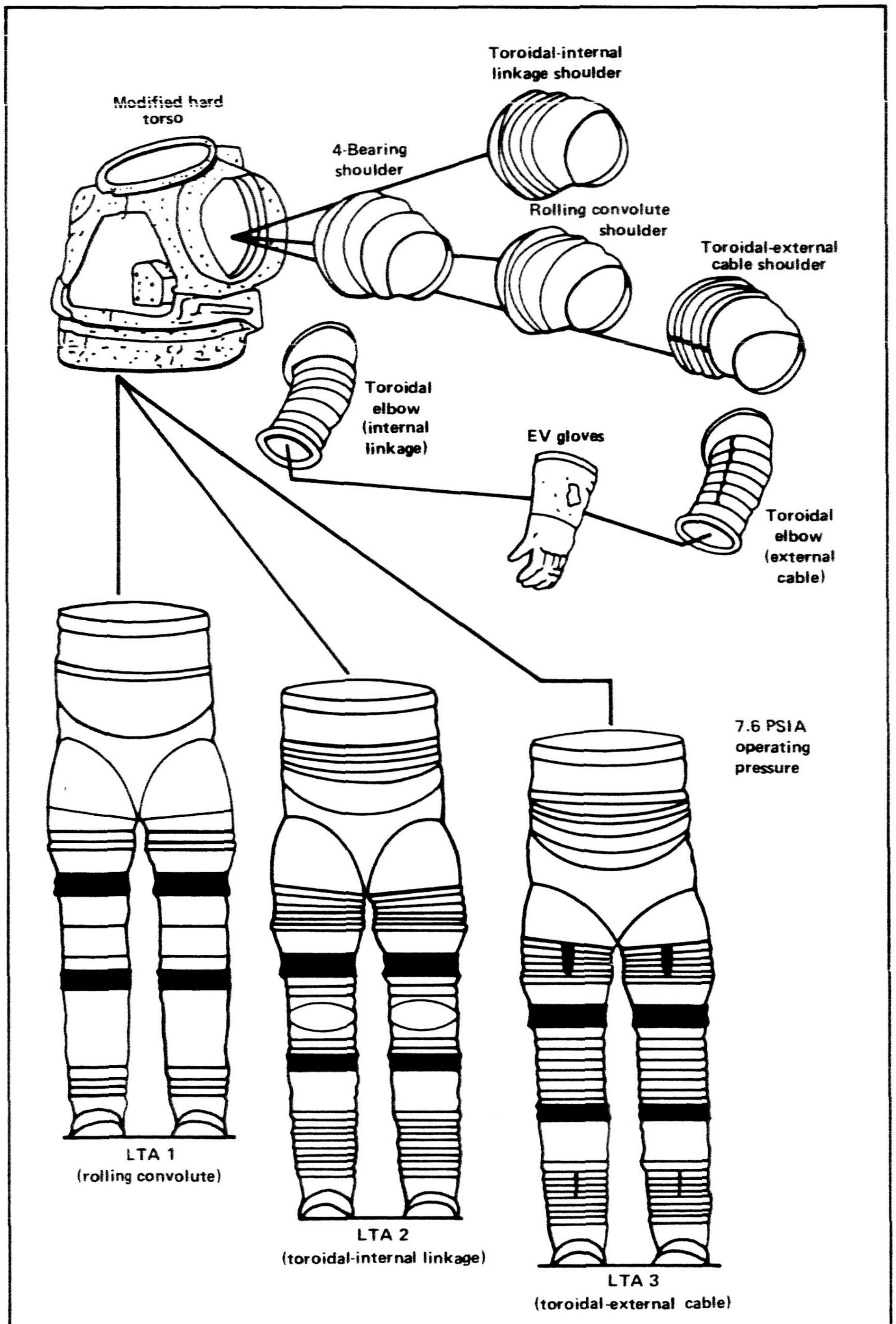
Contracts have been established for the design, development, and fabrication of four different, interchangeable shoulder joint configurations; three different lower torso assemblies (LTA); two different arm/elbow joint configurations; and three different pair of extravehicular (EV) glove configurations. Also, a current Shuttle space-suit hard upper torso assembly will be modified for use with the zero prebreathe suit system.

The overall result will be a zero prebreathe demonstrator space suit mobility model incorporating the various interchangeable component subassemblies previously identified and shown in figure 1. In addition, investigations will include the following.

1. Application of magnetic pulse-forming technology to improve the integrity of fabric-to-metal space-suit hardware attachments.
2. Utilization of woven, single-piece fabric toroidal joint assemblies based on heat-shrinking an elastomeric-coated laminate bladder/restraint layup on a master-shaping mandrel to eliminate the reliance on costly-sewn construction techniques.

The zero prebreathe demonstrator space-suit model hardware components are scheduled for delivery by December 31, 1982. The "next generation" EMU is planned for support of advanced activities such as Shuttle satellite servicing and Space Station operations.

Figure 1.- Zero prebreathe extravehicular mobility unit (demonstrator model).

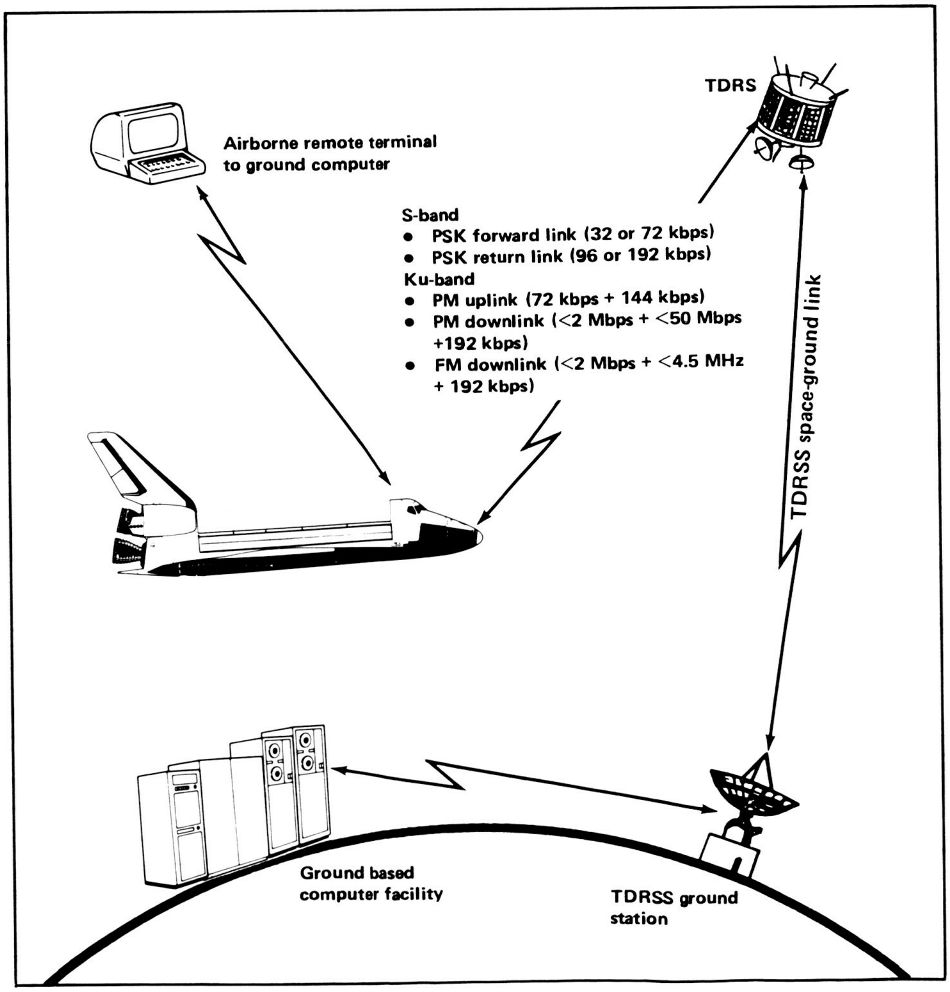


Onboard Remote Terminal

TM: Robert H. Brown/FM
Reference OSF 4

As the Space Transportation System program moves more into the operational phase, there is a progressive need to reduce ground support and increase onboard capability. One way of achieving this goal is to provide the flight crew with the capability to directly access the ground computers. JSC has recently completed a study to identify those activities which could be performed onboard a spacecraft utilizing computer support provided to the crew via a remote terminal link to a ground-based computer facility. The basic premise is that continuous communication, TDRSS or equivalent is available. See figure 1.

Figure 1.- Remote technical concept.



The approach used was in two phases. The first phase selected the candidate activities for remote terminal use. The second phase analyzed the comparative advantage of an onboard remote terminal and developed a proposed implementation plan. The remote terminal concept applies to the Space Shuttle and to Space Station utilization as well. Potential benefits from the remote terminal concept include the following major items:

1. Reduction in software development costs. Both critical and noncritical data could be processed on the ground and results displayed onboard. In this manner, cost could be reduced, and software checkout in an operational environment would be enhanced.

2. Reduction of ground crew training time. In long-duration missions such as the Spacelab or Space Station, the remote terminal would provide a mechanism for training a crewman for a special activity or retraining necessitated by either failure modes or as the result of earlier data assessment.

3. Mission and/or crew flexibility would be a key advantage. NASA has frequently had flight plan changes during past space flights which were verbally transmitted up to the flight crew. The onboard terminal could access the ground crew activity planning system to obtain updates automatically. The planning of Space Shuttle activities could be done on a week-by-week (or less) basis rather than trying to plan activities by the month or longer. This would allow the flight crew, in conjunction with the ground, to set priorities and optimize the schedule.

4. Consumables management. Most flights to date have relied on ground support to manage their consumables because onboard systems are not as accurate due to limited computer capability. A remote terminal to the larger ground computers would enable the flight crew to obtain more accurate system data. This type of link would be especially valuable to military operations.

A planned follow-on to this study includes an experiment to further validate the onboard remote terminal concept. The first part of the experiment would utilize a simulator (perhaps at Rockwell or Edwards) with a remote terminal to communicate with ground computers at JSC via satellite relay. The second phase would include an STS flight with a light crew workload to perform an actual space-to-ground computer communication. This would not only be valuable for STS-missions, but could continue to be used as a test bed for Space Shuttle software development and Space Station definition.

Space Station Avionics System

TM: William L. Swingle/EH
Reference OSF 5

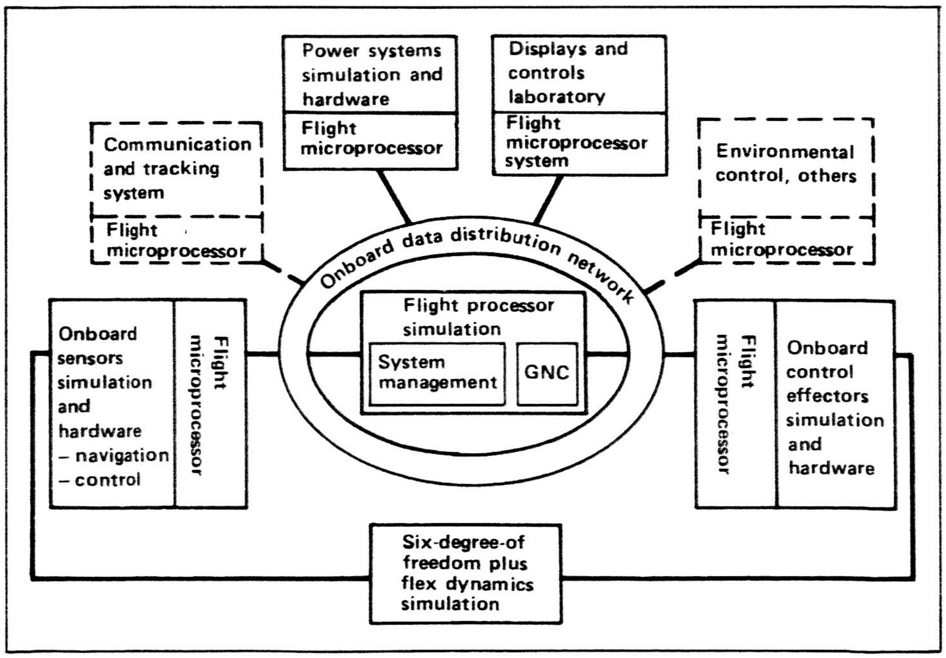
The Space Station program has several attendant requirements which dictate that the avionics system identify and develop new ways of doing business. The on-orbit buildup of major functional modules, along with the station's long-term evolutionary objectives, suggests that avionic system interfaces and functional responsibilities shall display a high level of autonomous operations. Specific emphasis on modular development and lower program operations cost has resulted in the need to develop new methods to support a more cost-effective approach to the design, development, and verification of the Space Station Avionics System. The significant cost incurred on past programs for hardware and software changes were, in part, due to the design and development of both hardware and software components before their evaluation in an integrated environment. This type of cost must be minimized on the Space Station through methods that provide a well-defined integrated avionics system design and development activity. The methods must also provide more efficient user interfaces for data handling, electrical power distribution and control, and avionics systems operations management and maintainability.

The generic concept for addressing these requirements and objectives is the recommended baseline of distributed systems architecture. The concept emphasizes that the avionics functional systems should be identified and organized such that their hardware/software design, development, test, and operation can be accomplished in parallel as standalone entities, but are compatible with an integrated avionics system test-bed approach. The design and development of an avionics test bed and a high-voltage, high-frequency dc/ac test bed have been initiated. The initial element of the avionics test bed will be design of the data management systems interfacing element. A bus interface concept which makes intersystem data transmission and communications transparent to the system software designer is proposed. The hardware necessary to accomplish this is being referred to as a standard Bus Interface Unit (BIU). The BIU, with its network operation system software and fiber optics links, will accomplish data communication transactions consisting of (1) addressing and routing, (2) bus transmission, and (3) error handling. Coupling the BIU with subject-oriented data handling and distributed data bases provides a user access flexibility required for evaluation and cost-effective operations.

The approach for the design and development of the high-voltage, high-frequency dc/ac test bed is to investigate several key areas of technology and demonstrate the feasibility of proposed approaches for power distribution. This would be followed by construction of a system test bed, representative of a space station power distribution system, for performance and integration analysis and evaluation.

Initial efforts of data management system design have concentrated on the analysis of program level requirements and their relationship to network topologies, network protocols, and BIU functional requirements and interface levels. A multinode Apollo computer system has been selected for in-house evaluation of networks and distributed data handling. The Apollo system provides a ring network (see fig. 1) utilizing a token passing access methodology. In parallel with the Apollo operations and evaluation, an in-house project is in progress to develop a breadboard version of a flight-type BIU. Architecturally, it will employ the ring network and will be functionally structured for multilevel interfacing of the hardware and software. The breadboard BIU will interconnect with the Apollo nodes by way of the multibus interfaces. Selected application programs will be developed to allow analysis and trades of different data techniques. A phase I high-voltage test bed funded by the Director's Discretionary Program, has been designed and built. The initial configuration investigated instrumentation techniques and transmission line characteristics with limited user hardware elements. Work has been initiated to update the phase I electrical power distribution and control test bed to a configuration more representative of evolving space station concepts to provide hardware design inputs for an integrated space station avionics test bed. Funds have been committed to purchase several candidate space station power distribution components, most notably a series resonant inverter and a bidirectional converter to perform power conditioning tasks. This latter activity is being conducted in cooperation with the Lewis Research Center.

Figure 1.- Avionics system test bed concept.



Remote Manipulator System Control Technology

TM: Henry J. G. Kaupp, Jr./EN2
Reference OSF 6

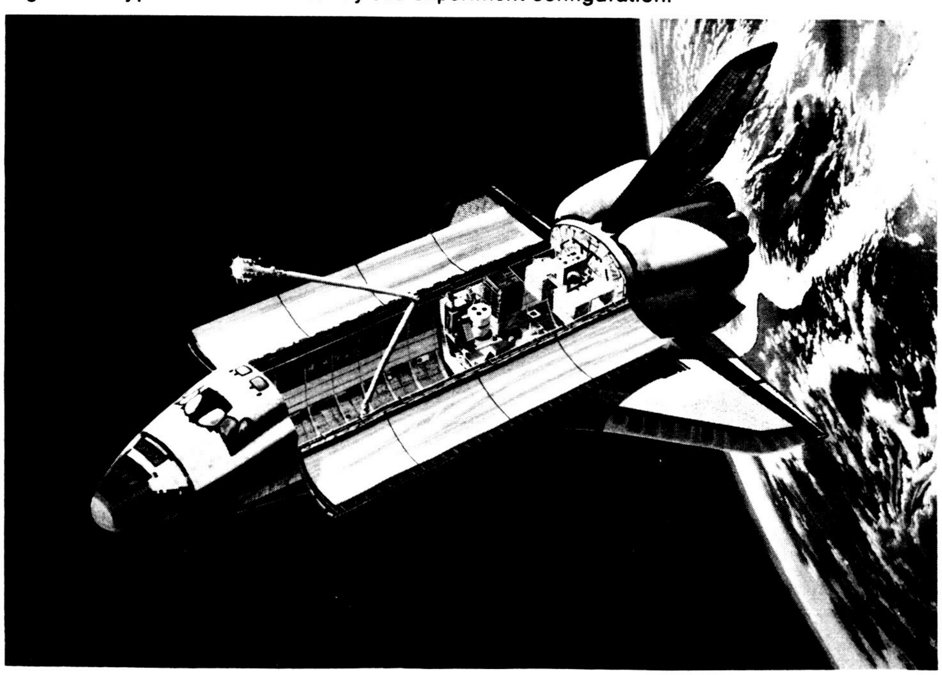
Large space systems control technology will require advancements in methods of accurately modeling flexible structures, practical application of systems identification techniques, and development of closed-loop active control laws. The Orbiter/remote manipulator system/payload system is a flexible structure that can be configured to study control problems such as space station deployment and assembly operations. It, therefore, constitutes an appropriate test article with which to investigate the feasibility of on-orbit flexible energy control (fig.1).

Two phases of on-orbit experiments, using the remote manipulator system (RMS) and instrumented payloads, are being designed to investigate potential control problems associated with space station development, construction, and operation. The first phase of experiments requires minimal integration with existing Shuttle hardware and software, and will support an evaluation of current modeling techniques and an assessment of the practical applicability of system identification algorithms. Since it is not possible to implement closed-loop active control without hardware and software additions to the Orbiter/RMS/payload system, the near-term experiments will serve primarily to augment the development of system identification algorithms and control laws for subsequent closed-loop experiments.

The initial experiment in the second phase will utilize the system identification algorithm and control law developed in phase one to demonstrate active vibration damping of the RMS and a payload. Succeeding experiments will investigate active control of the RMS and flexible payloads such as solar panels, appendages, containers, and elements of on-orbit construction that may be relevant to space station development. These experiments may necessitate additions or changes to the current Shuttle systems to facilitate implementation of closed-loop active control.

Modal frequency and damping characteristics of the unloaded and loaded RMS models have been identified from Fourier transform and auto regression analyses of flight data from Space Transportation System (STS) missions 2, 3, and 4. Based upon these results, an open-loop control experiment using the RMS and Shuttle Pallet Satellite (SPAS-01) payload has been designed for STS-7. Postflight analysis of data from RMS actuators and SPAS-01 sensors will augment development of real-time systems identification algorithms and control laws will, in turn, directly support the first closed-loop experiment using payload sensors, and RMS-general purpose computer identification and control algorithm, and RMS actuators.

Figure 1.- Typical Orbiter/RMS/Payload experiment configuration.



Space Construction Experiment Definition Study

TM: Lyle M. Jenkins/ET4
Reference OSF 7

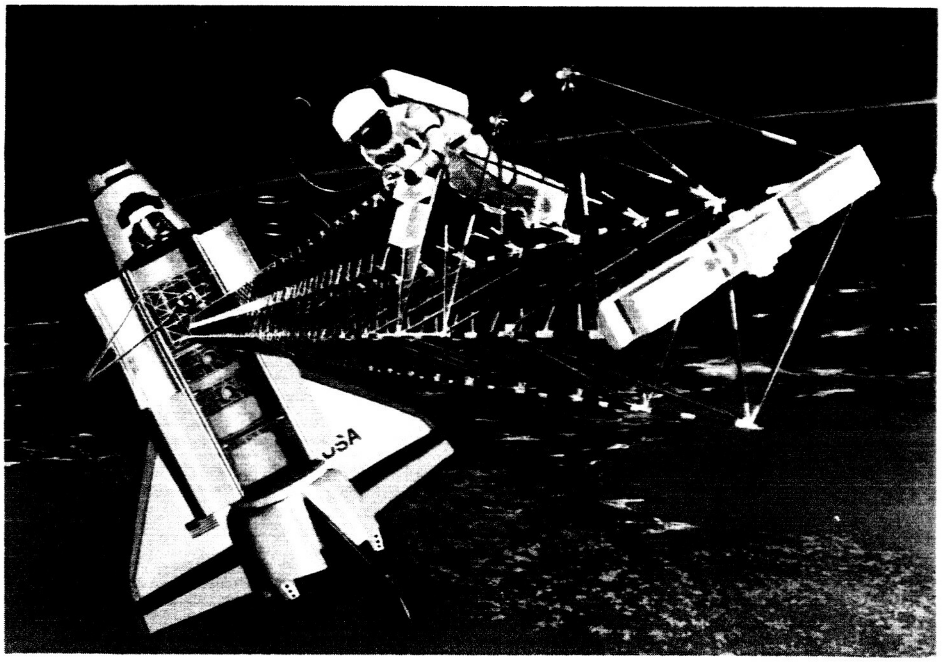
Future space program plans include large space systems such as antennas and platforms of a size and weight that exceed the single launch capability of the Space Shuttle. Implementation of any of these programs will require the capability to assemble or construct large systems in space. Although such construction will eventually be done from a Space Station, the initial projects may require assembly from the Orbiter. Until the ability to construct or assemble large space systems has been demonstrated, the user community will be reluctant to commit to large space structure concepts.

An appropriate experiment can provide significant data relative to the technology of space construction. Several complex and ambitious demonstration projects have previously been studied. Generally, these demonstration projects were of grandiose scale and did not integrate the desired objectives into a single flight experiment of a practical size and cost

The goal of the Space Construction Experiment Definition Study is to define an Orbiter-based flight experiment which provides a cost effective approach to deriving fundamental data relative to large space structures and to their construction from the Orbiter. The experiment objectives address the principal issues of dynamic characteristics of a deployable structure, structure/control interactions, and construction operations. The experiment is focused on a typical deployable structure that represents the dynamics and control issues of a low-frequency structure such as a large antenna or space platform (fig. 1). Construction operations would evaluate and demonstrate fundamental Shuttle capabilities involving the Remote Manipulator System and extravehicular activity. The Remote Manipulator System and extravehicular activity are used to aid in the deployment and to attach equipment modules. The ability of the Orbiter digital auto pilot to safely operate with such large attached structures would be confirmed.

Two parts of the contracted study have been completed. The selected graphite/epoxy composite diamond truss configuration was designed to deploy from a cargo bay support structure to a length of 100 meters. The first mode frequency is 0.08 Hz which will interact with the digital auto pilot by increasing vernier reaction control system thruster cycling only if dead bands are tightened. Incremental deployment and the slow buildup of deflections will add to the safety of the experiment. A preliminary hazard analysis was performed to identify safety requirements. In a third part of the study, technology objectives are being examined in detail by an intercenter group. Refined technical objectives and an evolutionary program are the expected output.

Figure 1.- Experimental beam deployment.



Carbon Dioxide Reduction

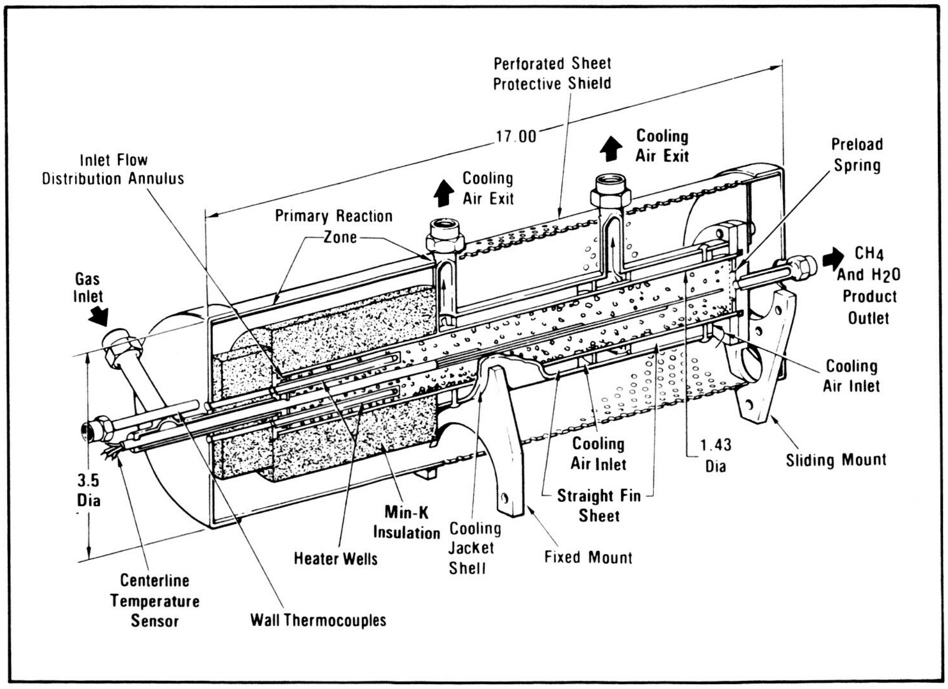
TM: Robert J. Cusick/EC3
Reference OSF 8

Future extended-mission manned spacecraft such as a space station will require regenerative systems to reduce the amount of expendables required for resupply. Reclamation of oxygen from carbon dioxide is a key requirement. The present Shuttle program uses expendable lithium hydroxide (LiOH) cartridges to remove the carbon dioxide from the spacecraft atmosphere. Conversion of metabolic carbon dioxide to water via a chemical reaction will result in substantial weight savings over present methods. The quantity of water recovered from chemically-reduced carbon dioxide with a regenerative system would be about 2100 pounds for an eight-man 180-day mission. Conversely, if this amount of water were initially launched in storage tanks, the total launch weight of tankage and water would be over 2300 pounds.

At the present time, the most reliable concept to convert carbon dioxide into water is the Sabatier reaction. The reactor (fig. 1) employs hydrogen and carbon dioxide in an exothermic reaction across a noble metal ruthenium catalyst to produce water and methane. Coupled with this process is a water electrolysis system to provide crew metabolic oxygen needs and recover hydrogen consumed by the Sabatier reaction. An intermediate step in the overall oxygen reclamation scheme employs the hydrogen in a nonconsuming fashion to electrochemically remove the carbon dioxide from the spacecraft atmosphere. The by-product methane is vented overboard to the vacuum of space. The Sabatier reaction process requires a heater to initially warm the catalyst to a temperature of 300° F. The reaction then ignites and proceeds on a continuous basis, to complete the conversion of carbon dioxide plus hydrogen to methane and water vapor. High temperatures at the inlet of the reactor, typically 1000° F, are required to obtain a high degree of conversion. Low temperatures near the reactor outlet, typically 200° F, yield reaction completion. The heater is not required after the reaction is started. Condensation of the water is accomplished with liquid or air-cooling of a porous plate water separator. The water is collected in a spring-loaded piston, diaphragm accumulator, which is periodically emptied by a pump to a water collection system.

A preprototype subsystem weighing 110 pounds has been developed to achieve the Sabatier reaction process. Over 800 hours of subsystem operation have demonstrated the maturity of the process for space station application. The control portion of the subsystem uses an advanced microprocessor-based controller and display that provides automatic control, 24-hour monitoring of subsystem water output, automatic shutdown, subsystem performance and flow monitoring, and provisions for maintenance servicing and checkout. A multicolored cathode ray tube (CRT) provides a continuous readout of system mode, subsystem anomalies system status and operations and instructions. The display provides maximum essential information at a glance and requires minimum interpretation and training for monitoring and subsystem control. Control of the subsystem is accomplished by keyboard commands designated on the CRT display. The microprocessor controller provides automatic sequencing, dynamic control, failure detection and isolation, instrumentation signal processing, water production rate calculation, and ground test instrumentation interfaces.

Figure 1.- Sabatier reactor cross section.



Vapor Compression Distillation Urine Water Recovery

TM: Donald F. Price/EC3
Reference OSF 9

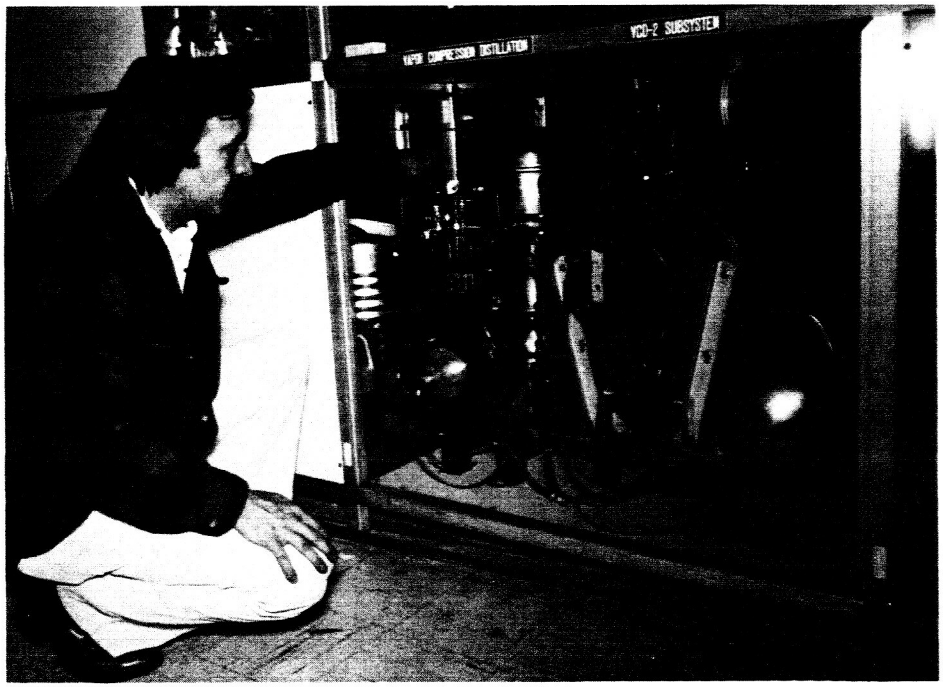
As manned mission requirements increase (i.e., larger crew size, longer on-orbit stay time, higher power usage), the need for inflight water recovery will become acute. This will be particularly true if solar power replaces fuel cells as the primary vehicle power source, as is planned for the Space Station. Water for drinking and evaporative cooling previously produced by the fuel cells must then be supplied either from stored water resupplied by Shuttle or from water recovered from crew urine, humidity condensate, and wash water. Tradeoff studies indicate that water recovery can be justified for Space Shuttle missions longer than 50 man-days and is the only practical option for missions aimed at providing a permanent manned presence in space such as the Space Station.

A phase-change process, Vapor Compression Distillation, has been demonstrated to be the most efficient and technically mature process for recovering potable water from urine and flush water. The basic Vapor Compression Distillation process involves the reduced-pressure evaporation of water from a feed-stock of treated urine, followed by compression and condensation of the water vapor. Evaporation and condensation occur on opposite surfaces of a rotating cylinder, allowing the transfer of the latent heat of condensation back to the evaporator, thus making the process highly energy efficient. No heat input is required by the system other than that provided by friction and the mechanical work done by the compressor in transporting the water vapor. The cylinder is rotated to provide an artificial gravity field. The process has been automated and adapted for Space Station application and has progressed through several developmental stages (fig. 1).

A second Preprototype Vapor Compression Distillation subsystem has completed 1400 hours of testing in the Advanced Life Support Development Laboratory at the Johnson Space Center while processing 2600 pounds of urine. The test program has demonstrated a water recovery efficiency of 96 percent. A total of 429 hours were accumulated without a component failure during which time the subsystem logged 287 consecutive hours.

During this preprototype system test, an Automatic Urine Collection and Pre-Treatment Unit was placed into operation and has consistently provided stabilized urine to the Vapor Compression Distillation subsystem. In addition, a Post-Treatment System was evaluated and proved that the current water specifications can be met using microbial check valves, carbon, and ion exchange purification beds. Investigation is in progress to further reduce organics using an ultraviolet oxidization device and continuous recirculation through the beds. This subsystem is currently being upgraded to support a parametric test program and to evaluate system reliability improvements. Eventually, the subsystem will support the unmanned advanced environmental control system (ECS) test in JSC's 20-foot vacuum chamber.

Figure 1.- Vapor compression distillation system.



Thermoelectric Integrated Membrane Evaporation Water Recovery System

TM: H. Eugene Winkler/EC3
Reference OSF 10

Long-duration manned space operations, such as that of an orbiting Space Station, will require vast quantities of water supplies for crew consumption, hygiene, and extravehicular activity. Transporting this water to orbit on a regular basis would be very costly. An estimated 43,000 pounds of launch weight could be saved each 90 days by recycling water for the Space Station having an eight-man crew.

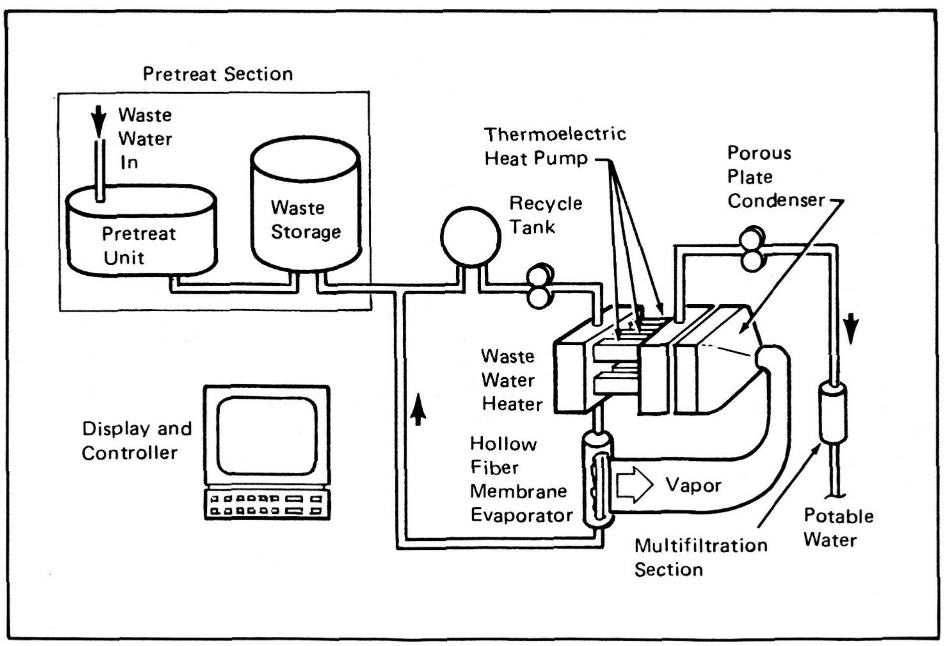
In January 1978, an effort was initiated for developing a urine water-recovery process that would be an alternate to the baselined, vapor compression distillation process. This process, thermoelectrically integrated membrane evaporation urine water recovery system (TIMES), utilizes a hollow fiber membrane evaporator and a porous plate condenser to recover potable water from urine and other sources by distillation. See figure 1.

Initially, the waste water is treated with a chemical agent to prevent carryover of volatile contaminants. The waste water is then heated to 150° F, passed through the hollow fiber membrane evaporator where the water vapor diffuses through the membrane walls to a reduced pressure steam plenum. The steam is then condensed on a porous plate condenser. Thermoelectric heat pumps are used to transfer heat from the condenser to the waste water, thus saving latent heat of condensation and reducing the system power penalty. The distilled product water is further treated by activated carbon, ion-exchange resins, and is disinfected by the addition of a biocide. The water, now of potable quality, is stored in tanks for use on demand.

The TIMES has been fabricated and tested at the contractor's facility. The system weighs 300 pounds, occupies 21 cubic feet, requires 108 Whr/lb of water, and produces water at a rate of 2 lb/hr. The system is microprocessor-controlled with a multicolored graphics data display. It has undergone over 2000 hours of testing with urine and wash water. Certain system components have been improved to enhance reliability, performance and product water quality. These improvements include a more durable hollow fiber membrane material, a more efficient temperature control technique, improved urine pretreatment, and a better post-treatment unit. Contractor testing and improvements will continue until the scheduled delivery to JSC in late 1982. At JSC, extended tests will be performed to evaluate overall spacecraft applicability and identify design weaknesses.

Overall, the TIMES water recovery process offers promise for satisfying a critical water supply need for extended manned space operations. Additional developments will improve performance and reliability and should qualify the water for spacecraft use.

Figure 1.- TIMES water recovery system.



Orbital Debris

TM: Donald J. Kessler/SN3
Reference OSF 11

The hazards from grain-sized meteoroids have been considered by engineers in determining a spacecraft's design and reliability. These natural particles cross the Earth's orbit at very high velocities. Should a particle larger than a few millimeters hit the Earth's atmosphere, it is observed as a meteor. If a similar particle were to strike a vulnerable spacecraft system, significant damage could result. As shown in figure 1, a hypervelocity impact causes significant ejecta from an aluminum sample even though velocity was not sufficient for complete penetration. However, for most spacecraft flown to date, their skins are sufficiently thick and the flux of meteoroids is sufficiently low that only a few spacecraft have required extra shielding for protection against meteoroids.

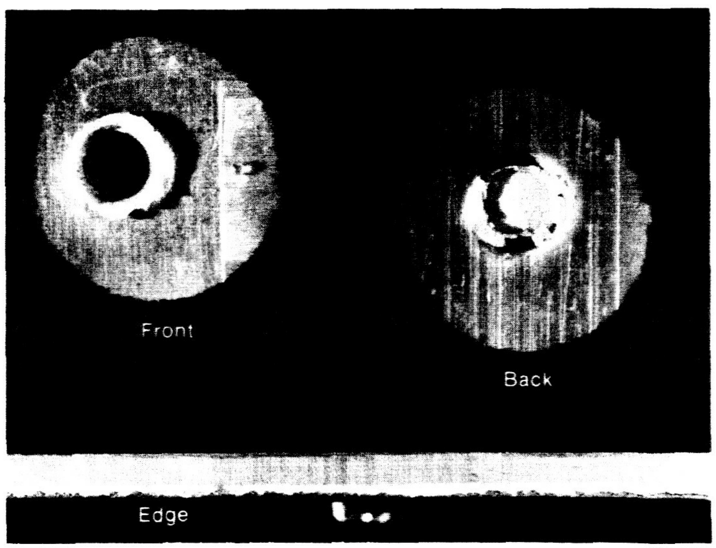
However, two changes are currently taking place: (1) New, lighter spacecraft designs make them more susceptible to more numerous smaller particles and (2) The flux of man-made objects of comparable size and velocity in certain regions of Earth orbit may soon be larger than the flux of meteoroids. The source of these grain-size, man-made objects is from the breakup of larger artificial satellites either by explosion, or collision. To protect against impacts by small debris, extra shielding on vulnerable spacecraft systems is required. However, the extra weight of shielding will also increase launch cost. Therefore, the spacecraft designer must consider the trade-off between reliability and weight. Since reliability depends on the frequency of collisions with these smaller particles, the environment must be defined before such a trade-off is possible.

Progress at JSC in defining the debris environment was made in the two areas of modeling and concept definition of an experiment capable of detecting orbiting debris as small as 1 mm in diameter. The JSC math model has been expanded to include the identification of the source of all cataloged objects. The model is also capable of predicting an untracked population by comparing the results of ground explosions with the distribution of sizes and orbits of the larger fragments cataloged by NORAD. The results predict an untracked population which is more numerous than the cataloged population.

Because the ground-based sensors cannot detect sufficiently small particles, a space-based experiment will be required in order to quantify these models. JSC has recently concluded a contract to evaluate various instrument concepts. The study concluded that any of three instruments could detect, obtain a measure of the particle size, and determine the orbit of particles as small as 1-mm diameter. The three concepts were a passive optical device (using reflected sunlight), active optical system (lidar), and a radar based instrument. All three concepts sample the environment by detecting objects passing within a few kilometers of the experiment. The passive optical appears to be the preferred instrument — it is lightest in weight uses the least power, and has the highest expected data rate. For the range and velocity to be measured, a particle must pass through the field of view of two of the three telescopes shown.

JSC is planning to expand its Orbital Debris Program to include ground experiments and an in situ experiment concept to improve knowledge of the current, small particle environment. A small, light gas gun is being activated to study the effects of hypervelocity impacts upon composite materials. Additional resources will concentrate on some of the unique problems of geosynchronous orbit.

Figure 1.- Hypervelocity test into an aluminum plate.



Aeronautics and Space Technology

Office of Aeronautics and Space Technology

Summary

The Johnson Space Center (JSC) plays a major supporting role to the Office of Aeronautics and Space Technology (OAST) for those disciplines where JSC has a development or operational responsibility. In particular, for the technology areas of Space Transportation and Space Platforms (as shown in table 1), JSC supports the majority of the space research and technology (R&T) disciplines. Current areas of systems emphasis include the following:

1. Transportation System R&T. For the Orbiter Experiments (OEX) Program, which uses the Space Shuttle as an experimental research vehicle, JSC performs the overall integration as well as providing several of the individual experiments.

2. Space Energy Conversion R&T. Continuing areas of energy conversion research include integrated orbital energy systems and the accompanying thermal control systems required for large space platforms such as the Space Station or the multi-hundred kilowatt orbital platform.

3. Computer Science and Electronics. JSC maintains a continuing program in synthetic aperture radar. In addition, several new projects in the avionics area are aimed principally at the upcoming manned Space Station initiative.

4. Chemical Propulsion. The advanced manned vehicle onboard propulsion technology studies are aimed at developing less hazardous propellants for onorbit propulsion systems.

5. Materials and Structures R&T. Recent studies have shown the feasibility of utilizing lunar materials for a variety of applications, both on the lunar surface and in Earth-Moon space. A manned facility on the surface of the Moon represents a logical extension of the space program in the early 21st century. JSC scientists are investigating ways of achieving economic mineral extraction and concentration of known lunar resources.

JSC has additionally provided wide-ranging in-house support to the OAST technology working groups. JSC chairs three of the Space Station technology working groups; Data Management, Crew and Life Support, and Thermal Systems.

Transportation Systems R&T

The OEX program utilizes the Space Shuttle Orbiter as a flight research vehicle for acquisition of information to

Table 1.- Space R&T Program Matrix Management Relationships

Disciplines/systems	Technology thrusts			
	Generic	Transportation	Platform	Spacecraft
Fluid and Thermal Physics R&T				
Materials and Structures R&T	JSC	JSC	JSC	
Computer Science and Electronics R&T	JSC	JSC	JSC	JSC
Controls and Human Factors R&T		JSC	JSC	
Space Energy Conversion R&T			JSC	
Chemical Propulsion R&T		JSC		
Multidisciplinary Research				
Transportation Systems R&T		JSC		
Spacecraft Systems R&T				
Platform Systems R&T			JSC	

verify and authenticate a wide variety of aerospace vehicle design parameters. A series of experiments have been perfected and others are continually being developed to exploit this unique research capability. Four Orbiter flights have been accomplished to date providing the Office of Aeronautics and Space Technology with a wealth of empirical data with which to verify and modify design specifications.

The final Space Shuttle test mission of the Columbia (STS-4) flew with five OEX experiments aboard plus the sixth external experiment installed on a C-141 aircraft for Orbiter Underflight. The OEX instrumentation was comprised of the Support System for OEX; the Aerodynamic Coefficient Identification Package (ACIP); the Dynamic, Acoustic, and Thermal Environment (DATE) experiment; the Tile Gap Heating Effects experiment; the Catalytic Surface Effects Experiment; and the Infrared Imagery of the Shuttle (IRIS) installed on the C-141.

Figure 1 pictorially depicts the DATE experiment sponsored by Goddard Space Flight Center as a part of the OEX program. The object of this experiment is to obtain Shuttle cargo bay inflight measurements that will provide the basis for accurate estimates of environments for the most realistic design and testing of payloads. All flights of this experiment thus far are considered highly successful. Mission reports for the flights have been published and widely distributed to all users and many potential users of the Shuttle services. The overpressure loads exhibited on STS-1 and the subsequent reductions on STS-2 through STS-4 were readily observed and analyzed. Acoustic and dynamic loads on STS-2, STS-3, and STS-4 were found to be consistent. Acoustic levels were slightly higher than predicted for low frequencies and lower than predicted for the middle and higher frequencies. This is particularly so in the high-frequency region. Measured data will allow more accurate predictions for future flights. Experimental data has resulted in the proposed downward revision of acoustic design and test criteria for all major Space Shuttle users.

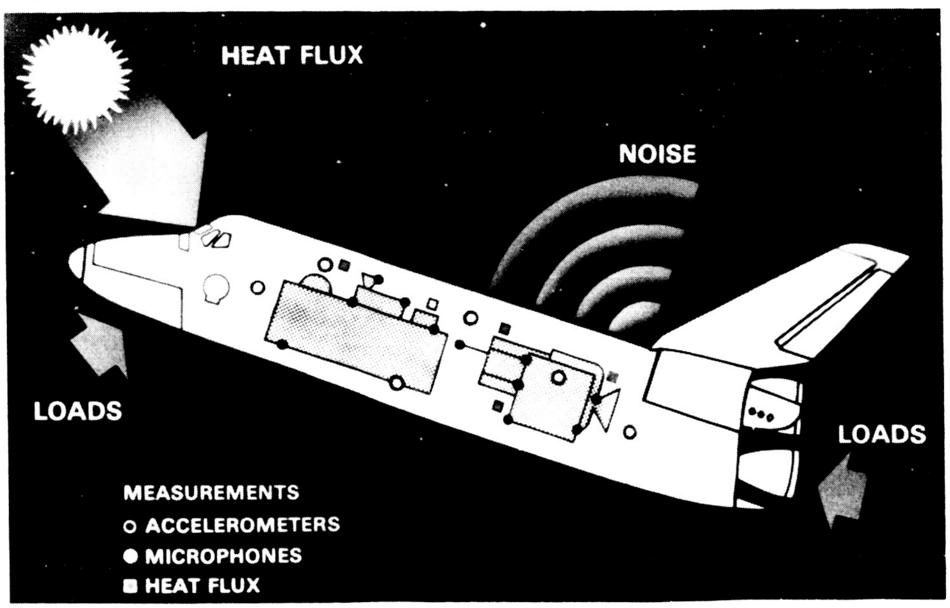
The ACIP project, which is under JSC sponsorship, has aided in confirming Space Shuttle operational parameters as well as providing data for future vehicle design. Its primary objectives are the following:

1. To collect aerodynamic data in the hypersonic, supersonic, and transonic flight regions in which there has been little opportunity for gathering and accumulating practical data.
2. To establish an extensive aerodynamic data base for verification and correlation with ground-based test data, including assessments of uncertainties in such data.
3. To provide flight dynamic state variable data in support of other technology areas, such as aerothermal and structural dynamics.

The ACIP incorporates three triads of instruments: one of dual-range linear accelerometers, one of angular accelerometers, and one of rate gyros. Also included are the power conditioner for the gyros, the power control system, and the housekeeping components for the instruments. The ACIP is aligned to the Orbiter axes to a very high order of accuracy.

The ACIP operates through the launch period and subsequently through the entry and descent phases of Orbiter flight. The internal instruments continuously sense the dynamic X, Y, and Z attitudes and performance characteristics of the Orbiter through these critical flight phases. In addition, the ACIP receives the indications of position of the control surfaces and converts there indications into higher orders of precision before recording them with the attitude data. The primary signals used for lateral-directional data extraction are roll rate, yaw rate, roll angular acceleration, yaw angular acceleration, and axial acceleration in the Y-direction. The signals proved to be highly useful on STS-4, meeting all requirements from a user standpoint. Noise identified on ACIP signals corresponds to reaction control system (RCS) jet firings, backing up the assumption that such noise is structural vibration.

Figure 1.- Dynamic, acoustic, and thermal environment (DATE) experiment.



Space Energy Conversion R&T

The Integrated Orbital Energy System research provides a central focus for several areas of JSC technology development. The solid polymer electrolysis (SPE) fuel cell promises to be a feasible and practical device for the multi-kilowatt manned Space Station, as well as for other large platforms in orbit. The SPE system can be combined with solar cells to provide power and water during "night side" operations, then reversing the action to electrolyze the water using the solar-array produced power on the light side of the orbit. A companion research activity (reported last year) involves the development of large-area solar cells for space use. These large-area cells promise to dramatically reduce the cost of large solar arrays such as that required for the Space Station. The third area of investigation for an integrated energy system is that of thermal management. Both pump-augmented and completely passive heat pipe thermal management systems are being investigated as candidates for a space constructable radiator system. Figure 2 shows the interrelationship between these JSC technology activities. Figure 3 is an artist's concept of the space constructable radiator that might be used for the Space Station Thermal management system.

Computer Science and Electronics R&T

Mass memory systems for today's flight hardware are typified by the electromechanical magnetic tape system employed on the Space Shuttle. These systems are highly restrictive in operations and applications. Bubble memory systems promise to be at a development state to satisfy future vehicle needs of greater life cycle reliability, large storage capability, and faster access time. JSC and Langley Research Center have initiated a joint program to develop such a bubble memory system for compatibility with a second generation Space Shuttle avionics update and the upcoming Space Station initiative.

Another area of electronics technology under current investigations is the Multifunction Synthetic Aperture Radar. The goal is a two-fold increase in the capability of the current single frequency systems. This activity will allow frequency variation, multipolarization, and extremely high resolution for a wide range of multimission resource mapping activities.

Chemical Propulsion R&T

The onorbit propellant system for the Space Shuttle utilizes a propellant combination of nitrogen tetroxide and monomethyl hydrazine. These propellants are extremely hazardous, requiring the strictest of safety precautions during their transfer or servicing. JSC continues to conduct studies to identify viable alternatives to these hyperbolic propellant combinations. Research has shown that liquid oxygen/hydrocarbon propellant can provide the required performance at a potentially lower cost, while greatly reducing the servicing hazards. A baseline system has been established for future design utilizing this nontoxic,

Figure 2.- Integrated orbital energy system.

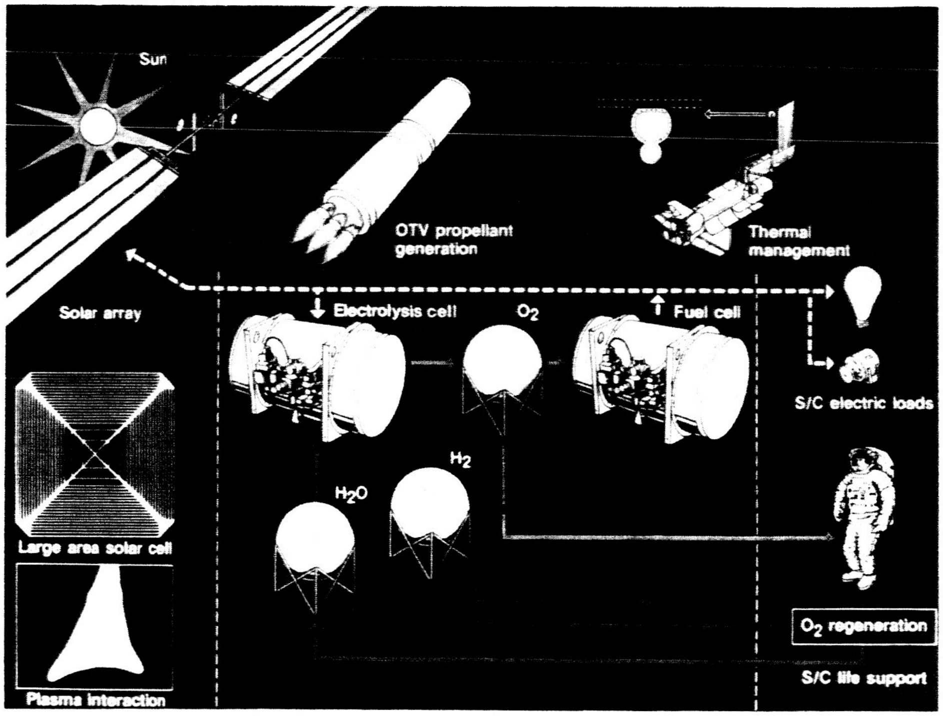
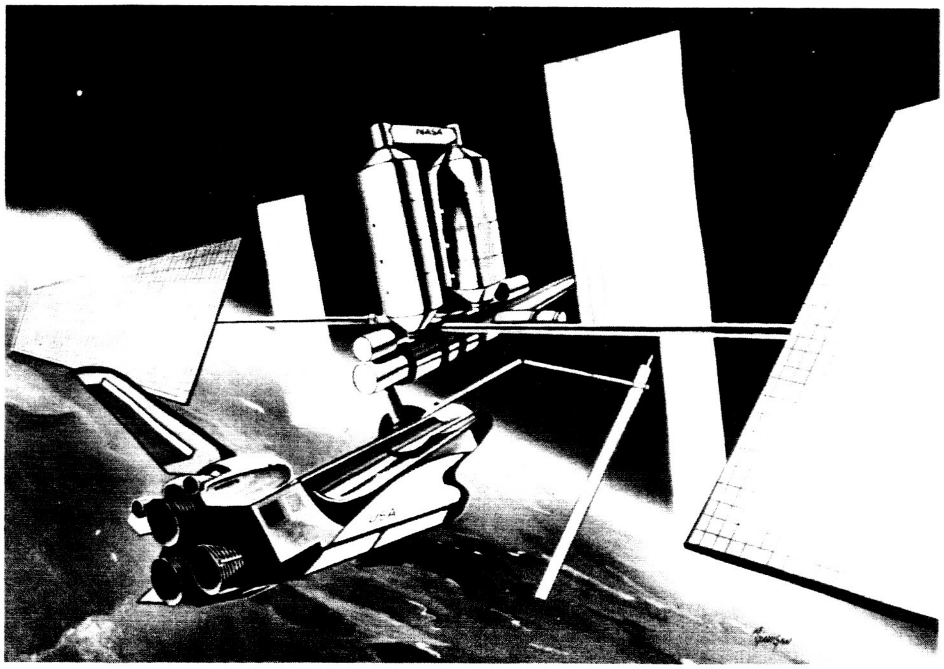


Figure 3.- Space constructable radiator.



noncorrosive system. The design is applicable to the Space Shuttle and to all new orbital systems requiring propellant for attitude control or orbital transfer.

Materials and Structures R&T

Future space activities may involve the construction of very large structures in space. Because significantly less energy is required to launch materials from the Moon than from Earth, these large-scale activities will benefit from the development of manufacturing factories in space that obtain their raw materials from the Moon. Over 90 percent of the mass for such a project could be supplied by known lunar resources if proper concentrations could be achieved for economical processing. JSC has developed a mineral separation laboratory to develop equipment and techniques for dry electrostatic separation and concentration of lunar soil analogs. Excellent results have been obtained for size ranges of 150 to 250 μm. A lunar processing and launching facility with which a solar-powered lunar mass driver could eject 4-kilogram packages of lunar materials into space for collection and chemical processing is shown in figure 4.

Figure 4.- Lunar mining and processing facility.

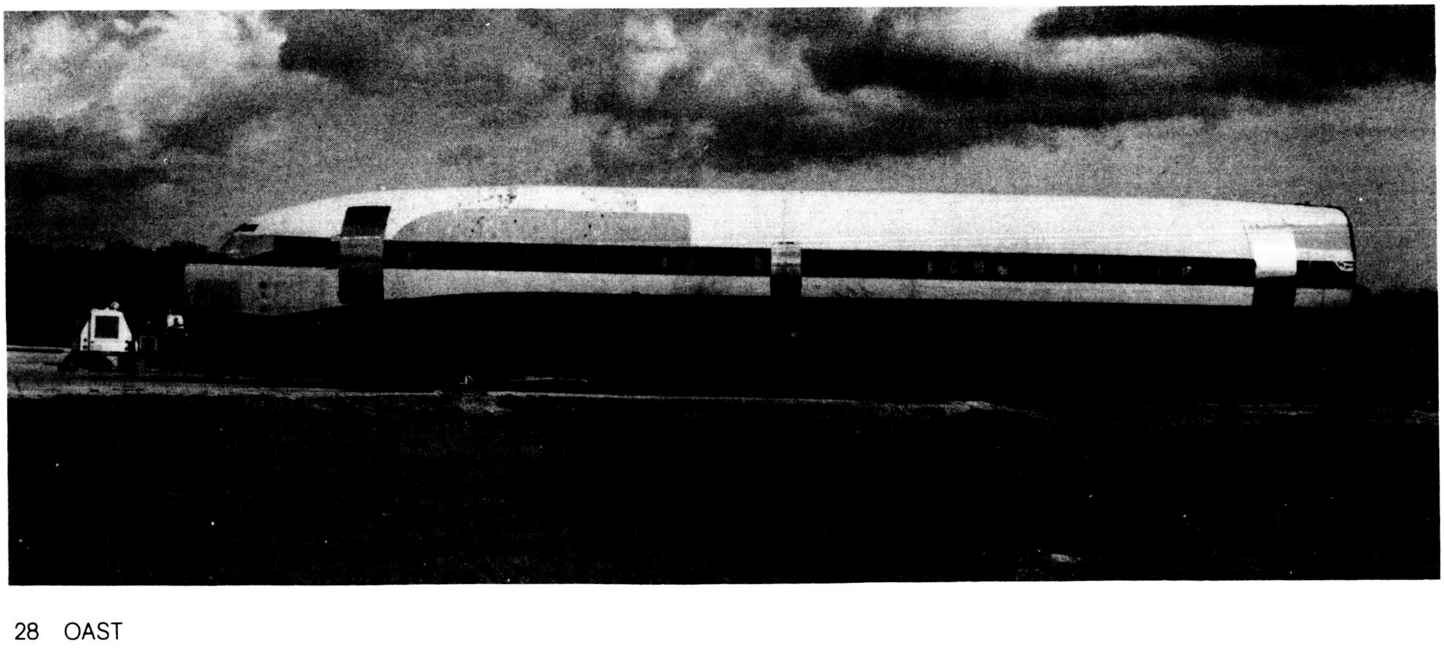
Aeronautics Research Programs

JSC performs a continuing research activity in support of aircraft fire safety. This includes the test of materials for fire resistance and low-smoke characteristics, as well as the toxicity testing of candidate aircraft materials. Materials developed through the program continue to find numerous applications in commercial aircraft. The NASA developed polyimide foams reported last year have been used by the Navy as shipboard insulation. The nonflame propagating material has also been used extensively in the Space Shuttle in widely varied uses such as insulation for the first refrigerator/freezer flown in space and as stowage cushioning for the onboard tool kit. Figure 5 shows the Boeing 737 fuselage located at JSC in which flammability tests are conducted.

Energy Programs

An item of high national priority is the search for sites for disposal of nuclear wastes. The leading candidate is deep burial in geologically-stable areas. As a spinoff from the planetary program, JSC has developed a test system for understanding the potential ground water flow that would control spread of these wastes in the event of leakage during thousands of years of planned storage. This technique should prove to be an invaluable tool in certifying potential repository sites.

Figure 5.- Boeing 737 flammability test fuselage.



Aeronautics and Space Technology
Significant Tasks

Aeronautics and Space Technology
Significant Tasks

Aeronautics and Space Technology
Significant Tasks

Aerodynamic Coefficient Identification Package

TM: Joe T. Rutherford/EN3
Reference OAST 1

The Space Shuttle Program has presented the first opportunity to obtain fullscale flight environment data for winged reentry vehicles throughout the aerodynamic flight regime. To capitalize on this opportunity, the Aerodynamic Coefficient Identification Package (ACIP) was designed under the sponsorship of the Orbiter Experiments Program. The objectives of ACIP are to collect data in the hypersonic, supersonic, and transonic flight regimes, in order to establish an extensive aerodynamic data base for verification and correlation of ground-based test data and to provide flight dynamics data to support other technology experiments. The quality of data produced by the ACIP during the Space Shuttle flight test program has provided valuable information concerning relative uncertainties associated with the extrapolation of wind tunnel tests to full-scale flight tests.

This experiment consists of an instrument package, which utilizes Orbiter-provided power, time, and environmental support. It is mounted on the wing box carry-through structure on the center line of the Orbiter, as shown in figure 1. Data are recorded on the Orbiter Experiments (OEX) tape recorder.

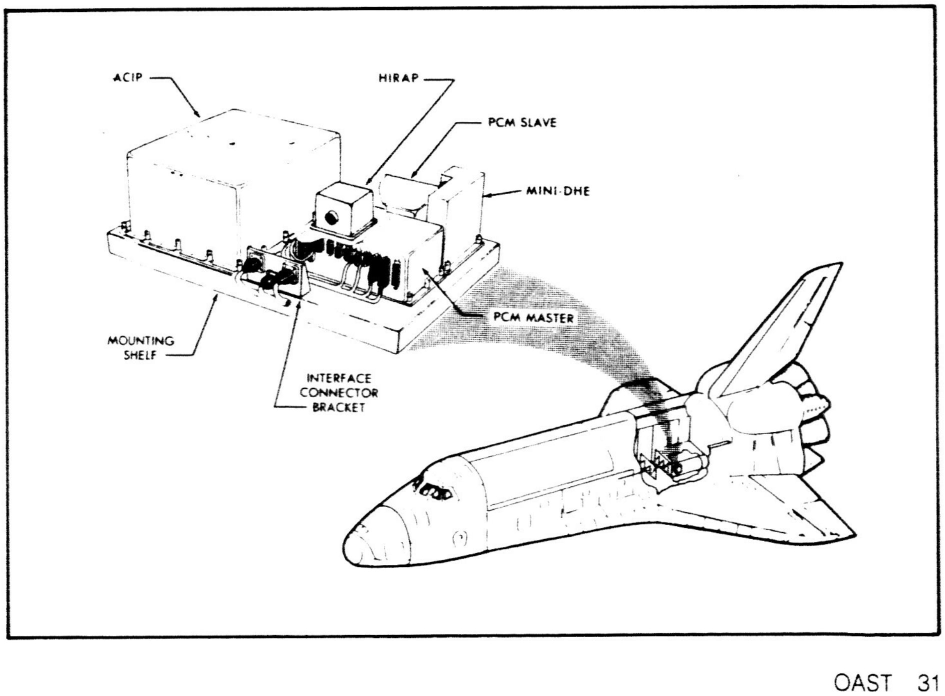
The ACIP hardware, designed, fabricated, and qualified by JSC, incorporates three triads of instruments — one of dual-range linear accelerometers, one of angular accelerometers, and one of rate gyros. The power control system and housekeeping components for the instruments are all self-contained in the ACIP.

The ACIP operates through the launch and ascent phases of the flight and subsequently through entry interface, descent, and landing. The internal instruments continuously sense the dynamic X, Y, and Z attitudes and performance characteristics of the Orbiter through these critical flight phases. The ACIP also receives the indications of position of the control surfaces and converts these indications into higher orders of precision before recording them with the attitude data.

An ACIP has been installed on each Orbiter, has flown on four flights, and will fly on all flights thru STS-20. The data gained were of the highest quality and met all expectations of the experiment designers and technologists. The acceleration and rate data depicted in detail reentry, the event of major interest. Utilization of this information and that gathered from subsequent flights will further enhance the aerodynamic data base of reentry technology.

The JSC has added a High Resolution Accelerometer Package (HiRAP) to the existing ACIP to add to the knowledge of reentry dynamics. This supplement provides accurate determination of microgravity aerodynamic coefficients at near orbital altitudes (up to 700,000 ft) heretofore unobtainable. The installation of the package has been accomplished and it will be flown on STS-5.

Figure 1.- ACIP with high resolution accelerometer package.



Power Generation and Energy Storage Utilizing Regenerative Fuel Cells

TM: Dale Denais/EP5
Reference OAST 2

The placement of a manned space station in low Earth orbit is presently being pursued by NASA as "the next logical step in manned space flight." This concept will require multikilowatts of electrical power to perform routine orbital operations and such specialized functions as satellite servicing, space construction, and materials manufacturing.

In the past, all U.S. manned space programs except Mercury and Skylab have utilized fuel cells because of their superior flexibility, weight, and cost factors. Fuel cells are today the most viable power system candidates for 1- to 2-week missions. However, the space station concept requires multiyear-continuous power in an alternating "daylight"/"nighttime" environment. Solar panels are an obvious solution to the "daytime" power requirements; and in the past, batteries were the power source for "nighttime."

An alternate means of providing power and storing energy for "nighttime" low Earth orbit operation is being pursued. This approach is to use a fuel cell that produces power and water during the dark side of the orbit and an electrolysis system that produces hydrogen and oxygen from the product water using solar-array-produced power on the light side of the orbit. These stored reactants are then used by the fuel cell. This concept is called a regenerative fuel cell system and is shown pictorially in figure 1.

The results of an 8-month study performed during the last year indicate that the approach of using regenerative fuel cells as an energy storage system is not only feasible but also practical and advantageous in many areas. Conclusions from this study include the following:

(1) High energy storage efficiency should be an important objective in selection and design of spacecraft power systems. This minimizes solar array size and cost, and reduces resupply for orbit makeup from solar array drag. Regenerative fuel cell systems can be designed with energy storage efficiency that is equal to or higher than present nickel hydrogen batteries.

(2) The regenerative fuel cell system has the best potential in a variety of areas. The advantages it offers include high efficiency, low weight, potential for long life, good emergency capability, potential for weight-saving by integration with other subsystems, the ability to take advantage of reactant residuals from the Shuttle, and the ability to service customer payloads at temporary, high power levels.

A joint effort between Lewis Research Center and JSC is presently underway to develop the technology of both the solid polymer electrolyte, solid polymer electrolyte (SPE) (acidic), and the capillary matrix (alkaline) for use in a regenerative fuel cell. These two technologies will be evaluated and compared by performing breadboard tests at JSC starting at the end of 1982 with a SPE system. This system is shown in figure 2. In early 1984, the testing of an alkaline breadboard system will be initiated. Development work will then be continued by producing an engineering model test article that will then bring the regenerative fuel cell technology to maturity by 1986.

Figure 1.- Regenerative fuel cell power generation and energy storage system.

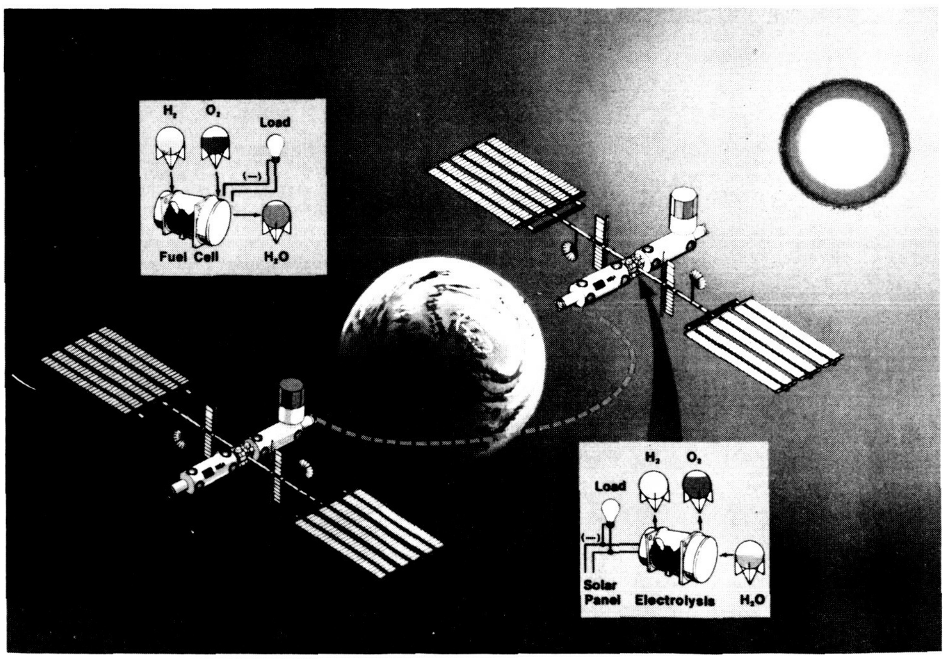


Figure 2.- Solid polymer electrolyte test station.

Thermal Management for Onorbit Energy Systems

TM: J. Gary Rankin/EC2
Reference OAST 3

For the next generation of space missions, long-lived space platforms are planned which may produce power levels of several hundred kilowatts. Efficient thermal management is mandatory because generation, transfer, and storage of the electrical energy needed for these applications will result in the dissipation of huge quantities of waste heat. A low cost, reliable orbital thermal management system does not currently exist capable of providing this level of heat rejection. Such a system would need to overcome limitations inherent in current system designs. Ways to increase energy capacity, reject waste heat, and provide power for a broad range of space applications will require an entirely new technical effort in thermal management.

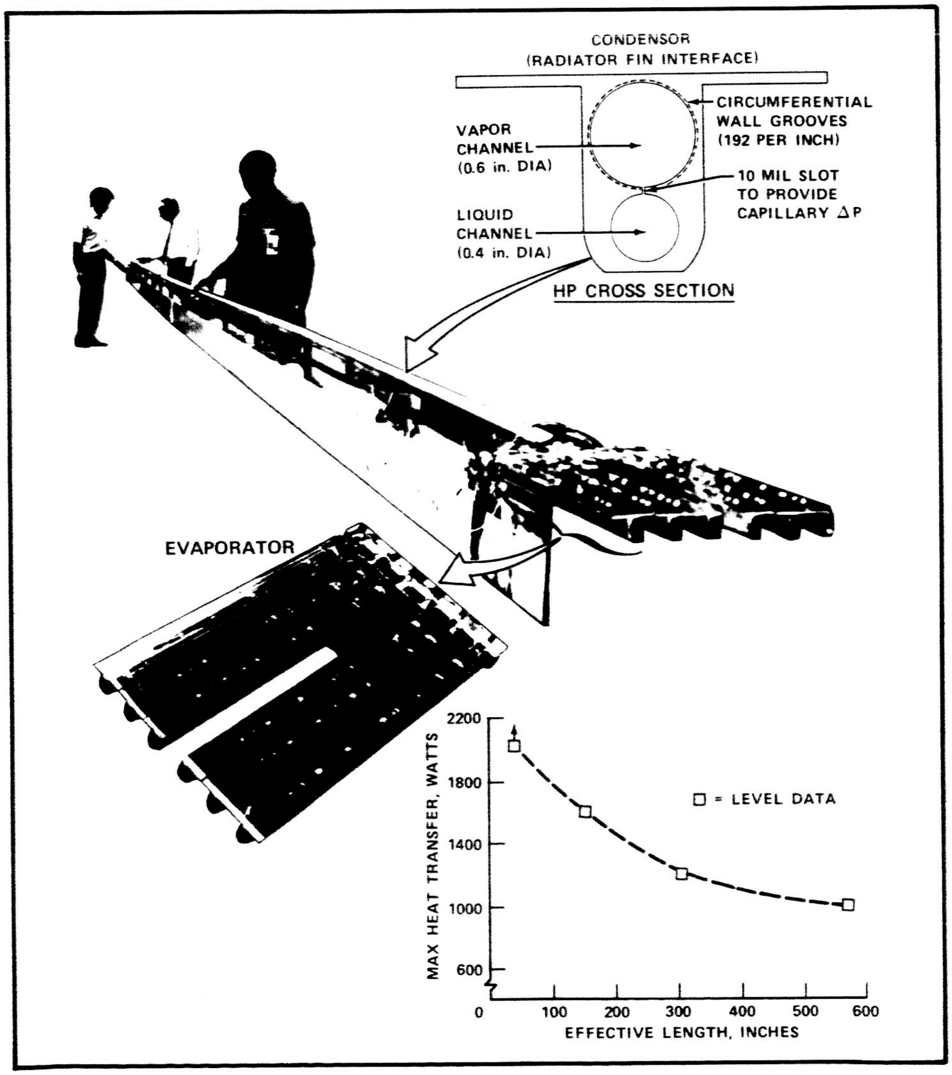
The key to the thermal management concept lies in the creation of a thermal "utility" system, analogous to municipal public utilities, where basic "trunk" lines are provided and into which individual customers can be integrated. The system must be designed so changes in location or load of individual customers have minimal effect on the utility's capability to serve loads of the remaining customers. Such a centralized system would allow reduced operational and payload integration costs, as well as reduced cost for all payload users, by having common instrument thermal designs. Keys to reduction in thermal management system costs are system modularity; subsystems integration; stepwise growth capability to very large satellites; volume and weight reduction; extended life by maintenance/replacement; and expansion of the thermal management technology base to provide simpler, more reliable systems.

To accomplish these goals, the system under study will consist of a central two-phase heat transport loop that is thermally connected to a variety of heat sources and sinks. The sources can be individual pieces of equipment or smaller versions of the central system, each transporting heat to its own variety of interfacing hardware. In keeping with the "utility" concept, not all of the potential interface locations would necessarily be filled during a particular mission phase. The location of the heat sources in relation to each other in the loop would not be critical (as it is in current pumped-fluid systems) since all the heat transfer is taking place at a fairly constant temperature via evaporation or condensation of the working fluid.

Development of the space constructable radiator portion of the system has progressed through the fabrication and laboratory testing of a full-size (50-ft long) dual passage, high performance heat pipe as shown in figure 1. Heat pipe performance demonstrated to date is approximately 600,000 watt-inches, which represents a factor of 5 to 6 improvement over the state-of-the-art of high capacity heat pipes at the beginning of this program. The design, fabrication, and checkout of a prototype test article comprising a representative portion of a complete system will follow, with thermal vacuum testing to be completed by July 1983.

A preliminary study of concepts for the centralized thermal bus, completed in March of 1982, indicated that a pump-augmented heat pipe was probably the most viable near-term candidate concept, with a completely passive capillary-pumped concept showing promise for long-term application. As a result of a competitive procurement, a contract is to be awarded in FY 1983 for a 3-year program to develop a thermal bus system concept from the initial design phase through hardware fabrication to thermal vacuum testing.

Figure 1.- Prototype heat pipe radiator.



Bubble Memory System Development

PI: Edgar A. Dalke/EH4
Reference OAST 4

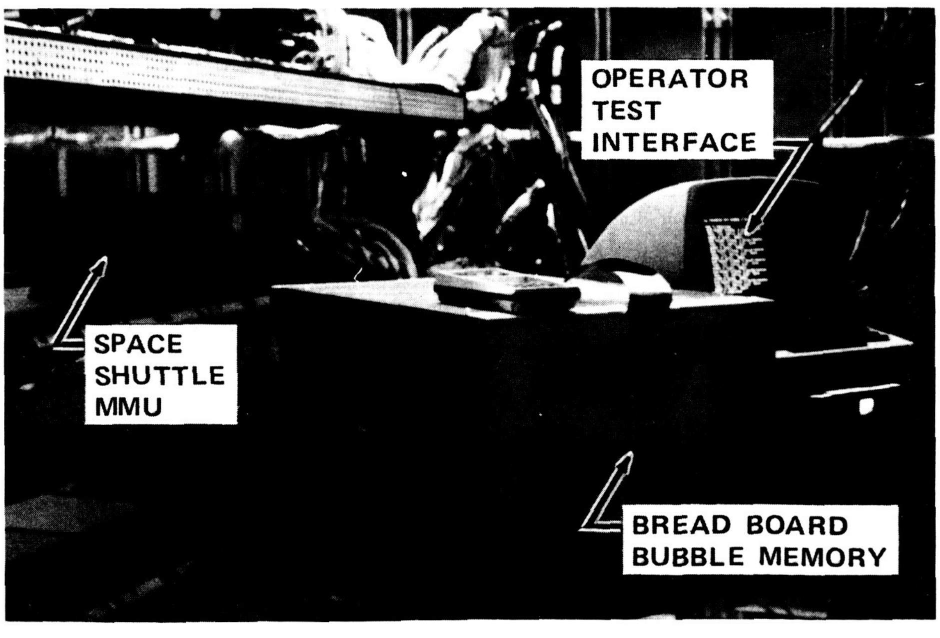
Today's technology in flight hardware mass memory is electromechanical magnetic tape systems, as represented by the Space Shuttle. These systems, however, have highly restrictive operations and applications, low life cycle reliability, and consequent high operational support costs. Bubble memory systems offer a potential solution to these problems for both the Space Shuttle and other spacecraft requiring large memory capacity. Solid state bubble memory technology appears to be at a point where a flight system can meet the necessary performance requirements with significantly higher reliability at lower costs.

The Johnson Space Center has current in-house activities investigating bubble technology and have proposed a joint effort with the Langley Research Center (LaRC) leading to the development of a space-qualified mass memory.

The basic approach is to target the existing Space Shuttle Orbiter mass memory unit (MMU) for replacement by a magnetic bubble system. The requirement is a one-for-one replacement which is totally transparent to the Orbiter software system as well as the electrical and mechanical interfaces. This requires three specific areas of activity· (1) the development of a space flight memory module with associated controller and interface devices, (2) development of an intelligent system controller which translates Orbiter mass memory operations and interfaces with the memory module controller, and (3) development of a system package for greater than 10^8 bits within the confines of the existing MMU physical dimensions. Development responsibility will be shared by JSC and the LaRC. JSC efforts will concentrate on the system controller resulting in a performance specification to be implemented by a selected system contractor. LaRC efforts will involve working with the system supplier and JSC to assure that the memory module satisfies requirements for performance, is compatible with technology evolution to higher density memories, supports the objectives for multifunction storage/retrieval applications, and satisfies critical space environment requirements.

The JSC in-house efforts consist of two phases each identifying a specific breadboard system. The purpose of Breadboard phase 1 is to demonstrate that bubble memory systems can substitute for the present Shuttle mass memory. It consists of one megabyte of currently available commercial bubble memories attached to an existing laboratory computer with a Space Shuttle serial bus interface. Software has been written to provide a one-for-one simulation of the present device. Breadboard phase 1 is currently being demonstrated by running the actual Shuttle Orbiter mass memory tests in the Shuttle Avionics Integration Laboratory (SAIL). See figure 1. The second phase of the in-house efforts (Breadboard phase 2) will involve the design and fabrication of a new system controller using the same bubble memory devices. Its purpose will be to specify the controller characteristics that are required to provide the one-for-one simulation of the present mass memory without affecting existing flight software. It will further formulate the new commands that will provide disk-type operation for future software programs.

Figure 1.- Mass memory breadboard tests in SAIL.



Multifunction Synthetic Aperture Radar Technology

TM: Kumar Krishen/EE4
Reference OAST 5

Synthetic Aperture Radar (SAR) systems have the potential for providing day/night surveys in nearly all weather conditions to a resolution not available with other systems. Current technology employing single-frequency SAR can produce mapping swaths of up to 100 kilometers. The functional requirements for precision geological and agricultural surveys include swaths in excess of 200 kilometers coupled with variable frequency, multipolarization, and high resolution.

To accomplish these objectives, NASA has developed a Multifunction Synthetic Aperture Radar program to develop technology for the fabrication of multimode, multimission SAR systems. The goal is to be capable of operating at selectable frequencies, polarizations, bandwidth, incidence angles, and wide swath with improved spatial resolution, reliability, and calibration. This technology will allow the fabrication of multifunction SAR's which will satisfy multimission objectives for a wide range of geology, agriculture and forestry, water resource, ocean, and polar ice applications in the same mission. The program element objectives are as follows:

1. Conduct studies, develop the design approaches, and demonstrate antenna system technology for multifrequency, multipolarization, distributed array, wide bandwidth, wide-swath SAR's.
2. Conduct studies, identify approaches, develop the necessary subsystems, and demonstrate calibration for Earth observation SAR systems.
3. Develop the design, fabricate, and conduct performance tests for an advanced distributed array SAR for Earth resources applications.
4. Develop technology to fabricate wide-band, wide-swath SAR subsystems.

Fiscal year 1982 accomplishments on the multifunction SAR technology program include (1) a plan for calibration subsystem testing based on completed analysis of SAR acquired data; (2) identification of design approach(es) for multifrequency, multipolarization microstrip, slotted waveguide, and interleaved waveguide arrays based on computer simulation and limited laboratory testing; (3) completion of a study showing the nonsuitability of shaped reflector, dielectric lens antenna configurations for multifunction spacecraft SAR's; and (4) identification of a design approach for aircraft verification of the distributed array SAR. Plans for FY 1983 include fabrication of antenna panels and SAR subsystems using FY 1982-identified design approaches (fig. 1).

Anticipated missions for the Synthetic Aperture Radar in the 1980's include Shuttle Advanced Microwave Experiment, Free-flying Imaging Radar Experiment, Aircraft Imaging Radar Experiment, Venus Orbiting Imaging Radar, and the U.S./Canadian SAR mission.

A Memorandum of Understanding (MOU) has also been signed by NASA and Air Force Systems Command (AFSC) to initiate joint SAR calibration program. The calibration system is shown schematically in figure 2. Other joint NASA/AFSC task areas have also been identified and plans for FY 1984 start have been made. These joint activities will result in major cost savings for both the AF and NASA.

Figure 1.- Dual frequency/dual polarization stacked antenna.

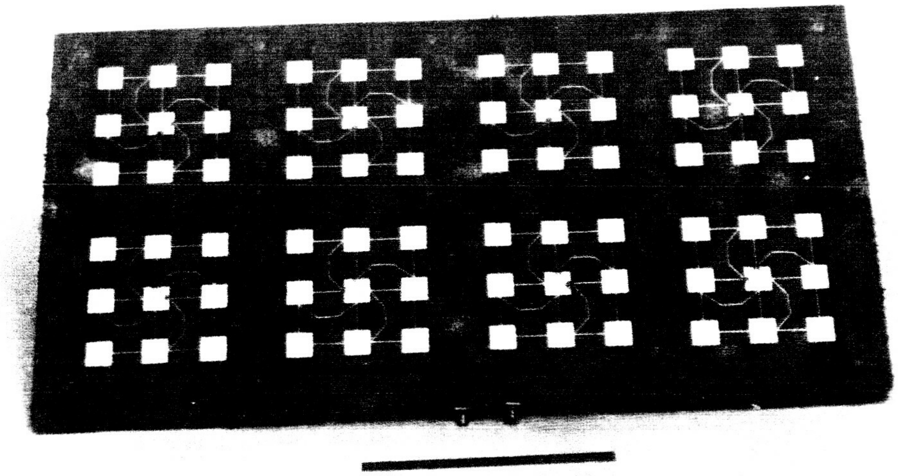
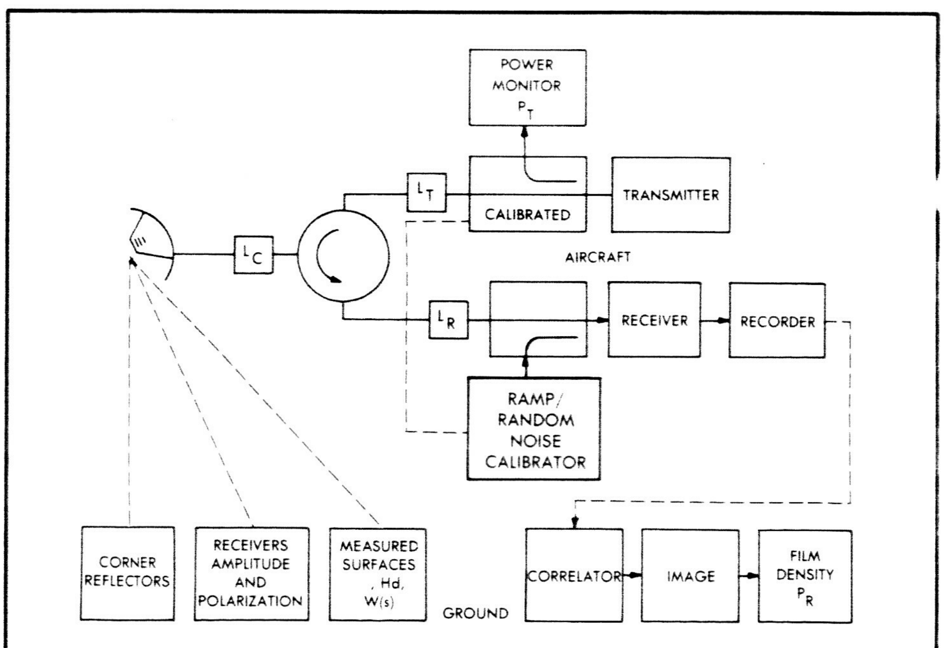


Figure 2.- Calibration System.



Advanced Manned Vehicle Onboard Propulsion Technology

TM: William C. Boyd/EP2
Reference OAST 6

As space operations progress toward the goal of routine aircraft-type operation, there is an increasing need for less hazardous propellants which will allow rapid and cost-efficient vehicle reservicing. The current propellant combination used in the Space Shuttle on-orbit propulsion systems is nitrogen textroxide and monomethyl hydrazine. These propellants are hypergolic, toxic, carcinogenic, corrosive, and expensive. Full protective clothing must be used when handling these propellants; the system must be decontaminated before components can be replaced; and other ongoing vehicle-servicing activities are normally terminated or severely impacted when these propellants are being transferred. For the propulsion systems of future highly reusable manned spacecraft, such as a second-generation Space Shuttle and manned orbital transportation vehicles, the hypergolic propellant combination will probably be phased out in favor of a noncorrosive, nontoxic, and less costly propellant combination.

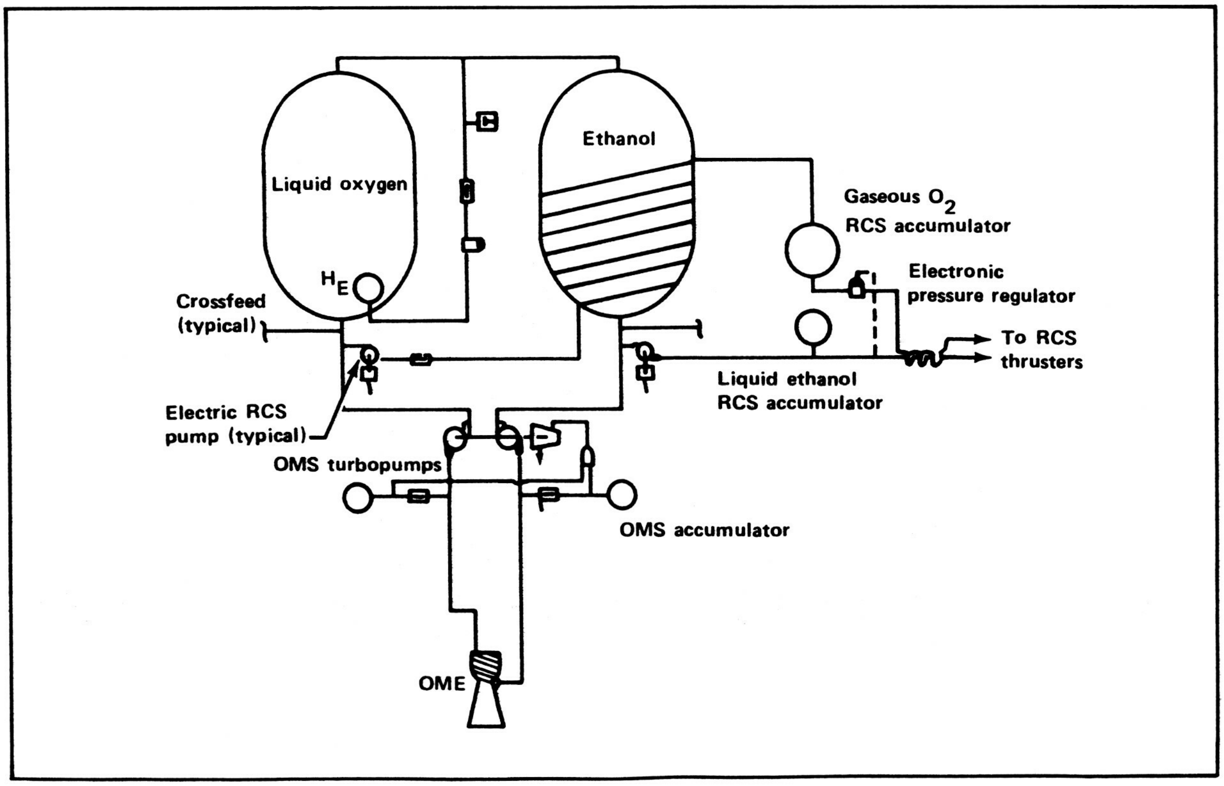
Propulsion systems design and critical component design studies have been conducted to identify viable alternatives to the current Earth storable hypergolic propellant combinations. The Shuttle on-orbit propulsion systems were utilized as the focus for this effort; however, the results also have applicability to orbit transfer and space station propulsion systems. The LOX/hydrocarbon family of propellants have been identified as the most applicable propellants. The LOX/hydrocarbon propellants exhibit the required performance and bulk density in addition to being low cost and nontoxic.

A broad matrix of hydrocarbon fuel and system design options were evaluated. Options included methane, propane, and ethanol as representative fuels coupled with pressure fed, pump fed, integrated system propellant storage, and feed options. Preliminary designs were established for critical components such as engines, pumps, and heat exchangers. Subscale injector and propellant cooling tests were conducted to verify critical engine design parameters.

As a result of the combined analytical and experimental efforts, a baseline system has been established which meets the design goals of a highly reliable system with flexible duty cycle capabilities as a potential replacement for the Earth storable hypergolic systems. The baseline system is indicated in figure 1. Basic features of this system include:

1. Nontoxic fuel and oxidizer minimizes ground handling hazards
2. Noncorrosive propellants improve component life potential
3. Ambient pressure feed to the reaction control system (RCS) maximizes duty cycle flexibility
4. Passive LOX gasification for simplicity and reliability
5. Electric pump to RCS accumulators for simplicity and reliability
6. Turbopump regeneratively cooled orbital maneuvering system (OMS) engine for performance
7. Ethanol fuel for low carbon combustion products and heat content for passive LOX gasification
8. Common OMS and RCS propellant storage for maximum storage mass, maximum duty cycle flexibility, and minimum weight
9. Potential 2000-lb payload gain over the current Space Shuttle auxiliary propulsion system

Figure 1.- Baseline LOX/hydrocarbon system.



Lunar Resources

PI: Richard J. Williams/SN7
Reference OAST 7

NASA long-range plans call for an eventual return to manned lunar activities. Recent studies have shown the feasibility of utilizing lunar resources for a variety of applications both on the lunar surface and in Earth-Moon space.

Lunar soil contains minerals rich in aluminum, iron, magnesium, titanium, and chromium. Abundant oxygen for fuel and atmosphere would be released in extracting these metals. The lunar surface is also a rich source of silicon, ceramics, and glass, as well as iron-nickel particles.

Over 90% of the mass and fuel for a lunar base or large orbital operation center could be derived from lunar material. A payload launched from the Moon requires less than 5% of the energy needed to launch the same mass from Earth. Raw material for large space structures are therefore more energy-accessible from the Moon.

To achieve economy of extraction, concentration of minerals must be enhanced. JSC has directed activities toward developing equipment and techniques for dry electrostatic separation of mineral components in simple lunar soil analogs. A mineral separation laboratory has been established in which two generations of electrostatic generators have been designed and tested based on commercial models. Electrostatic mineral separation data have been developed on mixtures of anorthite, ilmenite, olivine, and pyroxene in size ranges from 45 to 50 μm. Anorthite and ilmenite are prominent components in many lunar soil samples. They are potential sources of aluminum and titanium, respectively. Olivine and pyroxene are the common diluents of these soils.

Electrostatic separators offer significant advantages in space application because they are relatively lightweight and operate efficiently in vacuum over a very wide temperature range with low power consumption. The most successful separations have been obtained with the electrostatic separator (fig. 1). It employs an S-shaped grounded slide that imparts a horizontal component of velocity to the falling mineral feed and thus deflects the grains into the electric field established by an elliptical high voltage electrode a few centimeters from the slide surface. The deflected grains fall into nonconductor, middling, and conductor bins set at the foot of the slide. Conductive materials preferentially move toward the high voltage electrode regardless of electrode polarity. Nonconductors are either undeflected by the field or move toward the electrode opposite in polarity to their contact potential.

Using this apparatus, ilmenite concentrations in olivine mixtures have been increased from 10 to 95% after one pass. Similarly, anorthite in pyroxene mixtures show 46% gains (50 to 96%), olivine in anorthite mixtures 84% gain (10 to 94%), and pyroxene in olivine mixtures 54% (50 to 95%). These data were obtained at 1-atmosphere and 200° C for mixtures in the size range 150 to 250 μm. Figure 2 shows the mineral separates obtained from a 1:9 ratio ilmenite/olivine mixture after one pass. The dark fraction in the right-hand bin is 95% ilmenite. Separations for smaller size ranges have not been as successful, but the data so far obtained suggest that vacuum operation will greatly enhance the separation of the finer fractions. Contact charging of nonconductor and induction charging of semiconductor mineral species in the 150-to 250-μm range have been estimated from electrostatic displacement data in the separator and are in good agreement with more direct measurements made by other researchers.

Future activities include a series of separation runs for obtaining: (1) maximum mineral recoveries obtained by repassing binary mixtures in the slide separator, (2) the effects of various field strengths on mineral recoveries and purities, (3) the effects of mixed size fractions on separation performance, (4) separations of mixtures of more than two components, and (5) separation behavior in vacuum. Also planned are direct charge measurements on individual terrestrial and lunar soil mineral grains of the test species to measure electrostatic forces due to grain charging. Electrometer measurements of bulk charge on fractions collected will be compared with the other methods of estimating mineral grain charges. These data will be used for the design of a separator specific to lunar soil minerals.

Figure 1.- Schematic of mineral separator.

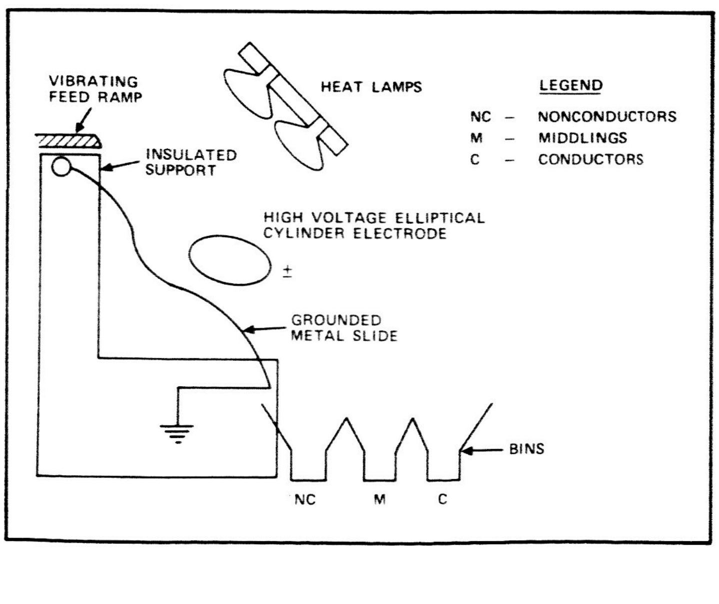
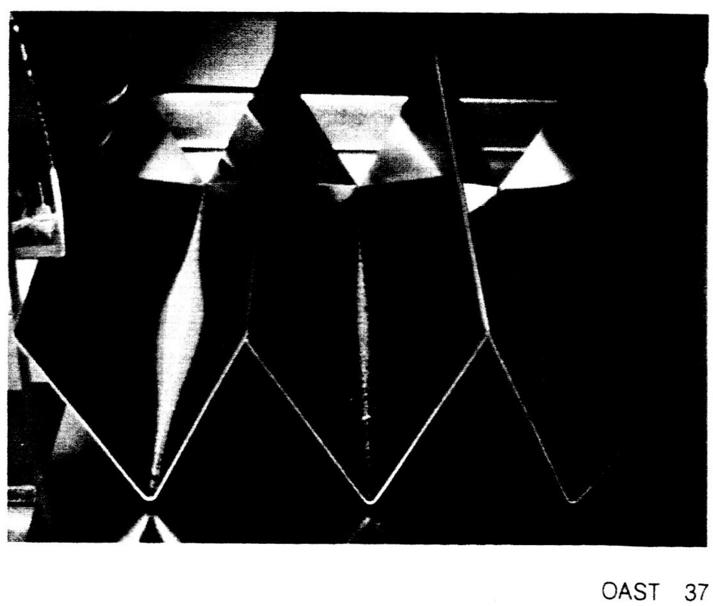


Figure 2.- Mineral separates of electrostatic separation test device.



Aircraft Fire Safety and Testing

TM: Daniel E. Supkis/ES5
Reference OAST 8

The general objectives of the program, known as the Firemen Program, are to develop and apply fire resistant materials technology to ramp and survivable crash fires in commercial aircraft and to conduct systems testing of new and modified fire resistant materials in configurations such as aircraft wall and floor panels, seats, fuselage sections, galley structures, and the overall cabin area. The detailed objectives of the program are the following:

1. To demonstrate that the introduction of fire barrier materials in the exterior wall of the aircraft will prevent an external fuel fire from entering closed and intact habitable areas for the minimum 5-minute period needed for passenger evacuation.
2. To demonstrate that a closed and intact cabin will not reach a temperature of 400° F (a lethal temperature for human beings) and will not generate smoke or toxic gases at this temperature as a result of external fire.
3. To demonstrate that a fire in the area of a cabin opening will not propagate throughout the cabin area during the minimum 5-minute evacuation period.

The aircraft fuselage burnthrough test program on Boeing 727 sidewall configurations was completed. The last three items of the scheduled program consisted of panels containing polyimide foam, fiberfrax, and asbestos foam/glass mat insulations. These fire-retardant materials formed effective fire barriers, but as soon as the Z-bars (to which the Kapton ceramic fiber-reinforced insulation bags were fastened) melted, the insulations fell into the fire. As of this date, no effective insulation retention system is available to hold the insulation in place against the wall board.

Two supplementary 727 fuselage panels were tested to obtain two additional data points. The first burned through within 3 seconds of the baseline. The second burned through in 9 seconds longer time than the baseline.

A lightweight, high strength floor panel has been developed jointly by JSC and Boeing. The panel, composed of a Ciba-Geigy honeycomb core and unidirectional carbon fiber/phenolic face sheets, was fabricated with approximately 30 mils L-4805 Fluorel elastomer on the bottom side. The Fluorel enhances the acoustic attenuation, improves the burnthrough properties, and prevents the corrosion of the aluminum structure by the carbon fiber face sheet. One of the panels, without Fluorel, has been installed in the United Airlines surveillance booth in the Sea-Tac airport and two with Fluorel in the high traffic area of a Pan American 747 airplane. The Fluorel laminated floor panels are lighter in weight than the polyimide foam-filled honeycomb baseline panels. The improved acoustical properties of the Fluorel elastomer further saves weight by permitting the heavy lead/vinyl acoustical liner to be removed.

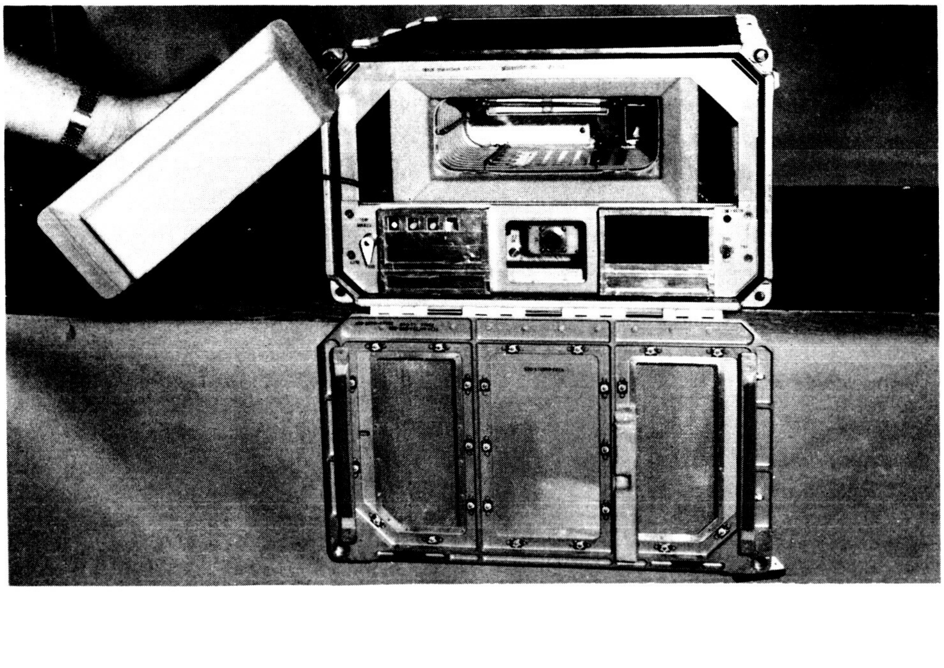
The final report of the polyimide resilient foam test program was published in 1982. International Harvester started production of the foam and mounted an advertising campaign resulting in the receipt of approximately 4000 inquiries. Quantities of the foam have been supplied to the U.S. Navy for use as insulation and liners in lockers onboard ship. It has flown on the Space Shuttle as stowage cushioning in the medical and tool kits in the Orbiter mid-deck. A significant application of polyimide foam on the fourth Space Shuttle mission was used as thermal insulation in the refrigerator/freezer. This was the first time a refrigerator/freezer had been flown (see fig. 1).

The two floor panels, containing polyimide foam, that were installed in two United Airlines 747's are still functioning well after 1-1/2 years and 11 months, respectively. International Harvester has formulated a foam with improved fatigue properties, and samples are being evaluated.

A program has been initiated at Chemtronic, Inc., to develop a rigid closed-cell polyimide foam and a production capability to make it commercially available. This foam is to be used in the fabrication of cargo bay floor panels and galley structures at Boeing Commercial Airplane Company and Weber Aircraft Company, respectively. Both of these companies are cooperating with Chem-tronics on the program.

The modified fluorcarbon elastomer, Fluorel L-4805, was developed by 3M and quantities forwarded to General Veneer for the fabrication into lightweight wall panels. Flat panels, 4 ft by 4 ft, were made wherein the Fluorel was sandwiched between phenolic glass face sheets. Panels were sent to the aircraft companies for their evaluation. The panel received at JSC weighed 0.281 lb/ft^2. A sample showed no burnthrough when tested on the Lennox burner. General Veneer will fabricate a flight panel at Lockheed-Burbank, and it will be installed in a L-1011 for flight evaluation.

Figure 1.- Polyimide foam used in the refrigerator/freezer flown on STS-4.



In Situ Instrumentation for Nuclear Waste Repositories

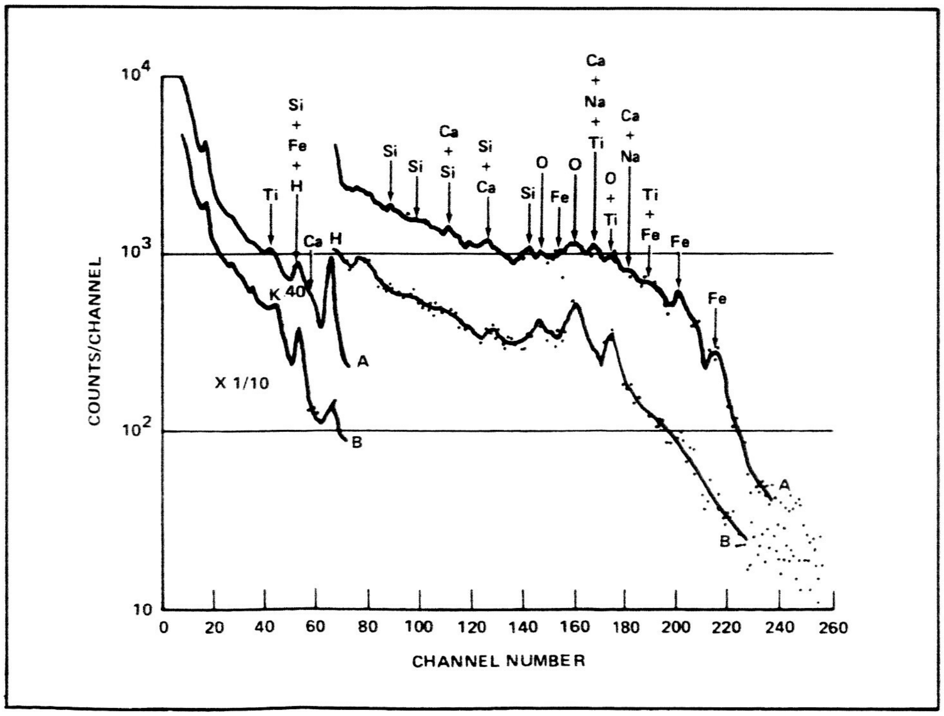
PI: James E. Keith/SN3
Reference OAST 9

The Nation faces a serious problem of how to deal with increasing quantities of radioactive wastes. Although space-related concepts such as disposal to the Sun or the Moon have been studied, the leading candidate solution is deep burial on Earth. Although geologically stable areas can be found, it is still necessary to establish that any site chosen will contain wastes that may leak from primary containers over time periods extending to thousands of years. Very sensitive devices must be used that can measure the movement of artificial tracers in goundwater that simulate the migration of dangerous, radioactive elements. These measurements need to be made without modifying the character of the natural groundwater flow.

A device that was first proposed for planetary exploration is being developed for use as a sensitive tracer of elemental migration. The significant radioactive elements, such as uranium and plutonium, are simulated in this technique by nonradioactive rare Earth elements called lanthanides. These lanthanide elements can be measured by a technique called pulsed neutron activation analyses, in which short bursts of 14 MeV neutrons are produced by a pulsable source. The interactions of the neutrons as they migrate through the rock are sensed with gamma (NaI and Ge) and neutron (He^3) detectors. Because the neutrons travel several tens of centimeters in rocks, tests can be devised that do not affect the primary fluid flow fields. Since many cycles of neutron production and detection must occur to build up the spectra such as those shown in figure 1, the experiment must be computer-controlled. The development of this technique involves the extraction of quantitative information from such spectra.

During 1982, a device has been assembled and integrated with a computer which controls the system and accumulates spectra. A test bed has been established that provides a simple yet realistic analog of a natural geologic situation. Experimentation in the coming year will focus on understanding the operational characteristics of the system and the data analysis procedures to extract data from the spectra.

Figure 1.- Neutron-induced gamma spectra from basalt.



Space Sciences and Applications
Lunar and Planetary Sciences

Office of Space Sciences and Applications

Summary

Lunar and Planetary Sciences

Lunar and Planetary Science is carried out through a combination of flight missions, ground-based (or Earth-orbital) observations of planets, laboratory research on samples of solar system bodies, experimental duplication or simulation of planetary processes, and synthesis of the data from all of these sources. The wealth of data and samples returned by the Apollo lunar missions are still being studied and evaluated by scientists at the Johnson Space Center (JSC), proving that scientific progress can continue long after the operational phase of a mission has ended. However, new sources of data are also important in providing new or otherwise unobtainable insights.

Research at JSC continues to concentrate on the inner planets and small bodies of the solar system, whose surfaces are accessible to remote observation from Earth or by spacecraft, and to collection of samples for analysis in terrestrial laboratories. The study of these bodies in the solar system is being tied to an understanding of the geology of the Earth in an interactive manner, improving our understanding both of Earth and the other planets. In an initiative begun this year, the JSC has begun the process of defining the future scientific exploration and utilization of the Moon, which is anticipated to be a major NASA program in about 20 years.

Some highlights of JSC research are described in this summary and a selection of research reports are included in the significant tasks section.

Lunar Science

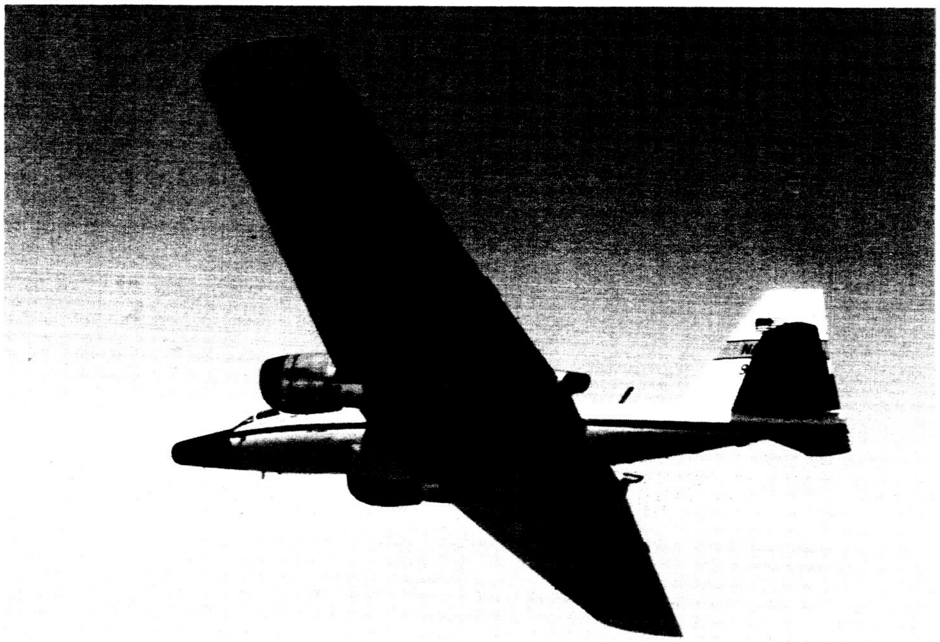
A major emphasis is being placed on understanding the early crust of the Moon. New rock types have been identified among small fragments in composite rocks called breccias, created over 4 billion years ago by intense meteoroid bombardment and mixing of the lunar surface. Ferroan anorthosite is an early rock type that is found at several lunar locations and is difficult to derive from the norite, which is also a major crustal rock type. Models are being constructed to determine the relationship of these rock types to the undifferentiated original lunar matter, which will then allow better characterization of the composition and chronology of the lunar crust. A key element in this research is the experimental determination of the distribution of trace elements of the rare earth element series between common lunar minerals and melted rock. Laboratory simulations duplicating conditions in the deep lunar crust provide another means of evaluating the relationships between rocks, the environment of formation, and the chronology necessary to make a coherent picture of lunar development.

Another active area of lunar research involves analysis of the mineralogy, composition, and sequence of deposition of the fragmental regolith that constitutes the upper few meters of the Moon. This layer records a sequence of erosion and deposition by impact processes. More importantly, the lunar soil grains contain evidence of the solar radiation received while the grains resided near the surface. The content of noble gases (e.g., neon, argon, krypton) in lunar core samples as a function of depth has been a continuing tool to characterize the irradiation history of the cores.

Origin of the Solar System

Meteorites and cosmic dust represent samples of material that has not been extensively altered since the solar system formed 4.5 billion years ago. JSC has collected stratospheric dust since 1981 on WB57 and U2 aircraft (fig. 1) using inertial wing-mounted collectors. The JSC cosmic dust col-

Figure 1.- WB57 aircraft with wing-mounted dust collectors.



Remote Sensing

Some of the planets can only be studied by remote sensing. However, the interpretation of mineralogical and chemical composition of planetary surfaces raises complicated issues in spectroscopy and data interpretation. Even apparently simple cases are not fully understood in terms of the physics of light scattering. In new work at JSC, Kubelka-Munk scattering theory has been applied to planetary remote sensing data to gain new insights into spectra for Mars and the Moon. Experimental synthesis of possible martian surface minerals continues in conjunction with laboratory investigation of reflectance spectra.

Technology

In order to continue at the forefront of expansion of knowledge, new technology must be developed. JSC actively seeks to develop instruments and techniques that support its research programs and open future opportunities. Highlights of this technique development during fiscal year 1982 include: establishing the new cosmic dust-clean laboratory and sample handling procedures; development of technique for analyzing tiny fluid inclusions; continuation of the development of an isotope dilution-mass spectrometer for use on automated spacecraft; and the addition of a new vertical hypervelocity impact facility for simulating collisions with icy satellites of Jupiter and Saturn. Other technology development that may potentially be utilized for planetary exploration is described in the Office of Aeronautics and Space Technology section of this report.

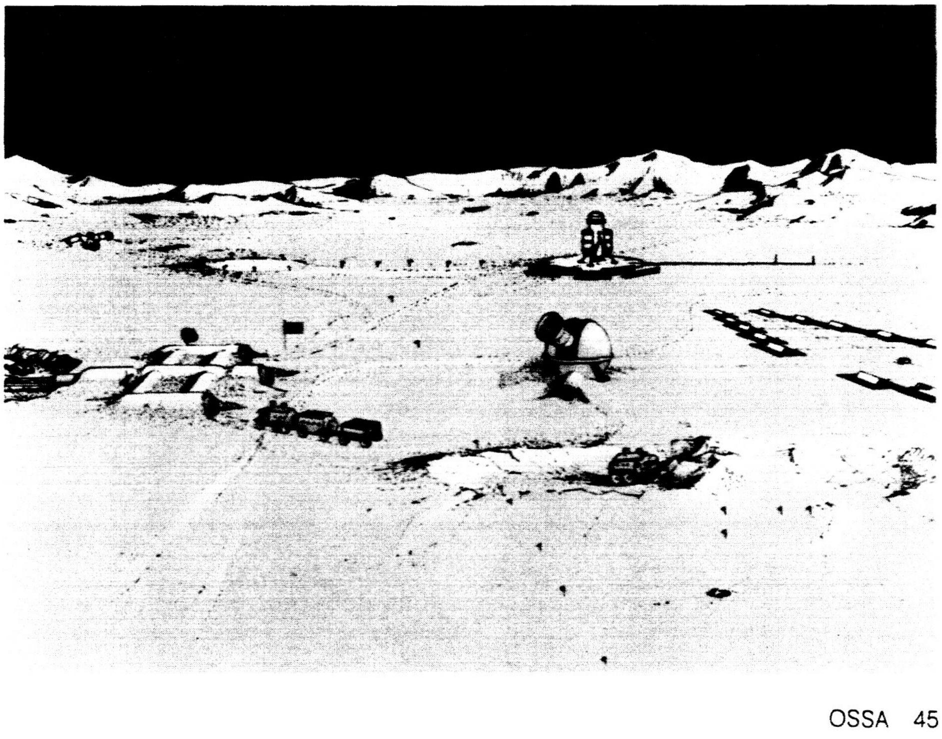
Lunar Exploration

The completion of the flight test phase of the Space Shuttle and the imminent first operational mission has heightened interest and excitement about the future of space activities. The Shuttle is but the first step in a process that can be viewed as an expansion of human activity into space — first, near Earth, later farther out into the solar system and eventually beyond. However, to systematically exploit these expansionary activities, near and intermediate goals and objectives need to be established to focus development activities. Looking toward the turn of the next century, a manned research base on the Moon is one of the possible goals that must be considered by NASA and the United States. In order to lay the basis for that consideration, the JSC has begun to lay out the rationale for a Moon Lab and steps by which such a program would be carried out. The goal is to establish the lunar research base by 2007, the 50th anniversary of the first artificial satellite, launched in 1957. This proposed work has not yet been funded by NASA.

A base of operations on the Moon is qualitatively different than the space stations that will be developed in the next two decades, because the Moon has substance, firm footings for extended structures, protection from high energy radiation, and elements and compounds from which material objects can be fabricated. Thus, a lunar program will have scientific and applications components. A better understanding of the formation and history of the Moon, the Earth, and other planetary bodies will be a prime objective of the initial station. The buildup of scientific capabilities will allow the Moon to be used as a research base for astronomy, high energy physics, life sciences, and other research. Also important will be research on how to use the lunar environment and materials to the benefit of humankind. Figure 3 pictures this research facility as defined in earlier JSC studies.

A lunar base would be a major undertaking that would require a space transportation infrastructure such as that shown in figure 4. The Space Shuttle or a heavy-lift launch vehicle provides for delivery of personnel and components to a transfer station in Earth orbit. A reusable Earth-Moon delivery system, either a high thrust system as is being investigated for orbital transfer vehicles (OTV) or a low thrust, slower-trip time system could be used to convey payload to a lunar orbital station. A descent vehicle is required that performs like the Apollo lunar lander to deliver cargo to the surface. That vehicle should probably be reusable, but whether it would be the main means of transporting material from the Moon to lunar- or Earth-orbit is questionable. One currently unanswered question of lunar science is whether volatile substances usable as rocket fuels are available. Although lunar samples are almost devoid of volatiles, there is speculation that caches of volatiles have been cold-trapped at the lunar poles. If that is not the case, an alternative means of transportation from the lunar surface is required perhaps electromagnetic induction powered by solar energy. Such a "mass driver" facility, capable of launching several kilograms into orbit,

Figure 3.- Conceptual lunar research facility.



is pictured in figure 5. This infrastructure also would serve many other purposes, and provides an avenue for future growth of space capability.

The Moon is the "high ground" of near-Earth space. To go to the nearest planet is significantly harder. However, the Moon may also be a stepping stone to the planets, particularly if useful resources can be located there. The initial definition done this year is only the start of a very long process of study, technology development, and scientific exploration that will be carried out in the next 20 to 30 years. The program can be modest in cost, although it will certainly include unmanned precursor missions, such as an advanced Lunar Mapping Satellite, which could be launched around 1990, and automated surface laboratories for the 1995 to 2000 time period.

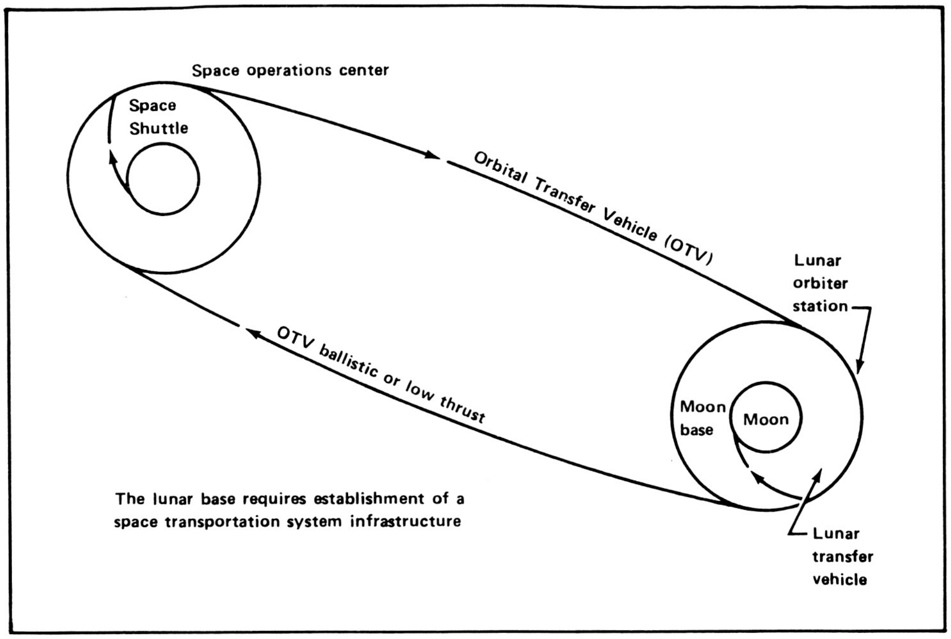
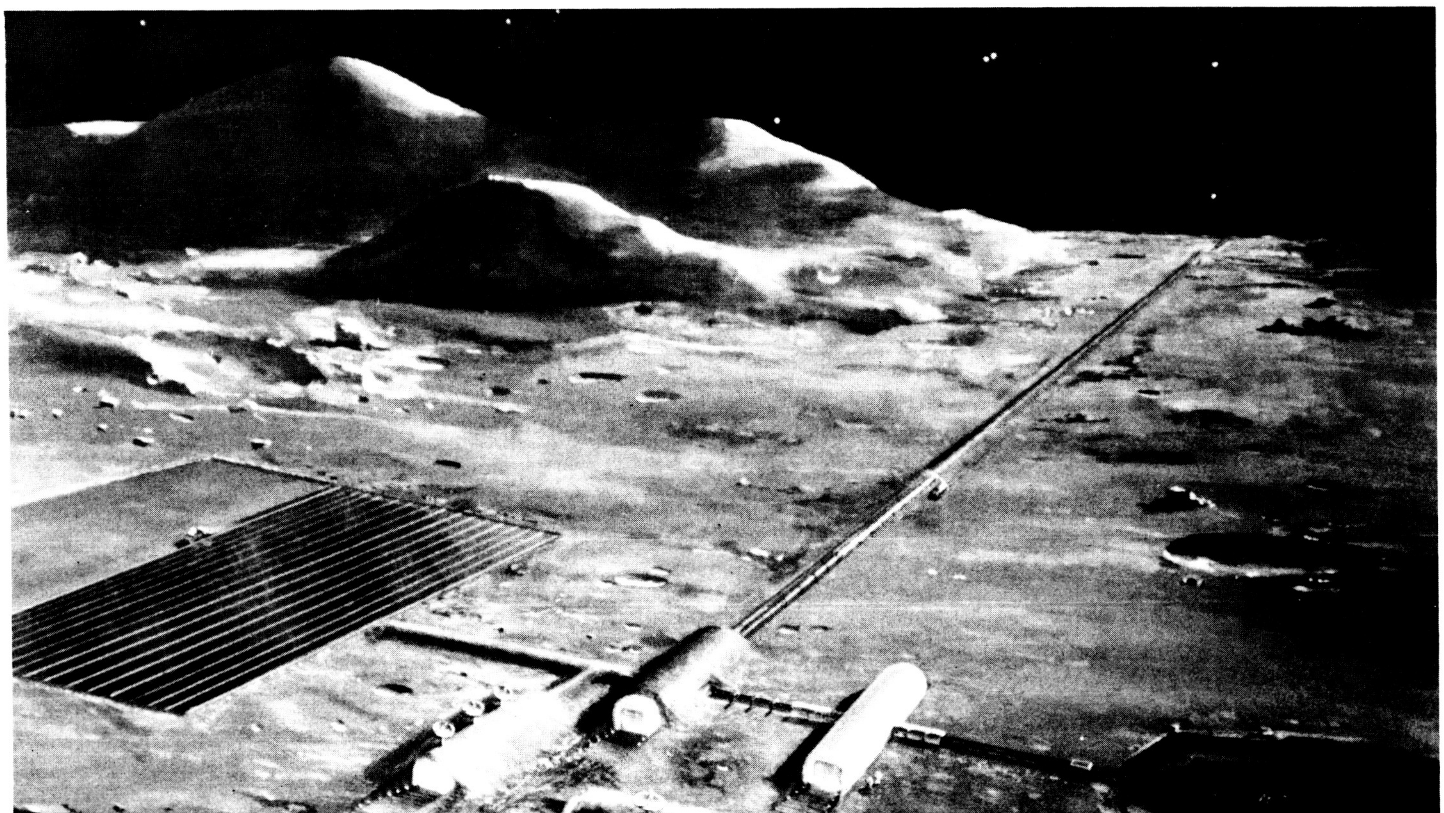


Figure 4.- Space transportation system infrastructure.

Figure 5.- Lunar mass driver facility.



Space Sciences and Applications
Lunar and Planetary Sciences
Significant Tasks

Experimental Trace Element Geochemistry

PI: Gordon A. McKay/SN7
Reference OSSA 1

Igneous processes involving the production, migration, and crystallization of silicate melts are known to have been important in the formation of planetary crusts on Earth, the Moon, Mars, and some meteorite parent planets. They probably were important on Mercury and Venus as well. Such processes leave distinctive signatures on the chemical and isotopic compositions of the rocks they produce. One of the goals of planetary geochemists is to try to reconstruct the history of these processes by deciphering the chemical signatures found in rocks from planetary crusts. Some particularly useful signatures are carried in the abundances of elements that are present in most rocks in concentrations of a few hundred parts per million or less. The abundances of these "trace" elements are strongly influenced by their "partitioning" between silicate melts and rock-forming minerals in contact with these melts. Some trace elements may be preferentially incorporated into one mineral, others into another mineral, and still others strongly excluded from all minerals and instead partitioned into the melts. Hence, a record of the history of melt-mineral interactions will be retained in the trace element abundances of resulting rocks.

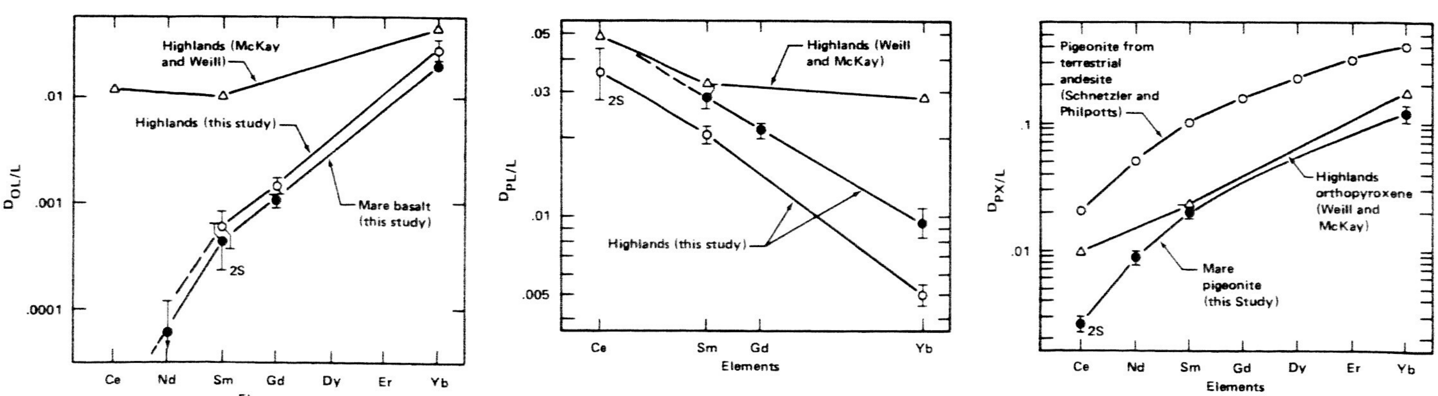
One approach to using trace element abundances to unravel the history of these melt-mineral interactions is through mathematical modeling. In this approach, a plausible history of melt-mineral interactions leading to a particular sample is postulated. The effects of this history on trace element abundances are then modeled, and the resulting calculated abundances are compared with observed abundances for that sample. This approach often allows certain postulated histories to be ruled out as incapable of producing samples with observed trace element abundances, and focuses attention on other postulated histories which result in good matches with observed abundances.

Recently, a program of distribution coefficient studies was started in the JSC experimental petrology laboratory. The experimental approach consists of equilibrating pertinent synthetic rock compositions at various near-liquidus temperatures and pressures, quenching the equilibrated charges to room temperature, and measuring the concentrations of the elements of interest in the resulting crystals and surrounding glass. These measurements are made by using special electron microprobe techniques with sensitivities of approximately 10 parts per million.

Work has focused on the partitioning of rare Earth elements (REE) between olivine, pyroxene, plagioclase feldspar, and lunar mare and highlands basaltic melts. Partition coefficient, D_1 (weight ratio of the concentration in the mineral to its concentration in the adjacent melt), appears lower for the REE on all the new study cases (see fig. 1). It is believed that these differences result from a combination of more precise analytical techniques and from large differences in the compositions of the melts.

Model calculations were performed to investigate the implications of the new or revised olivine, plagioclase, and pigeonite REE distribution coefficients for the petrogenesis of lunar anorthosites, a major constituent of the original lunar crust. Results suggest that formation of anorthosites via a process approximating simple crystal accumulation from relatively unfractionated liquids does not violate constraints imposed by REE systematics. Similar calculations using the earlier coefficients, violated these constraints. Considerable uncertainty still remains in the absolute and relative values for Eu and the trivalent REE for application to anorthosite petrogenesis. It is important to continue investigating distribution coefficients for application to this problem.

Figure 1.- Mineral/melt coefficient for rare earth elements.



(a) Olivine (b) Plagioclase (c) Pyroxene

Regolith Dynamics from Lunar Cores

PI: David S. McKay/SN6
Reference OSSA 2

Although the last cores collected by astronauts on the Moon were returned to Houston 10 years ago, detailed studies of lunar cores are revealing some new clues to the history and dynamics of the lunar regolith. Detailed studies during the past year of an Apollo 15 core (15007/8) shows that the lunar regolith is more complex than previously supposed. This core was collected from the slopes of the Apennine Front in an area of complex local geology on the flanks of St. George Crater. This is the only highland area core to be opened and studied from the Apollo 15 site.

Detailed petrologic, ferromagnetic resonance (FMR), and rare gas studies show that the core consists of four stratigraphic zones. The uppermost zone from 0 to 18 centimeters shows a range of FMR and agglutinate values. Relatively high $^{131}Xe/^{126}Xe$ ratios indicate that the soil in this zone was originally irradiated at greater depth, probably greater than 50 centimeters. This zone is interpreted as ejecta deposits from a 5-meter crater directly adjacent to the core site. Unlike the top layers of many lunar cores, it contains no obvious sign of a reworking profile. This means that the regolith represented by the core did not remain relatively static on a time scale long enough for micrometeorites to garden it in a systematic way and create a detectable profile in the maturity as measured by FMR.

The entire core lacks a reworking profile. See figure 1. The regolith represented by this core is therefore appropriately called a dynamic regolith rather than a static regolith of the type sampled by many other lunar cores.

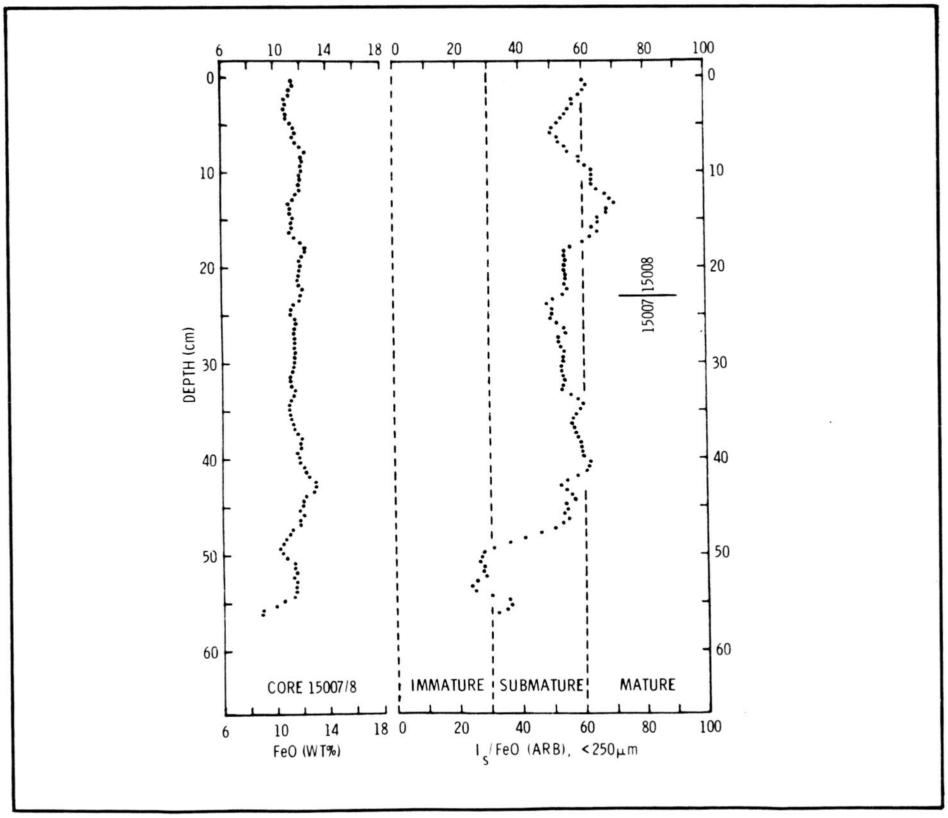
The other sampled cores apparently have not been grossly disturbed for perhaps 100 or 200 million years. It seems very likely that the difference between the dynamic regolith represented by core 15007/8 and the other static cores is related to the local geologic setting and, more specifically, to the slope of the surface in the vicinity of the core site. This slope causes a net downslope movement of material which tends to mix and homogenize the regolith and prevents the development of maturity profiles. While the presence of downslope movement in the lunar regolith has been a reasonable idea for a long time and has been inferred from photographs, these cores are furnishing the first real data on the effects of this process on lunar stratigraphy, maturity, and exposure relationships.

The zone from 49 to 55 centimeters is somewhat chaotic, is relatively low in maturity, and contains surprising large amounts of green glass, about 25 percent. This green glass is identical to the green glass droplets found earlier in clods and breccias from near Spur Crater. The presence of this green glass in abundance in the bottom of core 15007/8 shows that green glass is common constituent of the regolith all along the Apennine Front. This green glass is interpreted as the remnants of a volcanic pyroclastic ash layer that once blanketed the lunar surface in this vicinity and apparently was erupted at about the same time as the Apollo 15 mare basalts.

From 18 to 49 centimeters, the core consists of relatively well mixed regolith of intermediate maturity and shows very little structure. This zone is interpreted as a zone of mixing caused by downslope movement related to the Apennine Front slope. The lowermost zone, from 55 to 57 centimeters, contains the most highland-like soil yet identified at the Apollo 15 site. It contains only about 9 percent FeO. It is relatively low in maturity.

Detailed studies of this core have revealed a wealth of data directly related to lunar regolith dynamics. A comparison of dynamic cores with static cores may set limits on the effects of such lunar surface processes as downslope movement, crater ejection, crater filling, lateral movement, and other dynamic processes. Rare gas studies conducted in conjunction with other studies can add the additional parameter of time to our understanding of these complex processes. The complexity of these cores makes exact interpretation difficult, but detailed studies may lead to a better understanding of lunar regolith dynamics and, by analogy regolith dynamics on asteroids and on other satellites.

Figure 1.- Apollo 15 core 15007/8 sample analysis.



Cosmic Dust Program

PI: Uel S. Clanton and James L. Gooding/SN3
Reference OSSA 3

It has long been known that interplanetary space is populated by dust particles of unknown origin. Various suggestions for sources of dust included residual material from the formation of the solar system, material ejected from planetary or asteroidal surfaces by energetic impacts, or exotic material from interstellar space. However, the most widely discussed possibility for the origin of cosmic dust is disaggregation of comets. Laboratory analysis of cosmic dust particles should help answer questions regarding their origins and possibly provide the eventual identification of a cometary particle.

The high speeds of cosmic dust particles in space (10 to 70 km/sec) preclude particle collection by spacecraft. Hypervelocity impacts destroy the particles and produce microcraters in the surfaces which are struck. Fortunately, Earth's stratosphere has proven to be fertile territory for the collection of cosmic dust. Although incoming space particles experience atmospheric frictional heating, a significant proportion of the smaller particles (<100 μm size) neither melt nor vaporize during entry but survive intact and are slowed by atmospheric drag to gravitational free-fall speed. At 20-km altitude, 10 μm cosmic dust particles are concentrated about 1 per 1000 m^3 and fall at speeds of only 0.5 to 1 cm/sec. Given those conditions, airborne devices can be used to collect sufficient quantities of cosmic dust to support meaningful laboratory studies. See figure 1.

In addition to cosmic dust, particles collected from the stratosphere include sulfate aerosols formed in the stratosphere, solid-fuel rocket exhaust products, reentering spacecraft debris, and ash produced by large, explosive volcanic eruptions (fig. 2). Fortunately, optical microscopy, scanning electron microscopy, and elemental analysis by X-ray energy-dispersive spectrometry can be used to distinguish cosmic from noncosmic particles on the basis of particle morphology and composition. Cosmic dust particles can thereby be identified for further detailed study although noncosmic particles also remain available for other types of studies. Since May 1981, JSC has collected stratospheric dust by using inertial-impaction collectors mounted under the wings of research aircraft. On WB-57F aircraft, four collectors are mounted in each of two pylons; on U-2 aircraft, current configurations set a limit of two collectors in a single pylon. At an altitude of 17 to 20 km, each collector is extended into the laminar airstream with the collection surface normal to the air flow. Particles are captured on impact by a thin coating of silicone oil (kinematic viscosity of 600 000 centistokes) applied to each collector. At tropospheric altitudes, or when otherwise not in the active sampling mode, each collector is retracted into a sealed canister to prevent contamination. All pre- and post-flight handling of collectors is performed in a Class 100 clean room at JSC using techniques specially designed to minimize contamination.

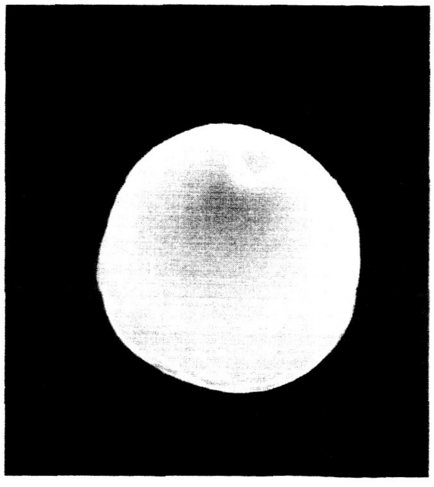
Particles are retrieved from collection surfaces, washed with hexane to remove residual silicone oil, and then characterized by nondestructive techniques. Those preliminary data are published in catalogs which are distributed to interested members of the world's scientific community. Scientists submit formal requests for specific particles (in some cases, for entire collection surfaces) for detailed research in their laboratories. The particle collection is preserved at JSC and used to supply documented samples in support of requests which have been approved by an outside scientific review committee.

Since its 1981 inception, the JSC program has flown 40 collection surfaces on WB-57F aircraft and six on U-2 aircraft. Two complete catalogs and two newsletters, describing a total of about 300 particles, have been sent to more than 260 requesters in 24 countries. Approved sample requests have generated the allocation of five whole collection surfaces and about 170 individual particles (including uncataloged particles) to eight scientific research groups. Large-area collectors currently being designed should eventually provide an adequate supply of large (+ 50 κm) particles which are of special interest to many researchers.

Contributions have also been made to studies other than that of cosmic dust. It has been shown that the JSC stratospheric dust collection contains numerous rocket-exhaust particles and probable spacecraft fragments, which should contribute to understanding the Earth-orbital "space debris" problems. In addition, particle collections made in May and July of 1982, captured ash injected into the stratosphere by the April 1982 explosive eruption of the El Chichon, Mexico, volcano. The unique JSC results are being used to supplement other data in an effort to understand the possible effects of volcanic eruption clouds on weather and climate.

Figure 1.- 13-μm cosmic dust fragment. Detailed analysis shows this to be a unique category of extraterrestrial material.

Figure 2.- 6-μm sphere of man-made alloy "Space debris" from explosion or reentry of spacecraft.



Meteorites from Mars

PI: Laurence Nyquist/SN5
Reference OSSA 4

Recent studies of several rare meteorites have produced some fascinating results. Briefly stated, everything which has been learned about the meteorites is consistent with their origin on the planet Mars. There are, of course, significant areas of ignorance concerning the characteristics of Martian rocks. Nevertheless, enough is known about the planet, primarily as a result of the Viking missions, that lunar rocks and most meteorites would not be mistakenly identified as of possible Martian origin.

The possibility that the rare meteorites may have originated on Mars is receiving increasingly serious scientific attention. The major objection to a Martian origin is the apparent lack of a mechanism to launch rocks from the Martian surface with velocities in excess of the Martian escape velocity, about 5 km/s. Citing experimental studies of hypervelocity impacts of projectiles incident at shallow angles to horizontal surfaces, it is suggested that such impacts may provide the required launch mechanism. The experimental studies show that at grazing incidence a ricochet phenomenon occurs. The projectile and some entrained surface material ricochets at velocities approaching that of the incident projectile. On a planetary scale, the target surface could be the planet Mars and the projectiles a population of Mars-crossing asteroids. A typical asteroid might be of the order of 1 km or larger in diameter and strike Mars at a velocity of about 10 km/s. A small percentage (about 5%) of the impacts will occur at shallow angles so that ricochet is expected to occur. These shallow-angle impacts leave characteristic "butterfly" craters. The craters themselves are elongated along the path of the projectile, whereas, the visible ejecta are concentrated to either side of the projectile path.

Figure 1 shows a butterfly crater on the Martian surface. The crater is located on a young basalt flow as would be appropriate for the meteorites in question. The existence of such craters and the experimental studies of oblique impact are supportive of the hypothesis that Martian rocks could be launched from the Martian surface to become meteorites.

An accepted explanation of the physical means by which rocks might be accelerated to escape velocity is presently lacking. However, preliminary calculations suggest that the fluid dynamic drag exerted by a vaporized projectile might provide a comparatively gentle acceleration so that solid rocks are preserved and not shock melted in the impact. This suggestion is currently being discussed in the scientific literature.

Figure 1.- Butterfly crater on Martian surface.

Fluid Inclusions In Meteorites

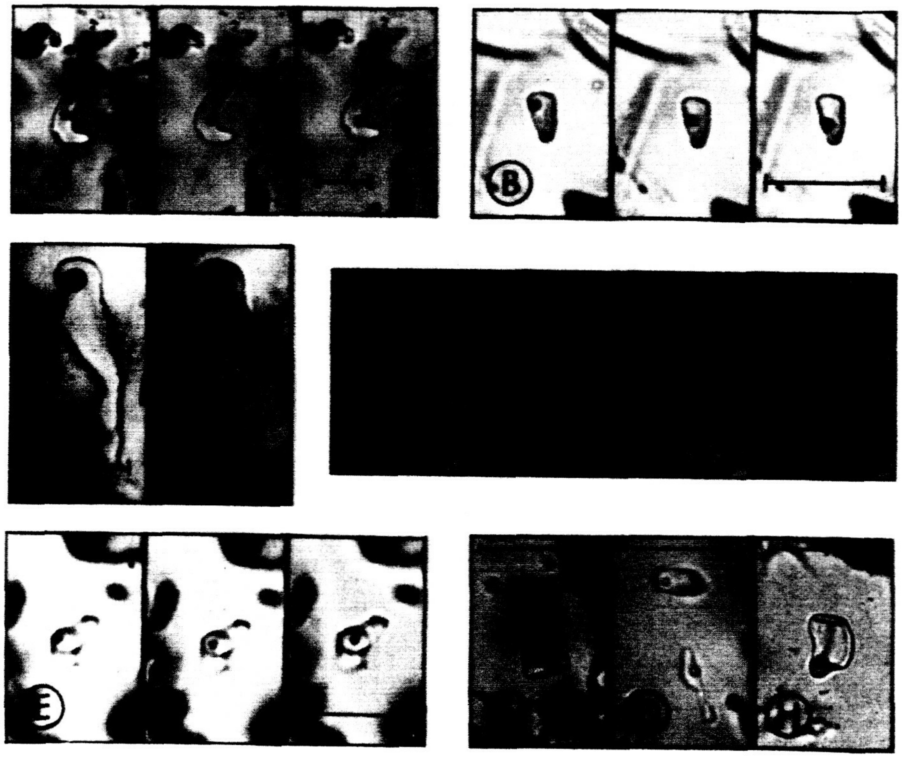
PI: Everett K. Gibson and Lewis D. Ashwal/SN7
Reference OSSA 5

Fluid inclusions, both primary and secondary, have been discovered and studied in chondritic and achondritic meteorites. Fluid inclusions are important probes of the petrogenesis of natural rock systems because they yield direct information about the chemical nature of the fluid present in the system at some stage in its history, and place constraints on the rock's P-T history between formation and collection. Such data would be especially important in the study of meteorites because the lack of a geologic context for meteorites hampers inferences about their history.

At least seven meteorites (both falls and finds) are known to contain fluid inclusions: chondrites-Faith H5, Jilin H5, Bjurbole L4, Holbrook L6, Peetz L6, St. Severin LL6, and diogenite ALHA 77256. Surprisingly, fluids in chondrites have the same properties as those in the diogenite achondrite. The include: (1) shapes, sizes, and occurrences: equant, rounded, varieties, up to 20-30 μm, commonly along healed fractures and larger isolated irregular ones, up to 100 μm; (2) presence of both two-phase (liquid + vapor) and three-phase [liquid + vapor + glass (?)] inclusions; (3) a broad range in temperatures of homogenization (T_h) of liquid + vapor to liquid from 30° to >220° C with no preferred temperature; (4) apparent difficulty in observing freezing phenomena, i.e., recognition of an observable crystalline phase at low (-180° C) temperatures; (5) increase of vapor phase volume (V_v) on heating from -180° C; and (6) Raman vibration bands at 3200 to 3600 cm^{-1}. Properties (3) and (6) are characteristic of an aqueous fluid, but the fluid cannot be pure H_2O because of (4) and (5). If observations of change in vapor bubble morphology from deformed to spherical at -20° to -25° C are inferred to represent final melting, this would indicate large quantities of dissolved components, possibly salts. Laser Raman spectroscopy on many inclusions show no vibration bands characteristic of CO_2, CH_4, H_2, N_2, O_2, of S-bearing species. Recent Raman spectroscopic work resulted in precipitation of a dark solid phase, with vibration bands resembling graphite. This was observed for both ALHA 77256 and Jilin. See figure 1. In one inclusion in Jilin, a broad Raman signal between 2850 and 3000 cm^{-1} was obtained which is characteristic of aliphatic C-H stretching. This observation must be confirmed by further Raman studies.

In the chondrites, inclusions occur in olivine both inside chondrules and within chondrule fragments, as well as in pyroxene (Jilin). In the diogenite, inclusions are only present in orthopyroxene. Occurrence of fluid inclusions within chondrules represents another factor which must be accounted for in any model of chondrule origin. Clearly, inferences about the origin of the fluids must await further characterization of their chemical composition. Morphologic, microthermometric, Raman spectroscopic studies, along with direct analysis of trapped fluids using the laser microprobe/gas analysis technique, are presently underway and the latest findings will be reported.

Figure 1.- Fluid inclusions in ALPHA 77256 achondrite. Scale bar is 10 microns.



Laser Microprobe-Gas Chromatograph

PI: Everett K. Gibson and R. K. Kotra/SN7
Reference OSSA 6

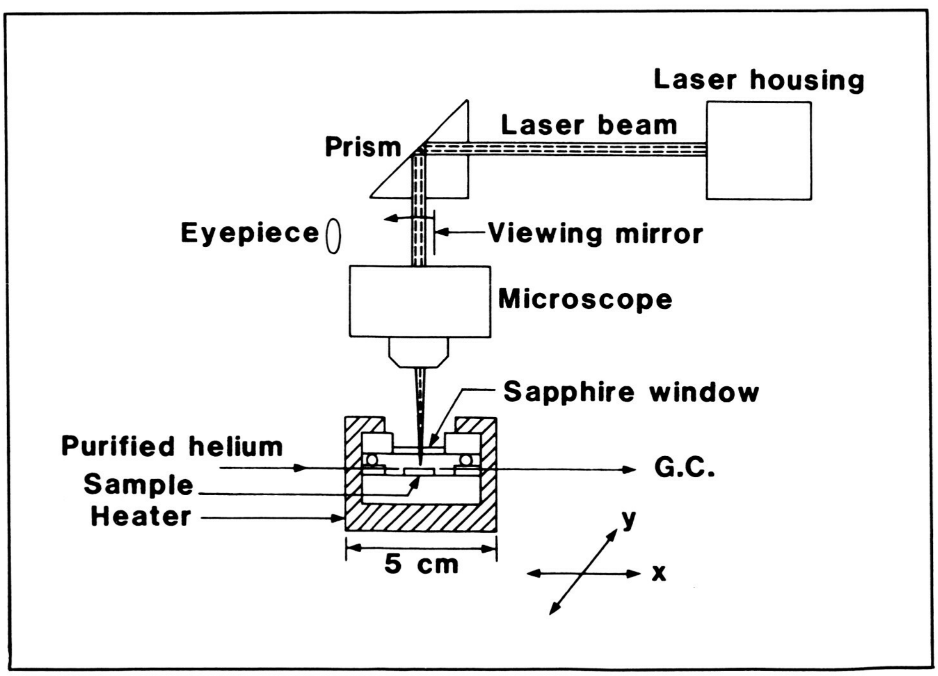
Direct chemical analysis of trapped vapors and fluids in terrestrial and extraterrestrial materials is one of the most difficult analytical challenges confronting geoscientists. A newly developed laser microprobe-gas analysis system has the capabilities of direct chemical analysis of gases, volatiles, and fluids in meteorites, lunar samples, terrestrial basalts, and cosmic dust samples. This technique permits the direct chemical analysis of volatiles in either individual inclusions or the complete samples. Samples may be either "thick" thin sections or individual particles. The laser microprobe is used either to "open" the fluid inclusion or "heat" the sample under controlled conditions. Released volatiles are directly analyzed through gas chromatographic techniques employing the ultrasensitive helium ionization detector developed by Andrawes and Gibson. A schematic of the laser and sample holder is shown in figure 1.

For the direct chemical analysis of fluid inclusions, 60 to 100-micrometer thick sections are used which have been prepared for thermometric analysis. The section is placed in the sealed sample chamber which is attached to the inlet of the gas chromatograph. The chamber for analysis of small particles has an internal volume of 1.53 cm^3, a 1-cm diameter quartz and/or sapphire window, while the chamber used for polished circular thin sections has a larger volume. Both chambers have an entry and exit port for ultrapure helium carrier gas. The chamber is mounted on the stage of an optical microscope that permits movement in the x-y-z direction for sample location and focusing. The optical window permits the Nd-glass laser beam to pass. The sample is located and, using a defocused beam, the surface of the sample can be "cleaned." The sample chamber can be heated externally to 150° C to remove absorbed gases. After calibration with the standard gases, the laser is pulsed to drill a 5 to 10-micrometer diameter pit a few micrometers deep. Gases within the sample chamber are swept into the gas chromatograph for analyses after each pulse. Repeated pulsing will excavate to the depth of the vapor or fluid inclusion. When the inclusion is opened, its contents are released, vaporized, and swept into the chromatograph column with the carrier gas. Because carrier gas flows at a rate of 10 to 15cc/sec, the sample chamber is flushed rapidly and the evolved vapors may be analyzed after each laser pulse. Laser pulses can be spaced 15 seconds apart if rapidity is desired.

The sample serves as its own crucible, and the operational blanks are at the nanogram concentration levels as measured by repeated analysis of tektite glass. Laser pulse duration can be as short as 1 microsecond. With the 1-microsecond pulse, propagation of a thermal pulse into the surrounding host material is minimized. The short pulse duration can explosively volatilize a 10 to 20-micron pit before the thermal pulse propagates into the surrounding host and improves the quantitative recovery of the volatile.

The gas analysis system incorporates an ultrasensitive helium ionization detector-equipped gas chromatograph. This method demonstrated the capability of analyzing both inorganic and organic gases at the subnanogram concentration levels. Water can be analyzed both directly and indirectly after reaction of water with calcium carbide to produce acetylene. Determination of acetylene is a routine task, whereas water, a polar compound, commonly passes through the chromatograph column too slowly for easy analysis.

Figure 1.- Schematic of laser microprobe and sample holder assembly.



Cosmic dust particles can be analyzed by assuming that the dust particle contains the average CI carbon abundance of 4 to 5 percent C. The carbon "signal" from complete conversion of the particle would be about 20 times the background if everything was converted to either CO or CO_2. In reality, the vapor products produced after laser pyrolysis of the cosmic dust grain would be a mixture of both oxidized and reduced species (e.g., CH_4, CO, CO_2, hydrocarbons, etc.).

With the capability of changing the laser's power output, and selectively filtering the beam, stepwise heating of individual samples can also be accomplished. This feature provides additional flexibility to the laser microprobe capabilities.

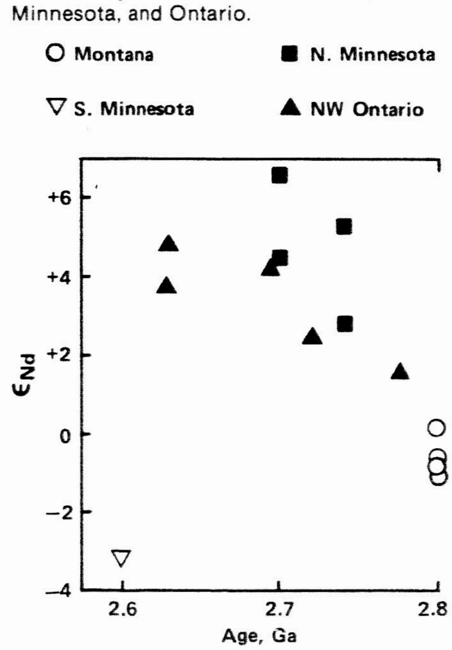
The Earth's Early Crust and Mantle

PI: William C. Phinney/SN6
Reference OSSA 7

The planetary processes that were involved in the earliest separation of Earth's crust and mantle remain largely unknown. The very rare occurrences of rocks from the first 1.5 billion years (b.y.) of Earth history severely limits the evidence for such processes. However, some of the more common younger rocks can preserve evidence that bears on older processes. Many volcanic or other igneous crustal rocks form by partial melting within the mantle. As the melts then rise into or onto the crust and form additions to the crust, they leave anomalous residual compositions in the affected volumes of mantle at various times throughout Earth's history. When one of these volumes of mantle undergoes further melting or fractionation at an even later time, the resulting crustal rocks of the later event may inherit clues about the earlier fractionations of crust and mantle in the form of anomalous isotopic ratios, trace element distributions, and/or mineral assemblages. The study of ancient rocks can provide evidence on the nature and location of even earlier events for which no crustal rocks are preserved. The resulting data can help us to understand the more basic questions of why and how these very early events took place.

Recent geochemical investigations of 2.6- to 2.8 billion year-rocks from Montana, southern Minnesota, northern Minnesota, northern Michigan, and northwestern Ontario indicate that by their time in history the Earth's mantle had developed extensive heterogeneities from previous fractionation events. For example: the isotopic ratios for $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ in the Montana, southern Minnesota, and northern Michigan areas are those to be expected when essentially no previous fractionation of mantle materials had occurred. Yet, for northern Minnesota and three widely separated areas of northwestern Ontario, these ratios are anomalously high for Nd and low for Sr. The results imply that an earlier fractionation of crust from mantle had depleted certain components in the extensive volume of mantle that now resides under northern Minnesota and northwestern Ontario, while other portions of the mantle to the east, south, and west had not undergone the same fractionation and depletion. By 2.8 b.y. there were at least two distinct types of mantle reservoirs supplying new igneous material to the crust in the Montana, Minnesota, and Ontario areas. Figure 1 illustrates these event differences. The plotted variable of ϵ_{Nd} is a measure of the departure of the $^{143}Nd/^{144}Nd$ ratio from an ideally nonfractionated mantle reservoir; the more positive the ϵ value, the more depleted the mantle reservoir. The northern Minnesota and northwestern Ontario samples show various degrees of depletion for their mantle reservoirs; whereas, the Montana samples show essentially no fractionation. The southern Minnesota sample, while not displaying the positive ϵ value of mantle depletion, does show a negative ϵ value, which probably results from contamination of the Nd isotopes by previously existing crustal materials.

Figure 1.- Nd isotopic data for 2.6- to 2.8-billion year rocks from Montana, Minnesota, and Ontario.



The precise areal extent of the depleted reservoir remains to be determined through studies of rocks from further to the east in Ontario and to the west into Manitoba. In addition, the time of the depletion event remains to be determined through studies of rocks older than 2.8 b.y.

Previous studies of lunar samples have revealed that similar depleted reservoirs in the lunar mantle resulted from a crust-mantle fractionation at about 4.4 b.y. Then a later fractionation produced the younger 3.0 to 3.7 b.y.-old mare volcanic rocks in which anomalies are preserved from the 4.4 b.y. fractionation. Because of differences in gravity, size, and volatile contents, the specific composition of the depleted components is a bit different on the Moon from that on the Earth. Thus, some of the large-scale planetary processes that were learned about in some detail from lunar samples appear to have similar terrestrial counterparts that are somewhat modified by the more complex geologic history of Earth. However, without the benefit of the simpler case provided by the Moon, it would have been more difficult to recognize the validity of the approach for terrestrial processes.

Effect of Aluminum Substitution on the Reflectance Spectrum of Hematite

PI: Richard V. Morris/SN7
Reference OSSA 8

Remote sensing makes extensive use of multispectral imagery; geologic units or terrains frequently are found to be delineated in false-color representations or band-ratio images. Generally, ground truth is required to identify dominant mineral and rock types in a particular unit. In some cases, regional rock types are known, and spectral units can be correlated with known spectra from laboratory experiments.

Ferric oxides and oxyhydroxides are a class of minerals important in remote sensing applications of Mars and the Earth. Despite their importance, little is known about the extent impurity-ion substitution in these minerals affects their spectal properties. This is potentially an important consideration since, in natural environments on the Earth, aluminum substitution for ferric iron is known to occur.

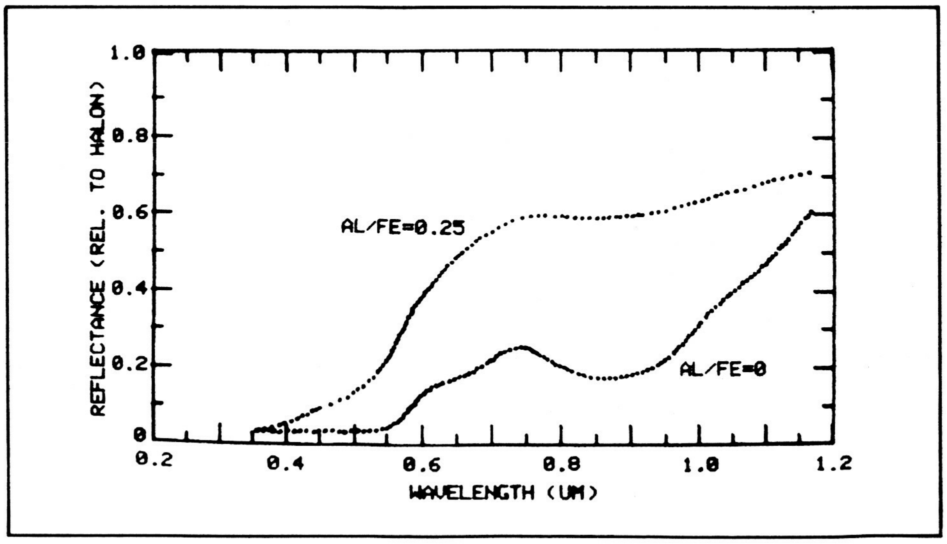
One of the spectrally-important ferric oxides is the mineral hematite (α-Fe_2O_3). The selected study approach was to conduct parallel syntheses of hematite and aluminous hematite under nominally identical conditions so that aluminum content was the only variant in the starting materials and procedures. The diffuse reflectance spectra of the synthetic powders were recorded on a spectrophotometer configured with a 9-inch integrating sphere. In most cases, aluminum substitution for ferric iron could be verified by shifts in the locations of X-ray diffraction lines.

The diffuse reflectance spectra of powders having Al/Fe 0.0 and 0.25 are shown in figure 1 over the spectral region 0.35 to 1.20 μm. This region encompasses the visible region (0.4 to 0.7 μm). The two powders are very different in their spectral properties. Visually, the aluminous hematite is tan and the aluminum-free hematite is dark red. Relative to the aluminum-free hematite, the near-IR band minimum for the aluminous hematite is shifted longward by about 0.02 μm, and it is considerably more reflective shortward of about 0.55μm. This is important because the visible slope and the red shoulder are often used in the construction of false color and band-ratio images.

The results show that aluminum substitution has a strong effect on the spectral properties of hematite and may as well for other ferric oxides and oxyhydroxides.

Consequently, there is the potential to use the spectral data for Mars to constrain the aluminum content of the spectrally active phases. Similarly, it may be possible to use multispectral imagery of the Earth to construct representations which discriminate according to the aluminum content of the target area.

Figure 1.- Diffuse reflectance spectra of hematite (Al/Fe = 0) and aluminous hematite (Al/Fe = 0.25).



Vertical Impact Facility

PI: Friedrich Horz/SN7
Reference OSSA 9

The phenomena associated with collisions between bodies of various sizes comprise the single most pervasive class of historical geologic process active throughout the Solar System. These collisions range in scale from submicroscopic impacts into individual mineral grains to events that can devastate tens of millions of square kilometers of the surface of a planet. Evidence for such occurrences are manifest in the millions of craters seen on virtually every solid-surface object observed by spacecraft, and there are indications that even more violent collisions have transpired in the past. It is now generally accepted that a large fraction of the present asteroid population is the direct result of destructive collisions between former members of the minor planet family.

The first-order effects of impact phenomena are reasonably well-known. The shock generated by an impact is responsible for (1) providing an energy source for the thermal metamorphism of target and projectile material, (2) deforming and fracturing the target rock, and (3) setting a volume of the target into motion. Release of the affected target volume from the high-pressure state induced by the shock could cause ejection of material from the crater cavity, excavation of the final crater, and, very possibly, the formation of various interior features of large craters, such as central peaks. The imprints left on various rock types by shock effects are also documented to a large extent. It is very important to recognize, however, that much knowledge of hypervelocity impact mechanics is of a descriptive, qualitative nature.

A means of obtaining quantitative information is to perform actual impact experiments under carefully controlled conditions. In this way, the individual variables can be monitored and constrained, experiments can be duplicated, and comprehensive documentation of the results can be performed. In addition, proper scaling of physical parameters can permit extrapolation to events much larger than those attainable under laboratory conditions.

A facility dedicated to the analysis of planetary impact phenomena is currently in the "shakedown" stage at the Johnson Space Center. This system features an electronically fired, vertical powder gun, which can accelerate projectiles to impact velocities approaching 2 km/s. Projectile diameters can range from 1.6 mm (the smallest that can be detected by the velocity measuring system) to 20 mm, which is the bore of the largest available barrel. The results of any given impact experiment are recoverable for subsequent analysis, and a high-speed framing camera system (up to approximately 400 frames per second) provides slow-motion movies for quantitative study of various dynamic processes as well as for the investigators' viewing. A high-speed motion-picture camera was used to make the sequence of photographs shown in figure 1. Such photographs, when combined with timing data, can be used to determine ejection and spallation velocities, efficiencies of momentum transfer, and data on other highly dynamic phenomena.

Perhaps the most exciting feature of the facility is the impact chamber, which can be refrigerated to temperatures well below the freezing point of water. This capability greatly facilitates investigation of impact phenomena in icy materials, which are of extreme interest in the study of ice-rich outer planet satellites, ring particles, and comet nuclei. A walk-in freezer with sufficient space for target fabrication, storage, and post-shot analysis is located in the gun area to support the low-temperature impact experiments.

The first investigations to which the new facility will be applied include analyses of the mechanisms of impact into H_2O ice, and the role of target size in determining the results of impact events (e.g., crater size versus degree of target disruption). These studies should shed considerable light on the geologies of the outer planet satellites and should yield information directly applicable to asteroid and meteorite analyses.

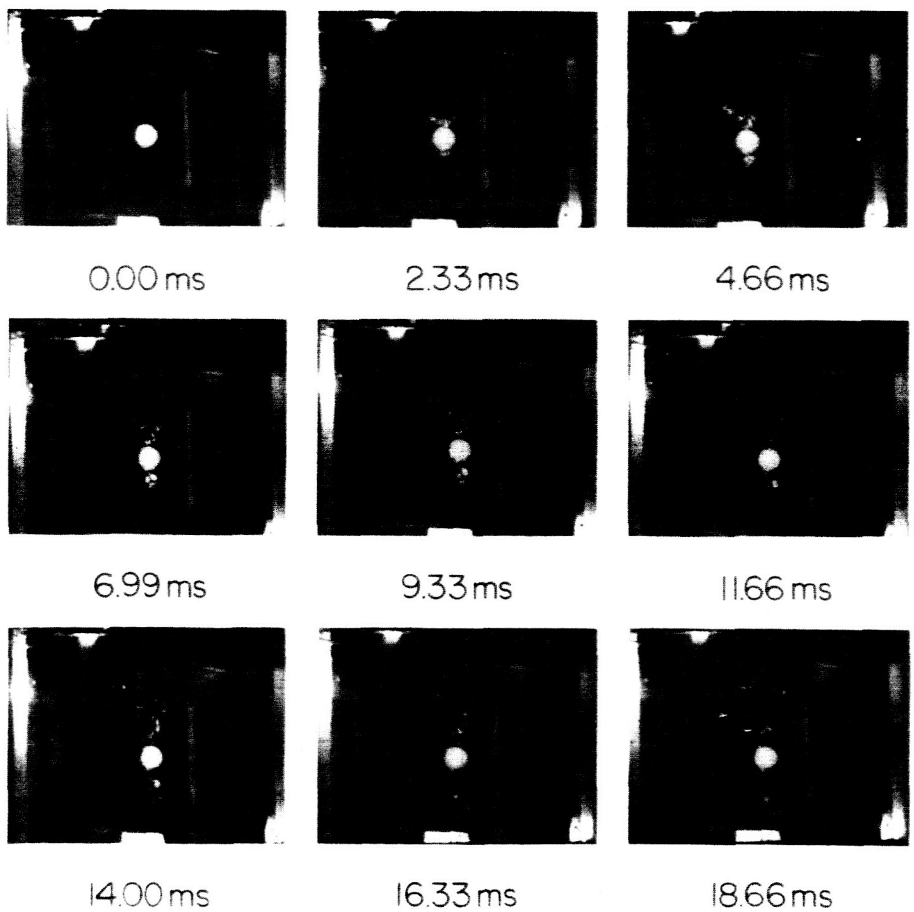


Figure 1.- A 1-gram stainless steel projectile impact into a 7.6-cm sintered aluminum oxide sphere at 670 m/s.

Space Sciences and Applications
Life Sciences

Office of Space Sciences and Applications

Summary

Life Sciences

During fiscal year 1982, the Space Shuttle test flights STS-2, STS-3, and STS-4 were completed. Life Sciences activities during this initial Shuttle test phase focused on operations as well as research. JSC has conducted a broad range of medical research and operations activities in support of the following Life Sciences Program goals:

1. To ensure the long-term health, well-being, and performance of humans in space; to characterize the medical constraints of space flight; and to enable participation by a broad segment of the population.
2. To use the space environment as a way to increase fundamental knowledge in medicine and biology.
3. To conduct the research and technology development necessary for maintaining life in space on a self-sustaining basis for long periods of time.

To accomplish these goals, JSC activities are funded by the Office of Space Sciences. In 1982 the major research activities were directed to the goal of long-term health, well-being, and performance of humans during space flight missions.

An in-house medical sciences space station working group has been established to begin the consideration of medical operations and life sciences activities that would be conducted on a space station. This includes health maintenance facilities, habitability factors, personnel selection and motivation, and research in the medical sciences as well as in biology. The effort will be supportive to the overall space station planning conducted by NASA headquarters.

In-house efforts have helped identify changes in physiology occurring after a human no longer is under the effect of gravity. Important among these effects are the following changes:

1. Otolith organ sends out uncharacteristic signals to which the central nervous system must adapt.
2. Procrioceptive input is greatly diminished.
3. Muscles of locomotion and posture begin to respond to underuse.
4. Portions of the skeleton needed for ambulation and standing begin to lose bone mineral.
5. The increased availability of the constituents of bone and muscle requires renal, gastrointestinal, and hematologic adjustment.
6. Labile portion of extracellular fluid is removed as it is no longer needed.
7. Fluid adjustment tends to unload the heart decreasing its end diastolic volume causing cardiac muscle changes.

1982 Physiological Investigations

Since the onset of manned space flight, NASA has been a leader in the biomedical community for motion sickness research. It has been theorized that understanding the neural adaptation to change in the direction of the gravitational environment will lead to a better understanding of motion sickness both on Earth and in orbital flight. In cooperation with the University of Michigan, the JSC neurophysiology laboratory has under development a motion sickness measurement system which will allow quantification of neural responses needed to maintain balance. The test system will quantify the responses of the complex postural control system which maintains our balance. A postural platform under computer control will provide unexpected movements while electronic instrumentation monitors the test subject muscle activity and body position.

Space flight causes a slowly progressive loss of calcium from the skeleton, which could eventually lead to osteoporosis, a weakening of bones due to mineral loss. The neutron laboratory located at the Methodist Hospital in Houston was equipped through NASA and Department of Energy grants. It contains equipment which is designed to quantify the amount of skeletal calcium in test animals and record changes in those animals without sacrificing or hurting the test subjects. The studies in this laboratory should provide valuable insight into both terrestrial human mineral deficiency states and the space-related calcium loss.

In addition to the abovementioned calcium loss, a number of physiological changes have been evident in bone, muscle, and blood after weightlessness or prolonged immobilization. Recent developments in nuclear magnetic resonancy (NMR) have made it possible to obtain superb tomographic cross-sectional images of entire organs and their relationship to one another. Tests conducted for NASA at Baylor College of Medicine are exploring NMR imaging as a potential noninvasive technique to study these mechanisms in vivo and aid in development of effective countermeasures.

During space flight, the fluid and electrolyte metabolism of the human body appears to undergo stable homeostatic adjustments appropriate to the environment of weightlessness which include: (1) loss of water, sodium and potassium inflight with subsequent retention postflight; (2) decreased leg volume inflight; (3) decreased plasma volume on first day after landing; and (4) increased excretion of aldosterone. A series of studies has been planned to study possible renal involvement in these adjustments. One study utilizing bedrest to simulate weightlessness is documented in this report. It utilized six females and eight male subjects in a 60-hour bedrest and 56-hour ambulatory period in which urine and blood samples were collected. Increases in renal flow were noted early in the test with the increase disappearing by 48 hours into the test.

Medical evaluation after spaceflight has demonstrated reduced orthostatic tolerance in all crewmembers tested. Although usually mild, this diminished ability of the cardiovascular system to function effectively against gravitational stress causes pronounced increases in heart rate and reduced pulse. The Lower Body Negative Pressure Apparatus was designed for Skylab to help diminish this process by decreasing pooling of body fluids in the head and upper torso during weightlessness. A new ambulatory device has been designed for use in prolonged Space Shuttle missions (fig. 1). Several important modifications have been incorporated to make this a useful tool in combating orthostatic deconditioning. The device also shows promise as a help to patients with disease-induced postural hypotension.

Figure 1.— New lightweight, stowable ambulatory lower body negative pressure apparatus with vacuum controller.

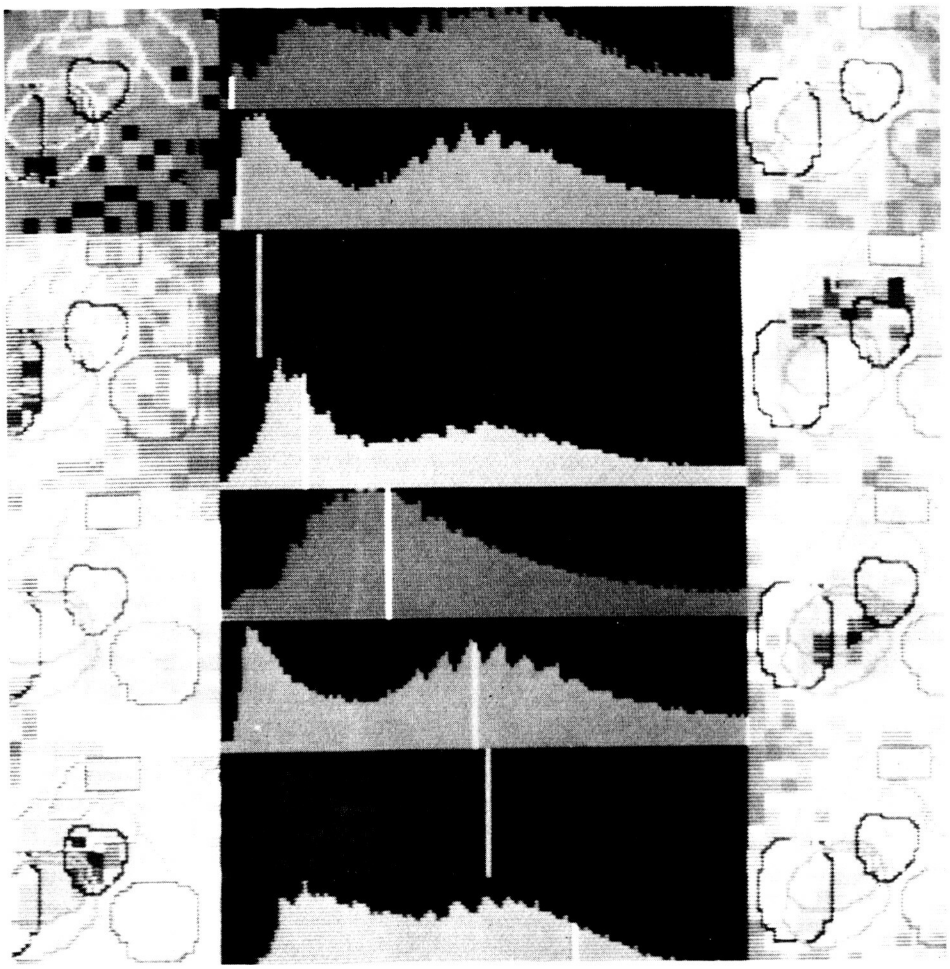
Space Biological Instrumentation

The Space Shuttle is the first U.S. spacecraft designed for multiple manned missions over a lifetime of several years. The potential for atmospheric contaminants is increased as system lifetime increases. Potential sources of contamination include plastics, lubricants, foods, products from human metabolism, and outgassing from spacecraft materials and carry-on experiments. JSC has developed a solid sorbent air sampling system which will give a history of organic contaminants present in the cabin and identify any event that might precipitate their increase in the Space Shuttle cabin atmosphere.

A similar piece of instrumentation has been devised to measure microbial contamination of the Space Shuttle. A hand-held centrifugal air sampler tests the cabin immediately prior to each launch and upon landing. The system has a series of wells containing microbial culture media which are incubated at the appropriate temperature after sampling.

In the area of clinical medicine, JSC has adapted a device commonly used in high-energy physics measurements into a promising clinical application of dynamic cardiac imaging. The Multiwire Proportional Counter Gamma Camera combines high resolution and low radiation and has obtained motion pictures of the moving myocardium or blood pool within individual heart chambers. JSC has received FDA approval for experimental human testing. Long-term testing of the device will be conducted at Duke University and the Houston Medical Center. Figure 2 shows a typical camera study.

Figure 2.— Dynamic radionuclide angiocardiography data obtained from a 40-kg animal subject injected with Ta-178 radionuclide. The histograms map radionuclide intensity variations through a 15-second study in 8 regions of interest. These regions are defined on selected images (around the border of the picture) in radiating colors. The variations in histogram level can be related to multicardiac volume in the structure residing with the given region.



Space Sciences and Applications
Life Sciences
Significant Tasks

Motion Sickness Test Instrumentation

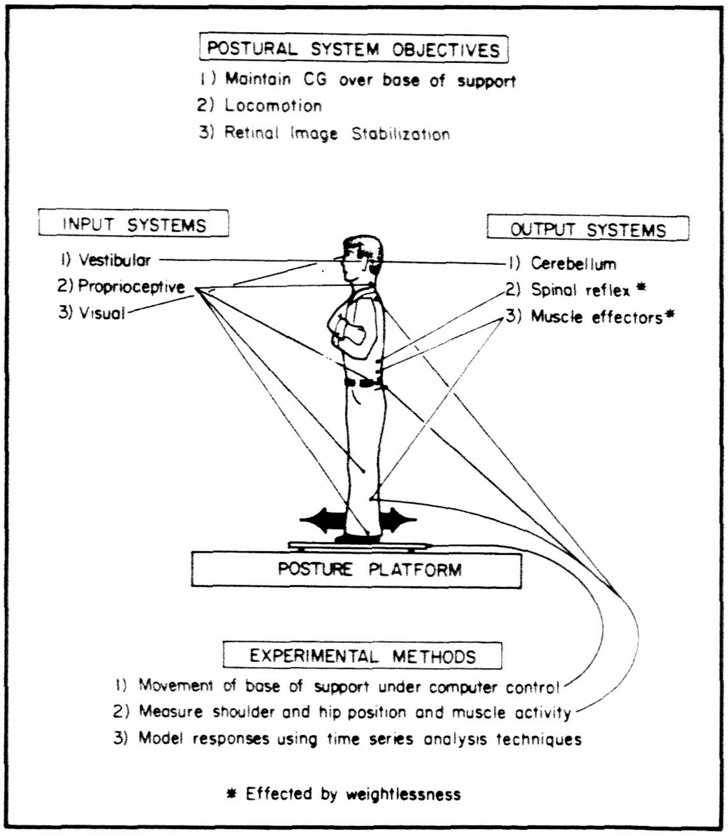
TM: Jerry L. Homick/SD3
Reference OSSA 10

NASA has both intramural and extramural research programs in all aspects of space motion sickness and has been a leader of the biomedical community in motion sickness research. The basis for motion sickness susceptibility testing has been undergoing transition from a catalog of subjective experience to an objective science over the few years that manned space vehicles have been operational. Although advances have been considerable, current activities and projected missions demand better prediction and countermeasures. Our further understanding of motion sickness can only be advanced by vigorous quantitative experimentation on the physiological systems and subsystems which are known to be involved in motion sickness. Among these systems are the vestibular system of the inner ear which senses head acceleration, the ocular motor system controlling eye position and the proprioceptive system which senses body position. The postural control system is the major system which integrates the above subsystems and controls normal standing and walking.

The keys to a successful research program lie in a combination of well thought out theories, sound experimental design to test hypothesis and measurement techniques equal to the unique challenges of biomedical research. An example of the measurement aspects of this triad can be illustrated by one of the projects being carried out at the University of Michigan under a contract with JSC's Neurophysiology Laboratory.

The objective of this project is the development of a measurement system which quantifies the response of the complex control system which maintains our balance (the postural control system) to unexpected movements of the base of support. A platform, illustrated in figure 1, moves in various patterns under computer control while electronic instrumentation monitors muscle activity and body position as a function of the platform motion. Technologies borrowed from several fields combine into a data collection system which enters the results of each test into a computer data base for analysis and comparison with data from other subjects and test conditions. The methods of analysis in use on the postural control system are similar to the engineering methods in use for the analysis of other systems such as aircraft and space vehicle dynamics. The motivation for the development of such a measurement system comes from the observation that individuals returning from extended periods of weightlessness perform well in static tests of postural equilibrium but may be less capable of performing dynamic tasks such as normal walking. It has been theorized that the understanding of adaptation to change in gravitational environment will lead to added knowledge about motion sickness because it is known that motion sickness most often strikes in the period when adaptation to a new motion environment is occurring.

Figure 1.— Postural control system test platform.



Neutron Activation Laboratory

TM: Philip C. Johnson/SD3
Reference OSSA11

The Neutron Activation Laboratory, located in the Methodist Hospital in Houston, is used by Baylor College of Medicine and Johnson Space Center scientists to study changes in total body mineral content. *In vivo* neutron activation is a technique by which a very small number of atoms of the naturally occurring elements within a live animal are made radioactive by bombardment with neutrons. Quantitating the resultant radioactivity gives a direct measure of total concentration. For example, total body activation analysis is an ideal way to follow and quantitate calcium balance in animals since the technique does not require blood, urine, or fecal specimens, yet is very accurate (±2 percent). Because the animal is not sacrificed the study duration is optimized and each animal can act as its own control, thus permitting multiple measurements which increase the confidence level of the animal. In addition, the procedure takes 30 minutes and is quite cost effective.

This laboratory was equipped through NASA and Department of Energy (DOE) grants. It consists of two rooms: a shielded irradiation facility and an adjoining room for the equipment needed to determine the amount of radioactivity induced in the animal. Within the irradiation facility are contained the storage shield and irradiator (fig. 1). The neutron source is a 3 mgm sealed capsule of Californium-252 on loan from the DOE. It is housed in a 1/2-inch diameter steel tube which is moved by remote control from the storage shield to the irradiator. Following activation of an animal, the source is retracted within the storage shield and the animal moved to the counting laboratory (fig. 2) where the activation products are quantitated. For this purpose, two opposing 12-inch diameter by 4-inch thick NaI crystals are employed. The aperture between the two detectors is variable to optimize for different geometries.

The results of a few recently completed investigations will be briefly described. Space flight causes a slowly progressive loss of calcium from the skeleton. This could eventually lead to osteoporosis which is a weakening of the bones due to loss of the mineral structure. Using aged ovariectomized rats as a model of human osteoporosis, clomiphene, a mixed estrogen agonist-antagonist was shown to protect ovariectomized rats from changes in body calcium and degradation of the femur. In another study, rats treated for a period of 3 months with the furosemide (Lasix) showed significant increases in urinary calcium as is found in humans during prolonged space flight, but did not produce a total body calcium deficit. Another study investigated the effect of exercise on total body calcium balance. It was shown that exercising rats gained calcium at a significantly greater rate than nonexercising animals; however, the advantage is rapidly lost following cessation of exercise since the previously exercised animals now had a calcium gain significantly less than the animals who were not exercised.

Figure 1.— Storage shield and irradiator.

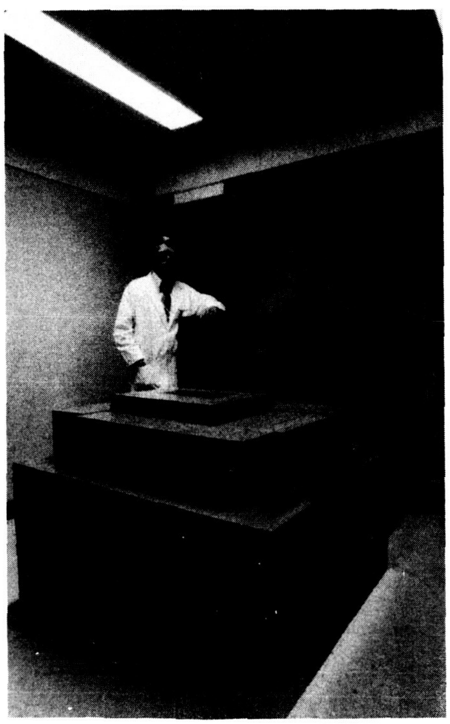
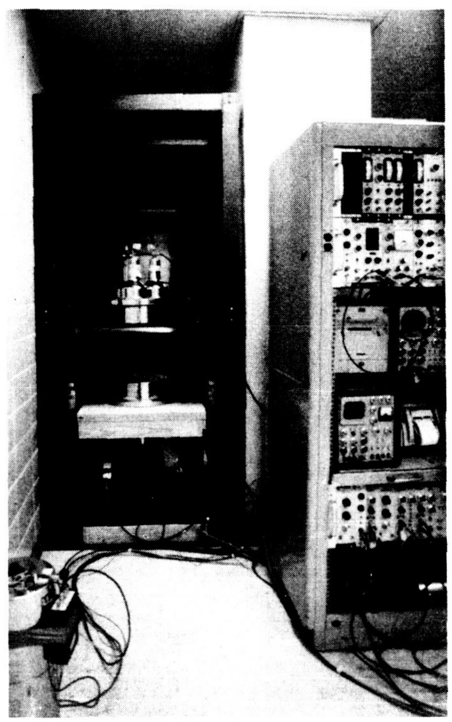


Figure 2.— Counting laboratory.



In Vivo Nuclear Magnetic Resonance

TM: Philip C. Johnson, Jr./SD3
Reference OSSA12

Nuclear magnetic resonance (NMR) is a well established investigative tool in chemistry and physics laboratories. The data obtained from NMR experiments can provide quantitative information concerning chemical structure and dynamic events. Nuclei having odd numbers of protons or odd mass numbers behave like tiny magnets, and when placed in a static magnetic field, align themselves in the direction of the field. Like a spinning top, the nuclei precess around the axis of the applied magnetic field. The frequency of this precession is specific for a given nuclear type. For example, hydrogen will have a different frequency than phosphorus; therefore, it can be separately identified. In order to detect the atomic nuclei, they are induced to emit signals. This is done by applying another magnetic field, perpendicular to the first, which is alternating at a frequency tuned to the processing frequency of the nucleus being investigated. The nuclei perturbed from an equilibrium state induces an electrical voltage in a surrounding coil. This is the NMR signal. The strength of the signal is proportional to the number of excited atomic nuclei while the rate each returns to equilibrium is a function of the physiochemical environment. Thus, structural and chemical information can be obtained from the measurements of time and frequency.

Recent developments have made it possible to obtain tomographic cross sectional NMR images of entire organs and their relationships to each other. In addition to providing superb anatomical images, NMR provides additional physiological information. This is under intense investigation at a number of medical research centers.

A number of physiological changes have been demonstrated in bone, muscle, and blood after immobilization or weightlessness. The elucitation of the mechanisms involved and the development of effective countermeasures is hampered because most of the quantitative techniques available prior to NMR are invasive and not suitable for human use. It is believed that NMR imaging will provide a noninvasive, safe technique for studying/monitoring these changes in crewmembers. The objectives of the work, conducted at Baylor College of Medicine (figs. 1 and 2), are to determine the feasibility of quantifying these changes with *in vivo* NMR imaging using animal models which simulate weightlessness and follow this with studies in humans.

Figure 1.— Baylor College of Medicine NMR tomographic imaging instrument.

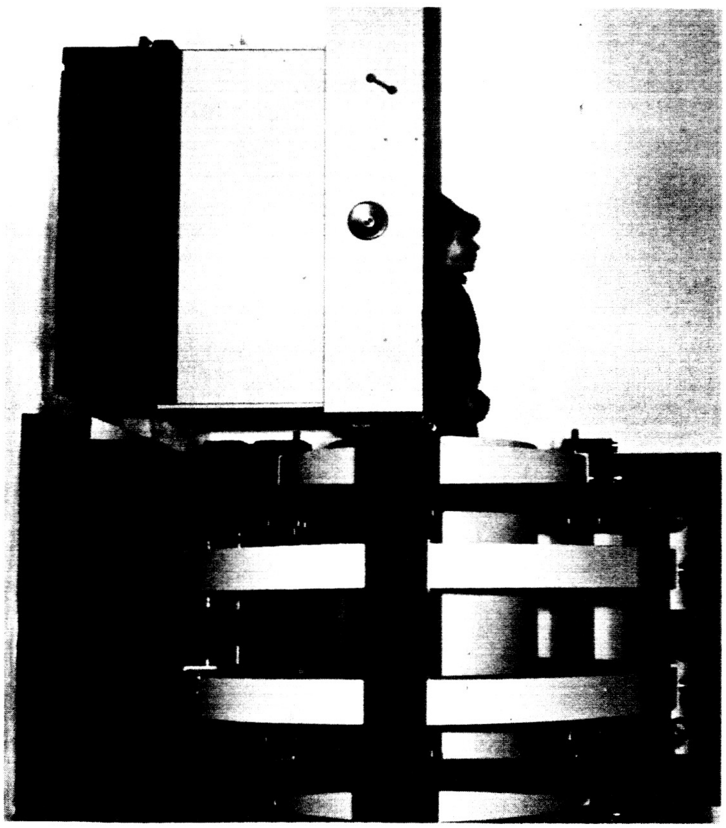
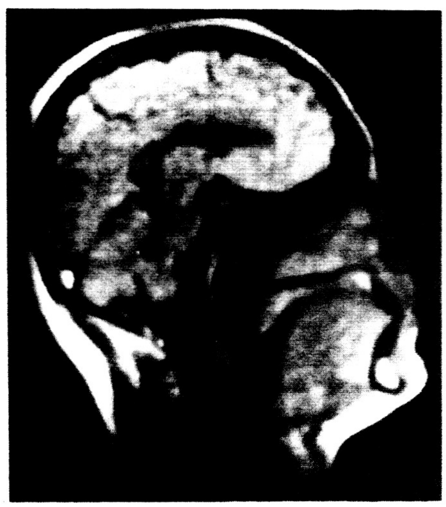


Figure 2.— Cross sectional NMR image of a human brain.



Renal and Endocrine Studies During the Early Phase of Antiorthostatic Hypokinesia

TM: C. S. Leach/SD4
Reference OSSA13

During space flight, the fluid and electrolyte metabolism of the human body appears to undergo stable homestatic adjustments appropriate to the environment of weightlessness which include: (1) loss of water, sodium and potassium inflight with subsequent retention postflight; (2) decreased leg volume inflight; (3) decreased plasma volume on first day after landing; and (4) increased excretion of aldosterone. A series of studies has been planned to study possible renal involvement in these adjustments.

A number of studies have shown the utility of the antiorthostatic posture during bedrest as an approximate analog to weightlessness in investigations focusing on fluid and electrolyte metabolism. Changes demonstrated in human subjects of such studies parallel the physiological responses measured in (or inferred from) the first day or two of actual space flight. Therefore, antiorthostatic bedrest was used to simulate weightlessness in the experiment to be described.

This study consisted of a 3-day ambulatory control period, a 60-hour bedrest period, and a 3-day ambulatory recovery period. The subjects (six females and eight males) were maintained on a controlled diet. Urine and blood samples were collected throughout the experiment. Measurements made during the control period were used to establish baseline values for all experimental parameters; later findings were compared with baseline data so that each subject served as his own control. The typical bedside procedure for blood collection is shown in figure 1.

Nonradioactive tracers were used for estimating glomerular filtration rates as well as renal plasma flow; I-125 human serum albumin was used for measuring plasma volumes. Blood and urine samples were analyzed for biochemical content. Total body water was estimated by means of the ethanol dilution technique, using expired breath samples and a sensitive gas chromatograph (fig. 2) brought to the subject's bedside.

A relative diuresis was measured during the first 48 hours of bedrest, with a return to normal by the end of the bedrest period. Body weights showed significant decreases after the first day in bed. By the end of the first 24 hours of bedrest, indicators of sodium balance had decreased relative to values seen during the 24 hours prior to bedrest. Sodium status returned toward normal by 40 hours into the bedrest period and then decreased briefly upon resumption of upright posture. Upon administration of a sodium load (in the form of a meal), sodium and water excretion increased earlier (by about 2 hours) in head-down bedrest in comparable circumstances in the control period. The renal function tests initiated 6 hours after inception of the head-down period show an increase of about 100 ml/min in the first measurement of the effective renal plasma flow. Within 48 hours (54 hours of bedrest), this increase was no longer apparent. Hormone concentrations were indicative of responses to conditions rather then to initiating factors, and the changes in renal and fluid flow parameters apparently preceded hormone change.

Further work will be undertaken to continue delineation of the earliest changes in antiorthostatic bedrest which are thought to be the same as those during space flight.

Figure 1.— Typical bedside procedure for blood collection.

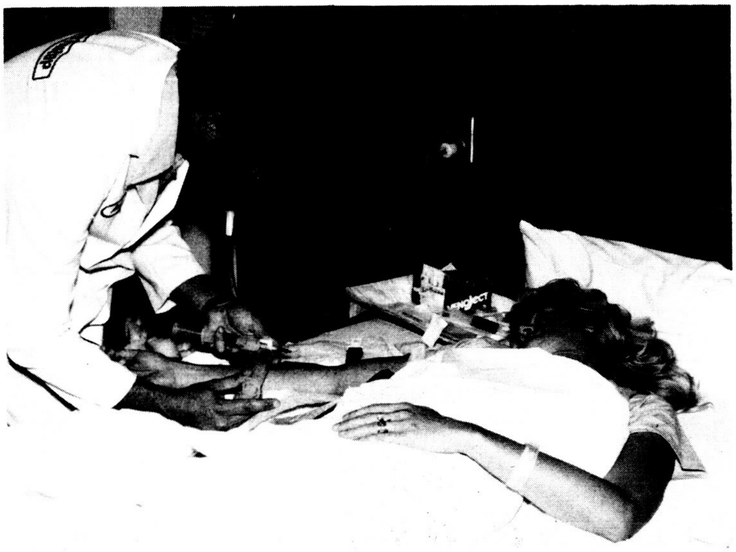
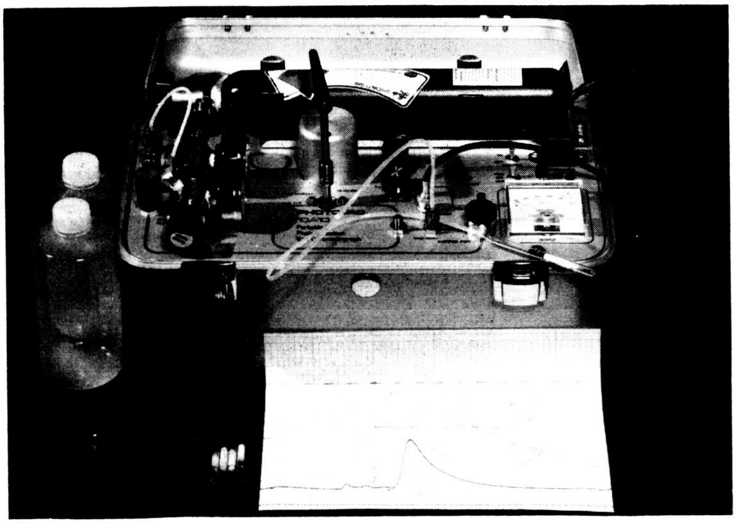


Figure 2.— Sensitive gas chromatograph.



Physiologic Testing of the Ambulatory Lower Body Negative Pressure Apparatus

TM: M. W. Bungo/SD3
Reference OSSA14

Lower body negative pressure (LBNP) refers to devices which apply decreased pressure (referenced to ambient atmospheric pressure) to the abdomen, pelvic region, and lower extremities. Medical evaluation after Gemini and Apollo flights demonstrated reduced orthostatic tolerance in virtually all crewmen tested. Interested in LBNP began in the early 1970's and a stationary LBNP was flown in Skylab. This reduced orthostatic tolerance, or capability to counter the stress of standing in gravity, is caused by prolonged exposure to weightlessness. The causal mechanism is body fluids pooling in the torso and head. During reentry, when gravitational forces increase and exceed normal gravity and following return to Earth, this pooling trend reverses. The result is a tendency for body fluids to pool in the lower or gravity-dependent portions of the body, namely the lower extremities and abdomen. In this situation, individuals have exhibited decreased pulse pressure, increased heart rate, and frank syncope. These tendencies have been demonstrated in returning space crews for periods up to 48 hours after flight.

Figure 1.— Lightweight, collapsible, canister-type LBNP device to be used to redistribute body fluids in flight for the purpose of preventing the deprecatory effects of microgravity.

Since Shuttle crews must be capable of functioning during the reentry and landing phases of the mission after being deconditioned in space, it is necessary to maintain orthostatic tolerance during the sojourn in the weightlessness environment. One means of maintaining orthostatic tolerance is to cause redistribution of blood from the head and torso during weightlessness to the lower abdomen and extremities by artificial or mechanical means. This is readily achieved by applying reduced pressure (referenced to ambient) to the lower abdomen and extremities for a period of time prior to reentry and return to Earth with a lower body negative pressure device.

The ambulatory LBNP is intended to be used to enclose the lower abdomen and lower extremities of the human body in a reduced pressure environment during periods of extended weightlessness with the minimal impact on subject mobility. Its use is primarily intended to maintain orthostatic tolerance in Shuttle crewmembers during space flight.

With the advent of the Shuttle era, a new ambulatory LBNP (figs. 1 and 2) was designed to maintain the orthostatic tolerance of the crewmen. The ambulatory LBNP device was constructed to (1) be of minimal weight, (2) be adjustable in fit for the entire crew population, (3) have an adjustable operational pressure in the range of 0 to 52 millimeters of Mercury differential, (4) provide crewmen with means to continuously monitor internal pressure while LBNP is worn, (5) allow donning and doffing without assistance, (6) have minimal gas leakage, (7) be suitable for continuous wear for up to 6 hours, (9) be of minimal stowage volume, and (10) provide over-vacuum safety protection.

Thorough testing of the new prototype in the Physiological Performance Laboratory disclosed several items that, with modifications, will allow the ambulatory LBNP to be a useful aid in combatting orthostatic deconditioning.

Figure 2.— Prototype LBNP vacuum controller that allows a selection of vacuum exposures for the LBBP profile on astronauts during space flight.

Shuttle Solid Sorbent Air Sampler

TM: Howard C. Schneider/ES22
***Reference* OSSA15**

The quality of the breathing atmosphere in a spacecraft is one of the factors affecting the physiological and psychological performance of the astronauts. Atmospheric contaminants evolving from various sources within the cabin must be trapped by the atmospheric purification system to keep the concentration of contaminants within the tolerance level.

Potential sources for organic substances contributing to the contamination of the spacecraft cabin atmosphere are plastics, lubricants, outgassing products from the spacecraft material, foods, and products from the human metabolism. To optimize the design of the purification equipment, especially for long-term space missions, detailed information is needed on the chemical nature of contaminants, on their concentrations, and their appearance in the cabin atmosphere during different periods of the mission. Appropriate analytical techniques are required which are either suitable for inflight measurement or for inflight sampling and postflight analysis.

An economical and technically appropriate adsorption system was designed which was particularly suitable for inflight sampling at different periods of the mission (fig. 1). Postflight analysis was used to analyze the volatile organic components in Shuttle atmosphere.

The sampling system is compact and rugged, requiring little attention by the crew. It allows complete collection of the substance in the considered range of volatility as well as efficient concentration of volatiles from a large air sample with no interference from moisture. Quantitative desorption of the trapped material for analysis is also possible with this system.

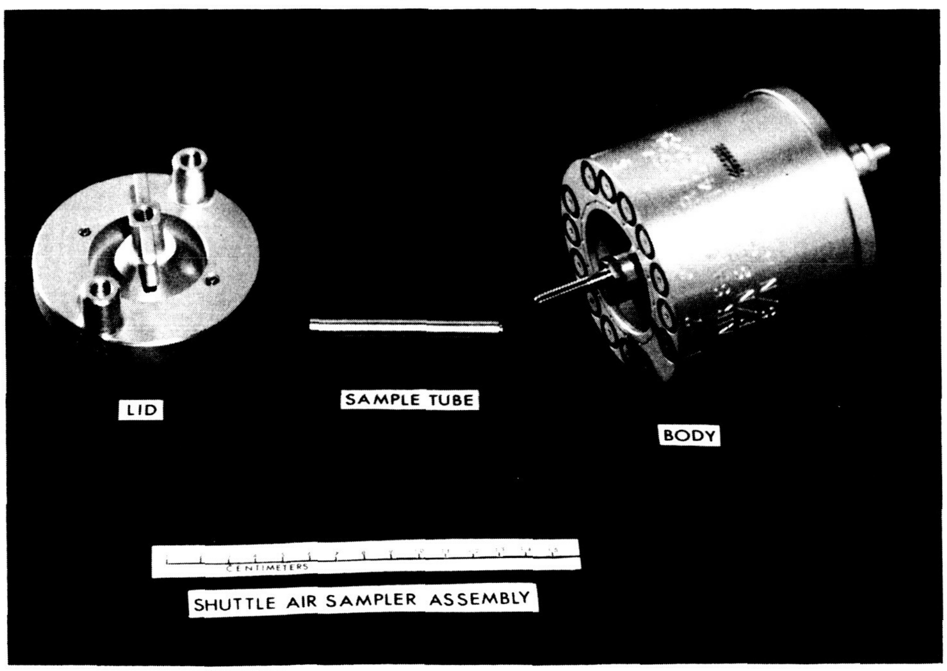
In these analyses, only volatile organics are considered; that is, all the compounds which have sufficient vapor pressure at temperatures up to approximately 200° C to be analyzed with gas phase techniques such as gas chromatography (GC) and mass spectrometry (MS). Although this definition does include gases and other substances of low molecular weight, only compounds less volatile than acetone are determined quantitatively due to limitations of the sampling procedure.

The sampling system consists of a cylindrical aluminum device containing fourteen stainless steel tubes. Each stainless steel tube contains a porous polymer of 2,6-diphenyl-p-phenylene oxide (Tenax GC) which has high temperature stability and is ideal for adsorption and subsequent desorption of volatile organic compounds. Sampling is conducted continuously; however, at 24-hour intervals, the device is repositioned or indexed to an unused sample position. There are two sample tubes at each sample position. The device will allow up to seven days of continuous sampling with "fresh" sample tubes being introduced every 24 hours.

This type of sampling will give a history on postflight analysis of the organic contaminants present, their potential buildup and of any event that might introduce organic compounds into the cabin atmosphere.

It has detected over 300 compounds and provided positive identification of 84 compounds with a molecular weight range of 58 to 592 in ground tests. It is planned to fly this device on the Shuttle in the near future.

Figure 1.— Shuttle air sampler assembly.



Microbiological Contamination Control and the Centrifugal Microbiological Analyzer

TM: Duane L. Pierson/SD4
Reference OSSA16

A new era for spacecraft began with the Space Transportation System and its concept of reusable vehicles. This type of spacecraft raised questions concerning the control of microbial contamination during missions. Since microbes remain airborne much longer in zero gravity than on Earth, this could present an increased health hazard if there was a continual buildup of these microorganisms.

To avoid this possibility, microbial buildup on interior surfaces of the Orbiter is carefully monitored from flight to flight. An important aspect of contamination control is monitoring of airborne microorganisms. This microbial content of the cabin air of the Orbiter is determined by using a small, completely portable, centrifugal air sampler. The battery powered instrument can be hand held or positioned free standing and requires minimum maintenance. It consists of a metal tube with an open drum on one end, a power pack attached to the side of the tube, and a screw cap for access to the batteries. The entire instrument is less than 35 centimeters long and weighs about one kilogram. A removable ten-blade impeller is housed in the drum assembly. For cleaning and sterilization purposes the entire drum assembly can be removed.

Prior to sample collection, a flexible strip consisting of a series of wells containing microbial culture medium is inserted into a groove on the inside of the drum. See figure 1. Air is drawn into the drum by the impeller blade assembly, and the microorganisms present in the air impinge upon the surface of the agar medium in the strip. The operating speed of the air sampler is 4092 rpm and draws 40 liters of air per minute. Sampling intervals ranging from 30 seconds (20 liters of air) to 8 minutes (320 liters of air) can be selected. Upon completion of the sample collection time interval, the agar strip is removed from the drum assembly and incubated at the appropriate temperature.

The quantitation of airborne microorganisms in the Orbiter's cabin air is conducted immediately prior to launch and upon landing. Measurements of this type allow assessment of the extent of microbial buildup during the mission.

Figure 1.— Shuttle microbiological analyzer.

Multiwire Proportional Counter Gamma Camera (MPCGC)

TM: J. L. Lacy/SD3
Reference OSSA17

A new technology for radiation imaging has been developed at the Johnson Space Center (JSC) based on the multiwire proportional counter — a device widely used in high energy physics radiation measurements. Unique electronic imaging techniques have been developed which provide a system for radiation image acquisition that is both simple and highly effective for high-speed high-resolution image acquisition.

The imaging system offers a significant advance in the clinical area of nuclear medicine imaging where the system has been shown to be superior to any currently available commerical instrumentation in the areas of spatial resolution image collection rate, image uniformity, and resistance to image distortion at high collection rates. The system is also highly compact, portable, and lightweight.

Unfortunately, the most widely used nuclear tracer (Tc 99m) is not compatible with the MPCGC. This presents the largest hurdle for widespread clinical application of the device. However, a number of standard clinical tracers are compatible including T1-201, Xe-133, I-123. Also, a new isotope (Ta-178) under development shows promise of being compatible with the MPCGC and also offering significant advantages over existing radiopharmaceuticals. The short half-life of this radionuclide reduces radiation dose by more than a factor of 20 over Tc 99m. This reduces each study radiation exposure to levels typically less than that of a standard chest X-ray.

A particularly promising clinical area of application is dynamic cardiac imaging. In these studies motion pictures of the moving myocardiam or blood pool within the individual heart chambers are obtained. The very low radiation exposure of Ta-178 combined with the high-rate, high-resolution imaging capability of the MPCGC could make possible such applications as widespread screening for coronary heart disease and diagnosis of congenital heart disorders in newborn and young children. Such applications are currently not feasible either due to lack of image quality or high radiation exposure.

The high image acquisition rates and image quality obtained for standard X-ray energies (10-100 keV) may open applications in the area of digital radiography. The MPCGC can produce high quality digital radiographs in relatively short acquisition times and is far more sensitive than many detection techniques (e.g., film, fluoroscope, etc.).

Construction of two prototype MPCGC devices has recently been completed at JSC, and FDA approval for experimental human testing of the Ta-178 radionuclide has been granted. Human testing of the MPCGC Ta-178 combination will begin at JSC in the near future. Long-term human testing will be performed at Duke University and the medical center in Houston. The device and ancillary equipment are pictured in figures 1 and 2.

Figure 1.— Multiwire proportional counter gamma camera including portable imaging head, electronics rack, and control terminal.

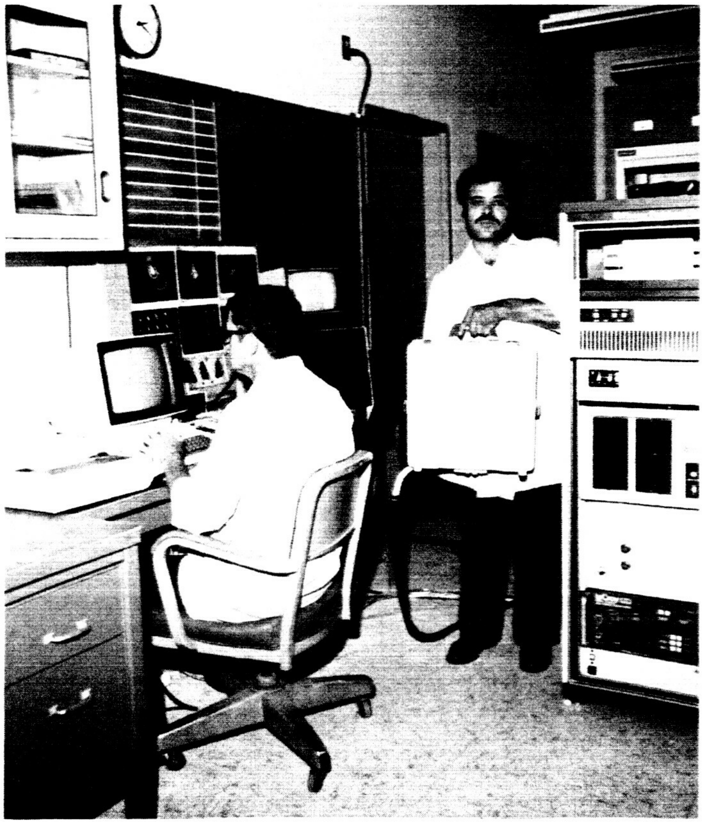
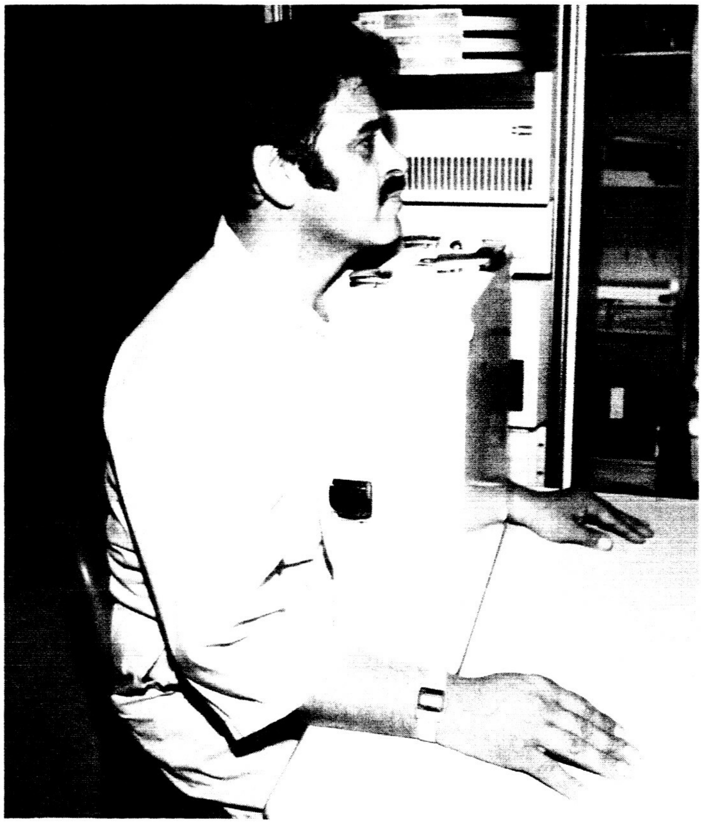


Figure 2.— Closeup of imaging head as positioned for a cardiac study.



Space Applications

Summary

AgRISTARS Program

The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) is a 7-year program of research, development, evaluation, and application of aerospace remote sensing for agricultural resources. It began in fiscal year 1980 and is a cooperative effort of the U.S. Department of Agriculture (USDA), NASA, and the U.S. Department of Commerce, the U.S. Department of Interior, and the Agency for International Development.

The goal of the AgRISTARS program is to determine the usefulness, cost, and extent to which aerospace remote-sensing data can be integrated into existing or future USDA systems to improve the objectivity, reliability, timeliness, and adequacy of information required to carry out USDA missions. The overall approach is comprised of a balanced program of remote-sensing research, development, and testing that addresses domestic resource management as well as commodity production information needs.

The program specifically addresses the information requirements identified in the USDA Secretary's Initiative.[1]

1. Early warning of change affecting production and quality of commodities and renewable resources.
2. Commodity production forecasts
3. Land use classification and measurement
4. Land productivity estimates
5. Conservation practices assessment
6. Pollution detection and impact evaluation.

While all six are important to the USDA, the first two — early warning and commodity production forecasting — have been given emphasis because of the immediate need for better and more timely information on crop conditions and expected production.

The technical program is structured into eight major projects as follows.

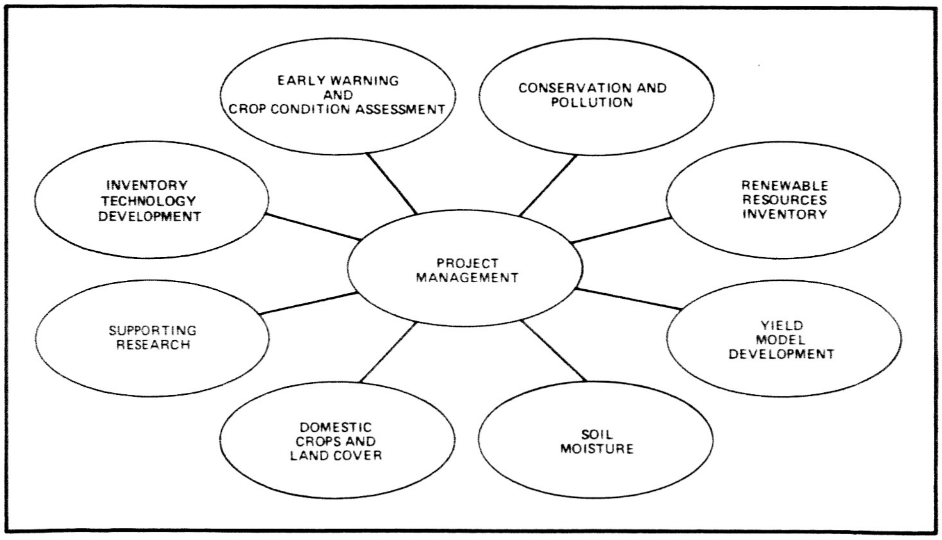
1. Early Warning/Crop Condition Assessment
2. Inventory Technology Development
3. Yield Model Development
4. Supporting Research
5. Soil Moisture
6. Domestic Crops and Land Cover
7. Conservation and Pollution
8. Renewable Resources

These elements (fig. 1) are interrelated through research, exploratory experiments, pilot experiments, and USDA user evaluations.

The Earth Resources Supporting Research focuses on advancing machine processing technology to map important vegetation types, their condition and maturity stage on a global scale using Landsat and other data types. In 1982 major advances in the technology were realized. For example, a completely automated technique for accurately classifying corn and soybean crops near harvest over large areas was successfully tested over key growing regions in the U.S. Corn Belt and the Mississippi Delta for three crop years. Underlying the success of this technology was a temporal profile technique, developed by JSC personnel. The technique permits raw multidate Landsat spectral data to be modeled in vegetative growth parameters which can relate to vegetation type such as date of emergence, peak greenness, length of growing season, and maturity stage.

An important FY 1982 accomplishment of the Data Systems support effort is the development of an integrated system to receive and analyze telemetry data. This system provides the capability to image the data (fig. 2) and perform many sophisticated pattern recognition and image analysis functions. The Data Systems effort provides Landsat, agricultural, and meteorological data vital to research as well as rapid, easy access to these data by providing a comprehensive

Figure 1.- Component projects of AgRISTARS.



[1]Joint Program of Research and Development of Uses of Aerospace Technology for Agricultural Programs, dated February 1978.

data base management system. In addition, the system provides an extensive interactive computational environment not only to other AgRISTARS projects within USDA and NASA but also networks these capabilities to the university community. This data system support permits the user community to have efficient access to a comprehensive set of research data and to share analysis capability.

The Early Warning/Crop Condition Assessment effort is focused on providing the technology required for worldwide identification of environmental conditions that affect agricultural production and surveillance of resulting crop conditions through remote sensing and environmental monitoring. A wide variety of tasks must be performed to provide that technology: basic research on crop response (both physiologically and spectrally) to the environment; field observations to support that research; extensions to or modification of the results of past research efforts and ongoing efforts both in and out of AgRISTARS; testing; and modeling the results into a system that can operate in a timely manner on available data and can be easily adapted to specific operational needs.

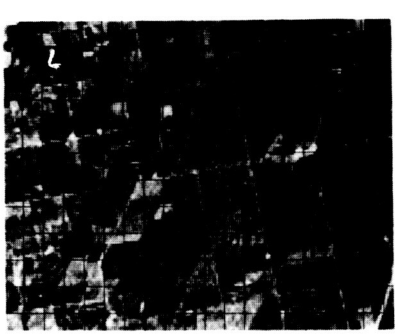
Early Warning/Crop Condition Assessment is colocated at the Johnson Space Center (JSC) with the U.S. Department of Agriculture Foreign Agricultural Service, Foreign Crop Condition Assessment Division, and responds to the research needs defined by that operational group. Much of the research is performed by researchers at Agricultural Research Service sites or by university groups. The molding of the research findings into the quasi-operational procedures is performed by the Early Warning/Crop Condition Assessment group in Houston on the same computer system used by the Foreign Agricultural Service in making their operational estimates of foreign production.

The Inventory Technology Development project addresses research and development of advanced technology related to satellite-aided production forecasts for crops and region combinations in the U.S. and foreign countries (U.S.S.R., Argentina, Brazil, Canada, and Australia) for small grains, summer crops, corn, and soybeans without requiring ground observations. This project will develop affordable procedures for using aerospace remote-sensing technology to provide more objective, timely, and reliable crop area and if possible, production forecasts several times during the growing season and improved preharvest estimates for the crops and regions of interest. The Inventory Technology Development activity builds upon the existing remote-sensing technology base and advances this technology as well as extending additional crops and regions. This technology is being evaluated by the USDA Foreign Agricultural Services for integration into its information systems.

In addition, information is derived which is useful in defining the characteristics of future satellite data acquisition systems.

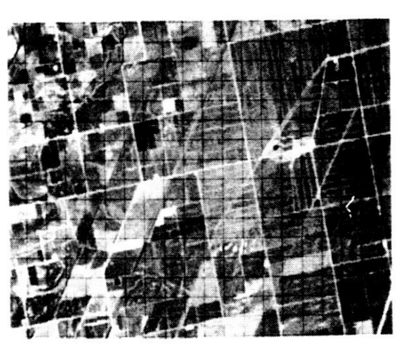
Figure 2.- Spatially registered Landsat 4 thematic mapper and multispectral scanner images acquired on August 22, 1982 over a 5- by 6-nautical mile agricultural area in Mississippi County, Arkansas. Region is predominately a soybean and rice-growing area. Irrigation ditches within fields are visible in the TM images. Images and registration produced by Data Systems Branch of the Earth Resources Research Division.

MSS



AREA: 5x6 NAUTICAL MILES
IMAGE SIZE: 117 LINES x 196 PIXELS
PIXEL SIZE: 57 x 79 METERS

TM



AREA: 5x6 NAUTICAL MILES
IMAGE SIZE: 351 LINES x 392 PIXELS
PIXEL SIZE: 28 1/2 x 26 1/3 METERS

Four organizations, the University of Kansas, Texas A&M University, Jet Propulsion Laboratory, and JSC, have been using ground scatterometers to verify the precision and accuracy of airborne and spaceborne microwave sensors to collect Earth resources data, and to provide ground truth data. To insure that the growing data base obtained from these ground scatterometers is mutually compatible, JSC coordinated the ground scatterometer cross-calibration experiment conducted at the University of Kansas during August 1982.

Each of the participating systems measured the extended scene radar cross-section per unit area for the same targets at the same frequencies, the same look angles, and the same polarizations on the same days. Data from the different systems can be compared and cross calibrated.

For the JSC system, each data set was gathered at 1.6, 4.75, and 9.5 gigahertz, using horizontal, vertical and cross polarizations. Six look angles were used, from 10 to 60 degrees. The common extended scene targets included cornfields, soybean fields, smooth short grass, rough/bare fields, and water (bait fish ponds). Also, point calibration targets were used, including a 4-ft diameter metal sphere, flat plate, corner reflector, and Luneberg lenses. Figure 3 shows the JSC grass field calibration system.

This cross-calibration effort was the first of its kind to be undertaken and is intended to be a baseline for any future similar efforts.

Texas Application System Verification and Transfer

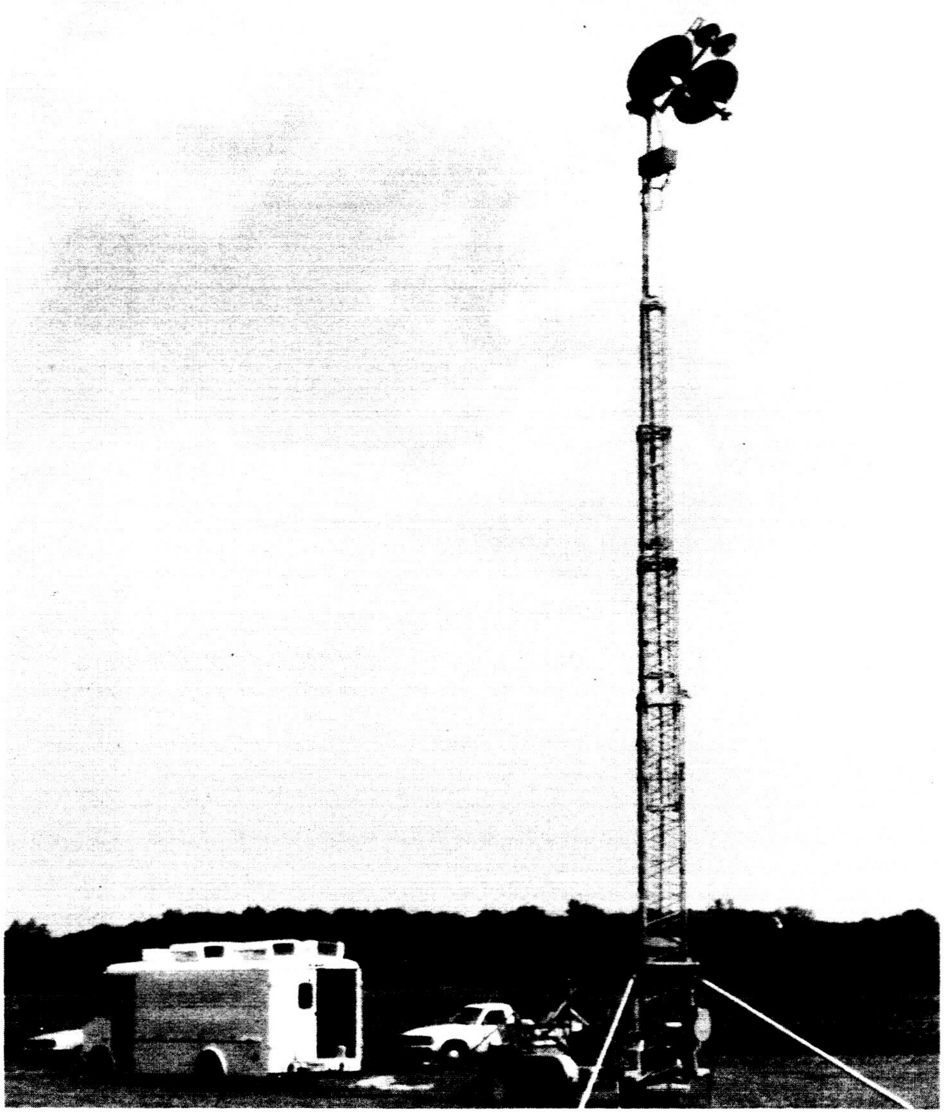
The JSC is participating with the State of Texas in a joint Application System Verification and Transfer Project to develop, evaluate, and transfer techniques for applying Landsat and other data to the needs of Texas natural resources management agencies. The major objectives of the project are (1) to update and integrate state-of-the art remote-sensing technology with other information sources available to the State to form a functional Texas Natural Resources Inventory and Monitoring System, and (2) to test and evaluate the utility and cost-effectiveness of natural resource information derived from Landsat data and other sources when applied in a total system context to selected State agency management activities. The Texas Applications Project began in June 1978 and will continue for 5 years.

The remote-sensing component, including technical assistance in techniques development of the system, is NASA's major responsibility. A prototype of the system is now operational on Texas facilities. The system is being tested and evaluated in support of application categories in the areas of coastal zone management, forestry, water resources, mineral resources, and wildlife management.

Shuttle Imaging Radar Antenna

The Shuttle Imaging Radar (SIR-A), developed by JPL for NASA, was carried aboard Space Shuttle Columbia as part of the first payload of scientific instruments assembled by NASA's Office of Space and Terrestrial Applications (OSTA-1). JSC was responsible for the development and integration of the antenna system for the highly successful SIR-A payload. A number of components have been salvaged and will be used in the manufacture of the SIR-B antenna to be flown on STS-17.

Figure 3.- JSC grass field calibration system.



Space Sciences and Applications
Space Applications
Significant Tasks

AgRISTARS Early Warning/Crop Condition Assessment Project

PM: Victor S. Whitehead/SH3
Reference OSSA 18

The Early Warning/Crop Condition Assessment Project of AgRISTARS is dedicated to development of a technology that will permit a timely response to factors that affect the quality and production of economically important crops. This involves the ability to identify the growing factors that influence crop conditions and to determine the amount and condition of the crops involved. Resources from the U.S. Department of Agriculture (USDA), NASA, and the National Oceanic and Atmospheric Administration (NOAA) are integrated to provide a comprehensive and efficient approach to this multifaceted problem. Project personnel are colocated with a using unit of USDA, the Foreign Agricultural Service (FAS), to better insure relevance of the resulting products.

Products provided by Early Warning/Crop Condition Assessment represent improvements over existing technology: improved accuracy, more timely performance, and extension to other areas and crops. Initial emphasis was placed upon the upgrading of procedures such as those used to objectively assess crop losses due to hot dry winds and poor harvest conditions (both major sources of reduction in U.S.S.R. small grains production). Another set of procedures addressed were alarm models that automatically track environmental conditions (these include soil moisture, budgets, and crop calendars) to permit the analyst to concentrate on the areas needing more attention. This activity has provided the Foreign Agricultural Service (FAS) with alarm models for small grains, corn, sorghum, and sugar beets. Development continues on models for sunflowers, soybeans, and cotton.

The maize stress indicator model was tested against meteorological and agronomic data for 27 stations in Missouri for 1979 and 1980, two highly contrasting years in terms of crop yield. The phenology algorithm has a mean error of 3.5 and 4.7-days error at silk-tassel and maturity, respectively. The number, timing, and designation of stress alert were consistent with ground truth information. The model is currently being compared to real-time stress data being collected in nine counties in South Dakota and it will be evaluated as a component of a larger integrated crop condition assessment plan now being initiated. Operational testing of the model has been started by USDA.

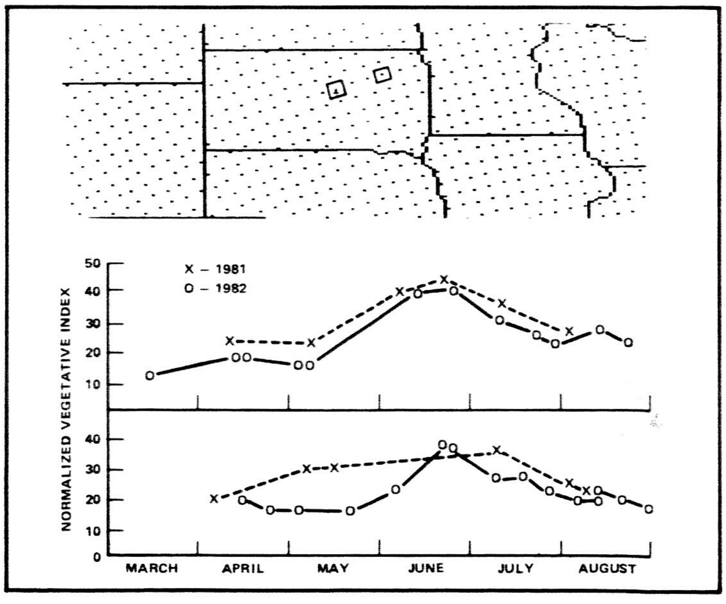
Additional planned inputs include evapotranspiration and spectral information. A yield reduction model based on the interaction of evapotranspiration and temperature as modified by stress duration, growth stage, and soil moisture has been developed. The algorithm reacts to hot dry wind conditions and is being tested against gridded data for United States Great Plains and Soviet Union wheat areas with initial favorable results. Stress is identified by the model and percentage yield loss is assessed; a base yield is not required.

USDA scientists have collected growth data on selected wheat fields for 3 years in several locations. The data received have been keyed into data files for future analysis. The data from Montana, North Dakota, and Texas includes 48 field-years of experience. Instrumented data were also collected in the fields on precipitation, temperature, wind, radiation, and soil moisture, and are being used to improve upon the current models for wheat along with Landsat spectral data.

Several tasks nearing completion rely heavily on satellite-based observations. Flood damage assessment, range condition assessment, and native vegetation as a crop stress indicator are specific examples of application of spectral data.

Because many of the user requirements placed on the Early Warning/Crop Condition Assessment project are of a broad-scale nature, emphasis was placed upon regional conditions instead of specific point conditions. This project has served as a pioneer in the application of environmental satellite data (NOAA-6) and -7 and GOES) as an agricultural surveillance tool. On a broad scale, estimates of vegetative indices based on data from these satellites can be used to bridge the spatial and temporal gaps in Landsat data. These estimates can be made daily with a pixel size of 4 kilometers on a side routinely available worldwide, 1 kilometer on a side available on prior request. Tracking of the progress of the seasons and surveillance of agricultural vigor are obvious applications. Figure 1 shows a comparison of normalized vegetation index temporal profiles between 1981 and 1982 for two grid cells in the EW/CCA research data base. During the past year, NOAA has begun to provide weekly worldwide depiction of a vegetative index based on the technology developed in this project.

Figure 1.- A comparison of normalized vegetation index temporal profiles between 1981 and 1982 for two grid cells



AgRISTARS: Inventory Technology Development

PM: Jon Erickson/SH
Reference OSSA 19

The Inventory Technology Development project has been established within the AgRISTARS program to conduct research and development of advanced technology in remote sensing for crop inventory applications.

Four categories of factors have been adopted that reflect key technological research guides. These are timeliness, affordability, general applicability, and accuracy. Timeliness emphasizes the quick extraction of information. Affordability reflects efficiency and low expense. General applicability refers to techniques that are applicable to crop regions, and remain objective and improvable procedures. Accuracy reflects the degree of bias and variance over time and the responsiveness to factors affecting departures from the average.

Research has focused on estimating crop area. Area estimates for regions are derived by processing statistical samples (segments) of satellite digital image data (Landsat MSS). The crop area should be estimated periodically throughout the season, from the time of planting through harvest.

While the overall objective of this research is to develop technology for extracting agricultural information of various kinds, the current emphasis is on improved non-U.S. production forecast technology which will be evaluated for possible integration into the USDA information systems. The objective is to develop procedures for using aerospace remote sensing and related technology to provide objective and reliable crop area forecasts several times during the growing season with improved pre-harvest estimates for selected countries and crops.

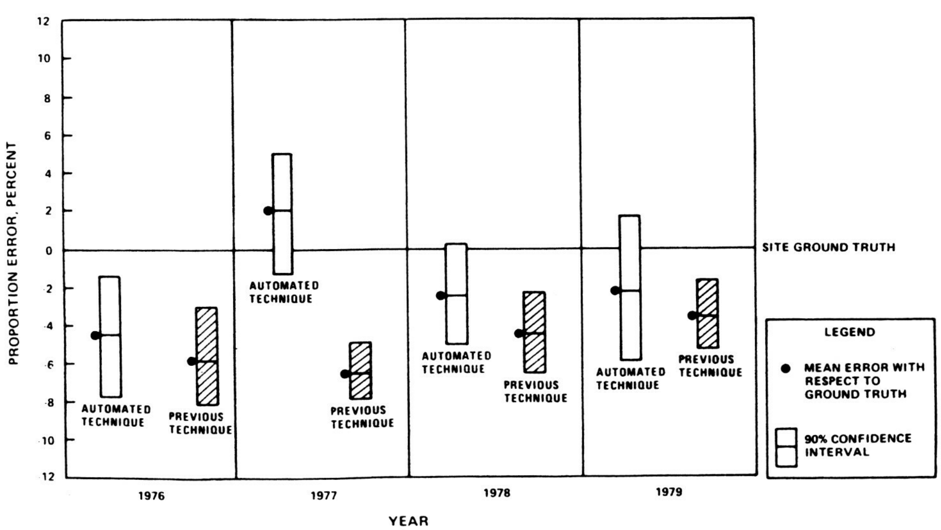
Since ground data will not be readily available, the non-U.S. crop forecasting goal is to develop a system which relies solely on Space systems. The technology development has been based on use of extensive ground observations obtained in the United States where the reliability of the observations is understood. Regions in the United States that are similar to foreign crop regions of interest have been selected as study areas. To handle dissimilarities, incremental testing over domains of greater variability of independent data sets is required. Such testing serves to establish levels of performance, isolate the technology deficiencies, and suggest required avenues of resolution.

An experiment was conducted to evaluate three highly automated Spring grain estimating technologies. The Landsat data used for this small grains experiment consisted of sample segments collected over a 4-year period (1976-1979) covering the U.S. Northern Great Plains (North Dakota, South Dakota, Montana, and Minnesota) and Saskatchewan, Canada. Ideally, the data set for this experiment would be completely representative of non-U.S. crop regions. This is the most extensive data set ever used in testing, including about 9,000 square miles of ground observations spread through four states and one province over 4 crop-years.

This first-time evaluation of highly automated spring small grains area-estimation technologies was very encouraging. There was definite improvement in near-harvest estimation efficiency.Although there was a loss in accuracy as compared to the best previous analyst-intensive approaches. The automation through modeling reduced analyst time from 4 to 6 hours to 15 minutes per segment, and computer time was reduced from 1 to 3 hours to 15 to 30 minutes. Even with no editing, it was somewhat encouraging that the mean absolute error in most cases was less than 10 percent. The results, when compared to the more labor-intensive historical procedures were generally comparable with lower bias and somewhat larger variance (fig. 1). The timeliness in the growing season is about 30 days before harvest. The Landsat 18-day overpass frequency provided sufficient cloud-free acquisitions for 50 to 65 percent of sample segments to be processed.

The significance of the present results is threefold: (1) The technique modeled the subjective human analyst with an objective process and achieved reasonable accuracies. (2) It was thereby possible to develop an information extraction technology which was not prohibitively costly in manual effort or computational resources. It is affordable within a reasonable standard. (3) If the results reported here could be achieved for foreign regions, substantial improvements in global crop information would result.

Figure 1.- Accuracy comparisons of spring small grains techniques.



Rangeland Biomass Estimate

TM: Kenneth J. Hancock/SH2
Reference OSSA 20

Experiments conducted in the past have demonstrated the capability of determining green biomass using Landsat spectral data. In 1974 Texas A&M University (TAMU), under contract to NASA, utilized Landsat to develop techniques for the quantitative estimation of green biomass over broad regions. A band-ratio parameter (TVI-6) was shown to be highly correlated with green biomass and the moisture content of vegetation. In later experiments (1979) band-ratioing techniques were extended into semi-arid, low biomass sites. Utilizing these previously-acquired data, test products were generated as gray maps of biomass in increments of pounds per acre (fig. 1) that provided area information on green biomass. These products were distributed to ranchers to determine their usefulness in ranch management situations. After evaluation, the ranchers' comments were quite positive, indicating that Landsat could be used to obtain vegetational information that could potentially improve the management efficiency of the cattle industry.

The final phase of these experiments (1981) was designed to further develop and refine techniques and procedures formulated at TAMU for generating rangeland green biomass estimates and organizing them into product formats that could be easily distributed to and utilized by the ranching community. To achieve this, a comprehensive data acquisition of simultaneous radiometer readings, vegetation clipping, and Landsat imagery was accomplished over the Texas Experimental Ranch (fig. 2). The ranch is staffed by Texas Agriculture Experiment Station employees and serves as a test bed for new and innovative ranching practices and as a field laboratory for basic research. It has been used previously for remote sensing research. The darker areas indicate heavy vegetation growth, with lighter areas indicating less biomass.

For identification of individual fields, an overlay of field boundaries and roads was superimposed on the spacecraft image.

The key to Landsat/ground data calibration is to have a range of biomass values, including both maximum and minimum values for an area, in the sample set. Maximum biomass production in the test area occurs during May and June. By sampling during this period, the widest range of biomass conditions could be found within the test area. Ancillary National Oceanic and Atmospheric Administration (NOAA) rainfall data were used to strengthen the biomass determinations.

A very significant finding of this research was that the slope of the calibration line produced from 1981 data is not significantly different from that developed 8 years earlier. Additional experimentation is needed to confirm this finding. Through this research, techniques were developed for the production of fast turnaround range-related products using Landsat spectral data. The key to a fast and efficient product generation is a sophisticated computing system and the availability of near-real-time satellite data.

Figure 1.- Individual ranch product example.

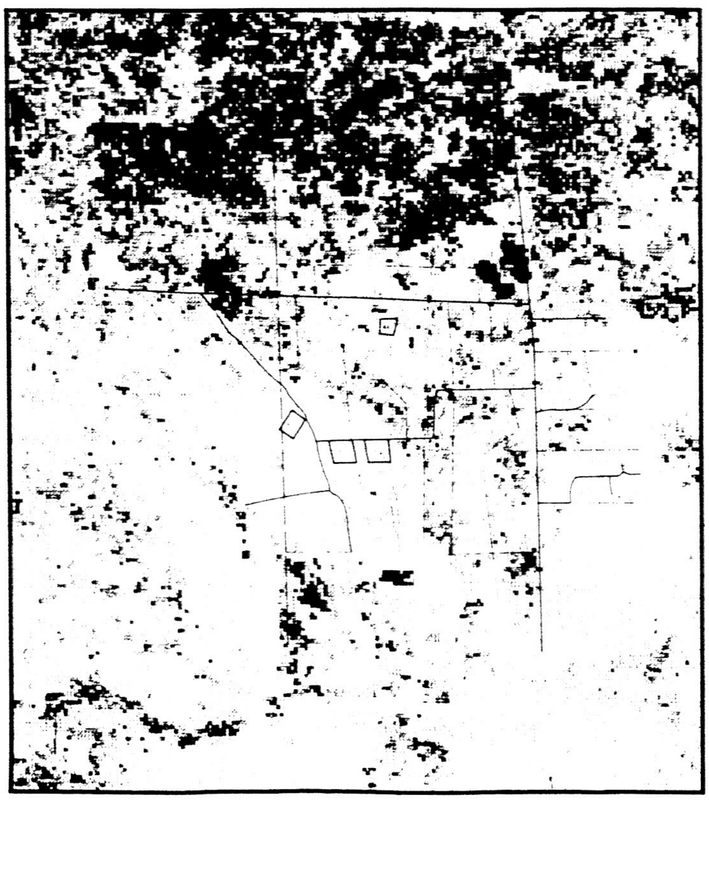
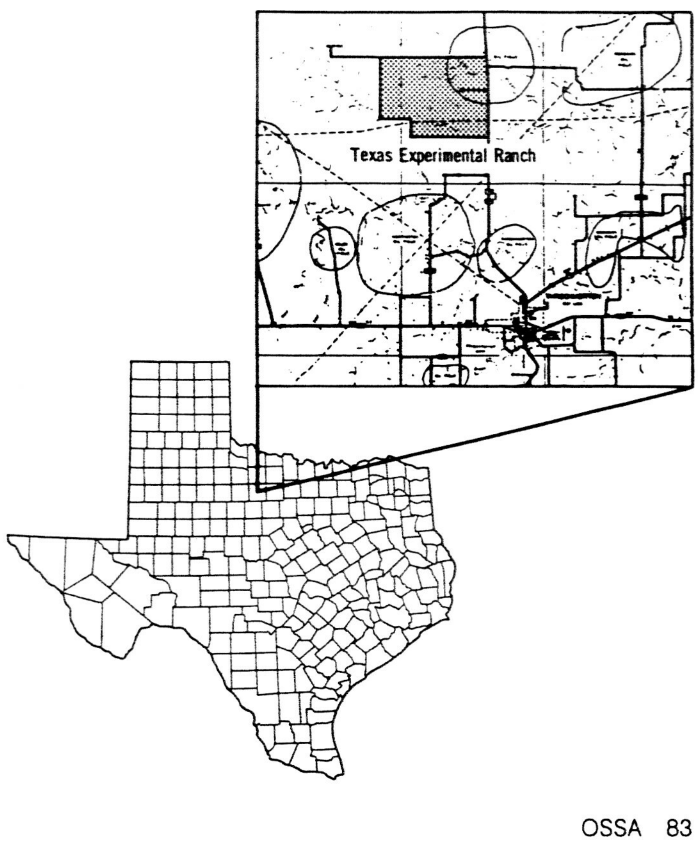


Figure 2.- Location of the Texas experimental ranch (TEXR).

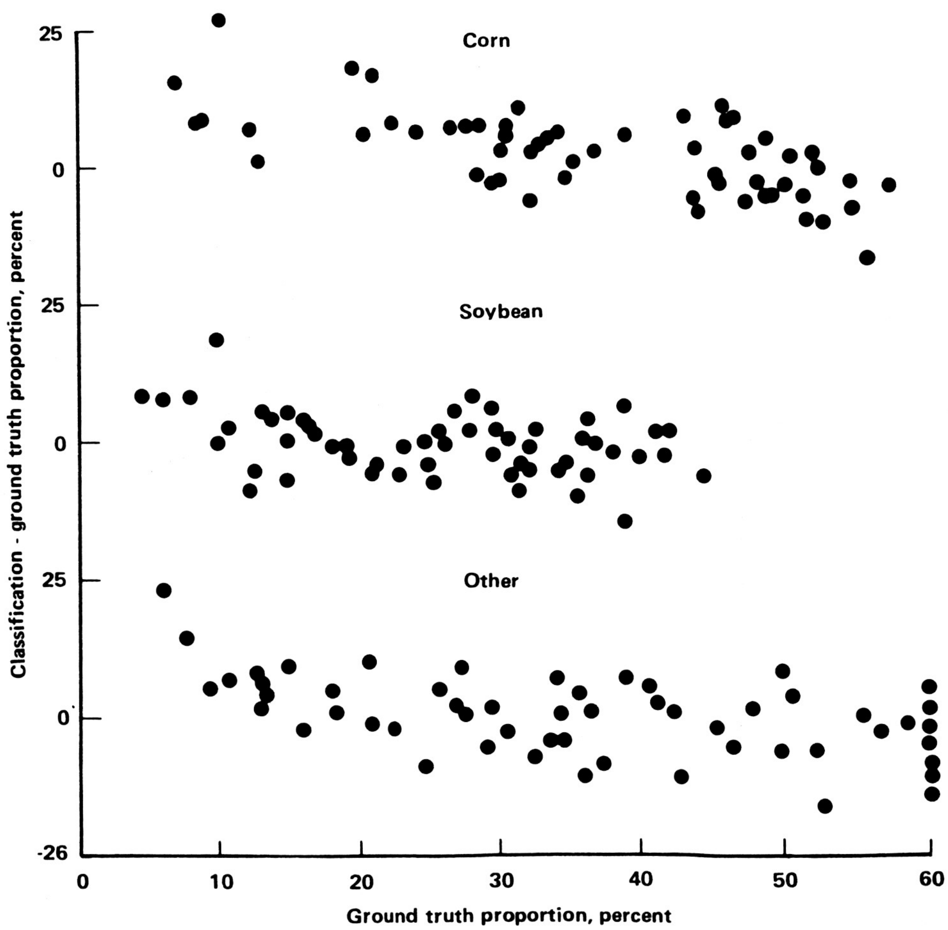


AgRISTARS: Supporting Research

PM: Forrest G. Hall/SG3
Reference OSSA 21

The Supporting Research Project of AgRISTARS focuses on advancing machine processing technology to map important vegetation types, their condition and maturity stage on a global scale using Landsat and other data types. Major advances in the technology were realized in 1982. For example, a completely automated technique for accurately classifying corn and soybean crops near harvest was successfully tested over all key growing regions in the United States Corn Belt and the Mississippi Delta for three crop years. The results of this test in which proportion estimates for 56 segments showed no significant bias (with a relative mean error of <3 percent and a relative standard error of $< \pm 2.9$ percent), are shown in figure 1. This procedure achieved significantly higher accuracy for crop identification and proportion estimation than ever achieved, especially over manual techniques which require hours of analyst time. Further, it is believed that this procedure can be cost-effectively implemented. Underlying the success of this technology was a temporal profile technique, which permits raw multidate Landsat spectral data to be modeled in terms of vegetative growth parameters relating to vegetation type such as date of emergence, peak greenness, length of growing season, and maturity stage. The relationship between these parameters and crop type is unique within the United States to corn and soybeans and stable over years and regions. One important thrust in FY 1983 will be to test this procedure on Argentina corn and soybeans ground truth segments. Preliminary indications are that the successful U.S. technique will, with only minor modifications, extend to the Argentina area. Another key effort is to extend this technique to early season while maintaining the high accuracies achieved near harvest. A third important area is to apply the Temporal Profile Technology to the identification/estimation of small grains. These research tasks are supported by a state-of-the-art intelligent interactive image analysis capability which affords on-line testing and adjustment of algorithms with permanent retention, including high quality film recording of analysis results.

Figure 1.- Accuracy assessment results of evaluation of completely automatic corn/soybeans at harvest classifier. Ground truth proportion versus error in the proportion estimate at a segment level.



In addition to the crop identification problem, an equally important area of research is the estimation of crop stage and condition. Temporal Profile Technology has made possible a major breakthrough to a long-standing problem, the accurate estimation of crop emergence date, critically needed to start agromet stage of maturity models. Research results indicate that the Temporal Profile Models can potentially be used to accurately estimate other key development stages such as floral initiation, heading, and senescence. Research to refine these techniques will continue in FY 1983. Important results were achieved in FY 1982 in the use of spectral data to assess crop condition. In FY 1983 these results will be extended to develop techniques for estimating two of the most important determining factors in crop condition, Leaf Area Index and Solar Radiation Interception.

The improvements of Registration Technology, essential to all Supporting Research efforts, will continue. In the longer term research, the investigation of the microwave regions of the spectrum to help map the type, stage, and condition of crops and other vegetation will be pursued.

In other areas, the Supporting Research will concentrate on the use of current and future sensors to improve the reliability, accuracy, and efficiency of mapping vegetation type, condition and stage of maturity, focusing on the use of optical and thermal data to estimate two of the most important determinants of vegetation condition, leaf area index, and solar radiation interception.

Texas Natural Resources Inventory and Monitoring System

PM: Leo F. Childs/SK
Reference OSSA 22

The Texas Natural Resources Inventory and Monitoring System project is a joint effort of JSC and consortium of 13 Texas agencies known as the Texas Natural Resources Information System. The project started in June 1978 and is expected to span 5 years. The project will develop, test, and evaluate a Texas Natural Resources Inventory and Monitoring System based in part on information derived from remote sensing. The system will consist of three components: a remote-sensing information subsystem, a geographic information subsystem, and a natural resources analysis subsystem. Figure 1 illustrates a type of output product associated with each subsystem.

The major responsibility of NASA is to assist Texas in upgrading its existing experimental remote-sensing data analysis capability and to interface this capability with other sources of natural resources information available to the state. The software capability is being developed in two parts. The first part was completed by NASA in early fiscal year 1980. the major responsibility of Texas includes developing the remaining remote-sensing software; expansion of the existing geographic information subsystem; development of the natural-resources analysis subsystem; and preparation, testing, and evaluation of output products.

To carry out the responsibilities of both parties, a Memorandum of Understanding was instituted. Responsibility for management of the project is shared by a Texas Project Manager and a JSC Deputy Project Manager.

This technology developed for this project will be documented for transfer to the public domain through NASA's Regional Technology Transfer Centers and the Computer Software Management and Information Center (COSMIC). Texas will also furnish a final report on the utility of the system and a cost and accuracy analysis study.

A major objective of the Texas Application System Verification and Transfer (ASVT) project is to demonstrate the capability of using Landsat data to map the forest lands of East Texas by their predominant classes, descriminating between pines and hardwoods or mixtures of the two. The end goal is to register this information on standard topographic quadrangle sheets along with other information as may be specified.

The two scenes (figs. 1 and 2) are false color composites (FCC) of the Center-S.E. 7.5-mile quadrangle located in a heavily forested area of east Texas. The image shown in figure 1 is the standard false color composite produced by Earth Resources Observation Satellite (EROS) Data Center while the images in figure 2 were produced by Texas Natural Resources Information System (TNRIS) for the East Texas ASVT Project. On a TNRIS color image, pine forest (dark blue) is easily distinguishable from hardwood forest (red), while on an EROS image this is not the case. The distinction between pine and hardwood on the TNRIS image also makes possible identification of the mixed pine and hardwood areas. This is an example of being able to custom-make or enhance the false color composite using the electronic image processing system established in Austin under the ASVT.

Figure 1.-False color composite produced by the Earth Resources Observation Satellite (EROS) Data Center.

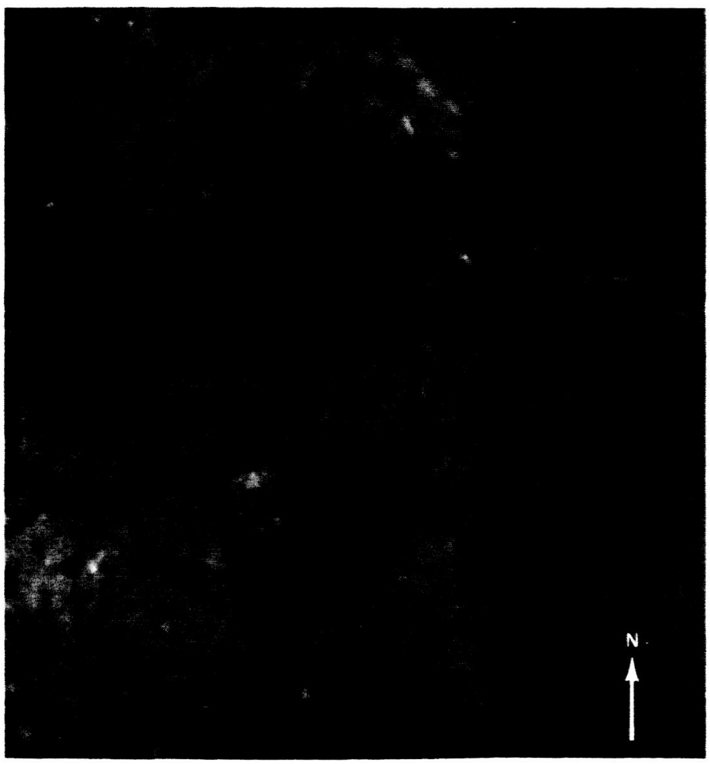
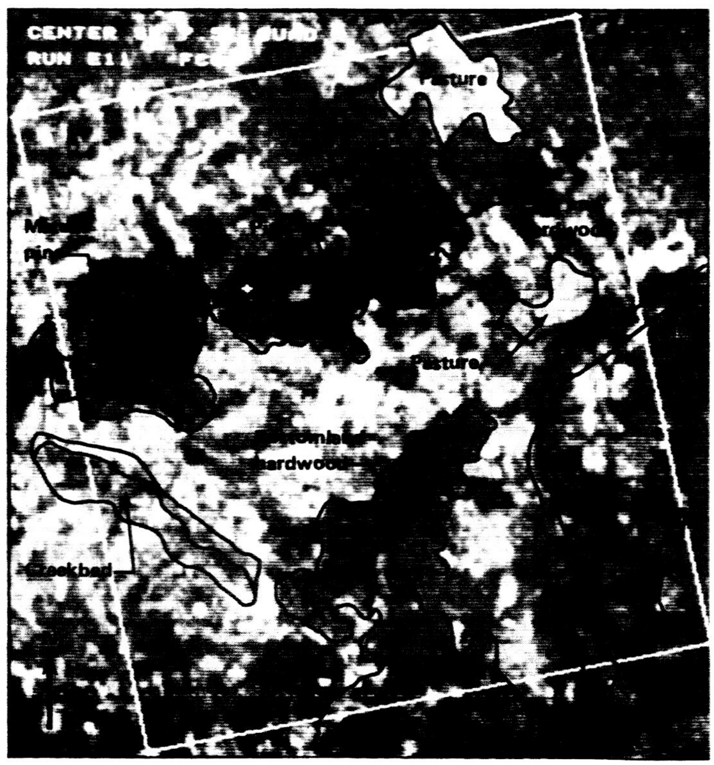


Figure 2.-False color composite produced by the Texas Natural Resources Information System (TNRIS).



SIR-A Antenna Mission and Deintegration

TM: Harold A. Nitsche/EE6
Reference OSSA 23

The Shuttle Imaging Radar (SIR-A) — developed to evaluate the potential of spaceborne imaging radar as a tool for geologic exploration and, in general, for mineral exploration, petroleum exploration, and structural mapping — is part of the Office of Space and Terrestrial Applications (OSTA)-1 payload flown on the Space Transportation System (STS) second mission in November 1981. The SIR-A antenna was developed by JSC to be used with the SIR-A electronics developed the Jet Propulsion Laboratory.

The SIR-A antenna (fig. 1) consists of seven microstrip array panels mounted on a triangular support structure. The antenna is attached to the OSTA-1 pallet by an aluminum truss structure. The nondeployable 9.44- by 2.1-meter antenna is mounted in the payload bay in a fixed position at 47°. Thermal protection is provided by the multilayer aluminized mylar covering the support structure and by the Beta cloth covering the total system.

The image of cropland in New South Wales, Australia, is the first processed data acquired by JPL's Shuttle Imaging Radar-A (SIR-A) experiment aboard NASA's Space Shuttle Columbia during the Shuttle's second flight, November 12-14, 1981. (fig. 2) As an imaging radar, SIR-A acquired images despite darkness or cloud cover. The Lachlan River is on the top left and the Lachland Range extends south from the river with Lake Brewster to the right of the range. Cropland in the image is primarily small grains and pasture. The image covers a 50- by 100-kilometer (31 by 62 miles) area, shows features as small as 60 meters (200 ft), and was acquired by SIR-A in 15 seconds. This successful SIR-A experiment, designed to determine the potential of using spaceborne imaging radars as tools, acquired images covering 10 million square kilometers (3,861,000 square miles) in regions all over the world.

Figure 1.- SIR-A antenna mounted in Shuttle Orbiter.

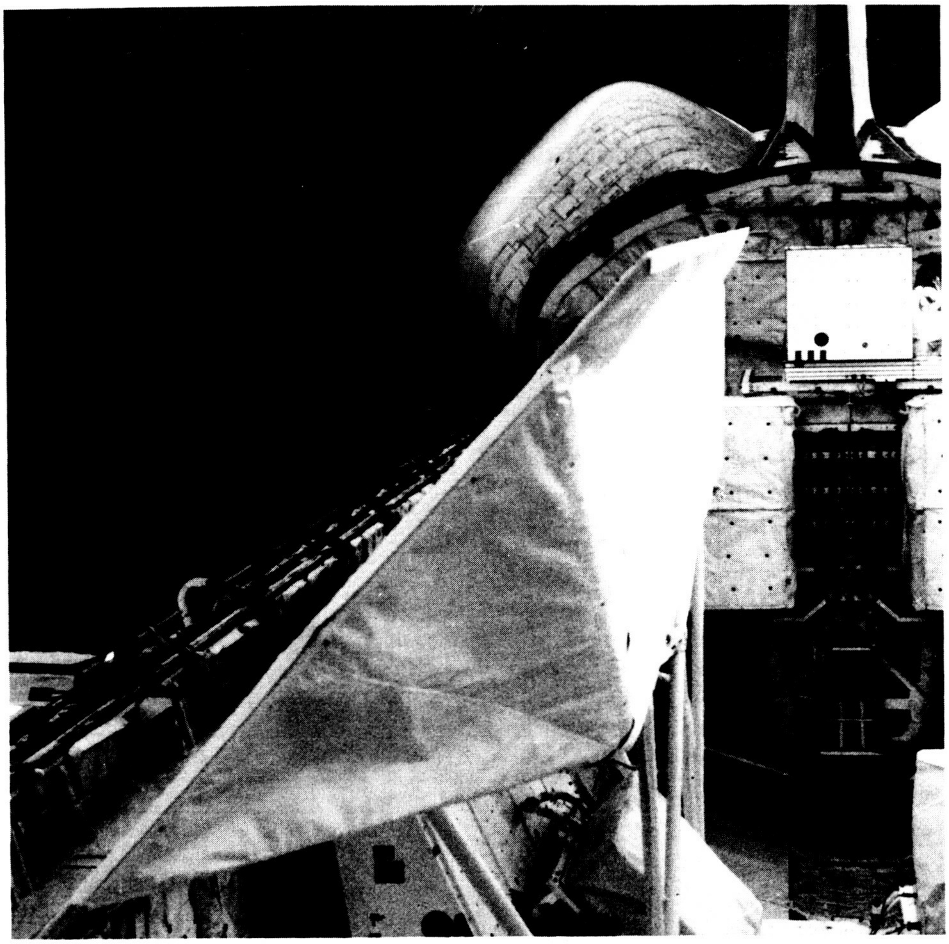


Figure 2.- Image of cropland in New South Wales, Australia.

(AgRISTARS Sample Segment 4113) 0——5 Statute Miles

Index

Reference Number	Significant Task
	Office of Space Flight
OSF 1	**Proximity Operations Vehicle** Funded by: Advanced Development (UPN-906) Technical Monitor: Ronald H. Gerlach/EN5 Task Performed by: Lockheed Engineering and Management Services Company, Inc., Contract NAS 9-15800
OSF 2	**Advanced Rendezvous and Docking Sensor** Funded by: Advanced Programs (UPN-906) Technical Monitor: Harry O. Erwin/EE6 Task Performed by: Lockheed Engineering and Management Company, Inc., Contract NAS 9-15800 RCA Corporation, Contract NAS 9-16252
OSF 3	**Zero Prebreathe Extravehicular Mobility Unit** Funded by: Advanced Development (UPN-906) Technical Monitor: Joseph J. Kosmo/EC1 Task Performed by: Hamilton Standard, Contract NAS 9-15150 David Clark Company, Contract NAS 9-16347
OSF 4	**Onboard Remote Terminal** Funded by: Advanced Development (UPN-906) Technical Monitor: Robert H. Brown/FM Task Performed by: Science Applications, Inc., Contract NAS 9-16165
OSF 5	**Space Station Avionics System** Funded by: Advanced Development (UPN-906) Technical Monitor: William L. Swingle/EH Task Performed by: Lockheed Engineering and Management Services Company, Inc., Contract NAS 9-15800
OSF 6	**Remote Manipulator System Control Technology** Funded by: Advanced Development (UPN-906) Technical Monitor: Henry J. G. Kaupp, Jr./EH2 Task Performed by: Charles Stark Draper Laboratories, Contract NAS 9-16023
OSF 7	**Space Construction Experiment Definition Study** Funded by: Major System Studies (UPN-906) Technical Monitor: Lyle M. Jenkins/ET4 Task Performed by: General Dynamics-Convair, Contract NAS 9-16303
OSF 8	**Carbon Dioxide Reduction** Funded by: Advanced Development (UPN-906) Technical Monitor: Robert J. Cusick/EC3 Task Performed by: Hamilton Standard, Contract NAS 9-15470
OSF 9	**Vapor Compression Distillation Urine Water Recovery** Funded by: Advanced Development (UPN-906) Technical Monitor: Donald F. Price/EC3 Task Performed by: Life Systems, Inc., Contract NAS 9-16374
OSF 10	**Thermoelectric Integrated Membrane Evaporation Water Recovery System** Funded by: Advanced Development (UPN-906) Technical Monitor: H. Eugene Winkler/EC3 Task Performed by: Hamilton Standard, Contract NAS 9-15471
OSF 11	**Orbital Debris** Funded by: Advanced Development (UPN-906) Technical Monitor: Donald J. Kessler/SN3 Task Performed by: Lockheed Engineering and Management Services Company, Inc., Contract NAS 9-15800

Reference Number	Significant Task

Office of Aeronautics and Space Technology

OAST 1 **Aerodynamic Coefficient Identification Package**

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: Joe E. Rutherford/EN3
Task Performed by: Bendix Aerospace Systems Contract NAS 9-15588

OAST 2 **Power Generation and Energy Storage Utilizing Regenerative Fuel Cells**

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: Dale Denais/EP5
Task Performed by: General Electric Company Contract NAS 9-15831
Life Systems Contract NAS 9-16659
Boeing Aerospace Company Contract NAS 9-16151

OAST 3 **Thermal Management for Onorbit Energy Systems**

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: J. Gary Rankin/EC2
Task Performed by: Grumman Aerospace Corporation Contract NAS 9-15965
Vought Corporation Contracts NAS 9-14907, NAS 9-16321, and NAS 9-16582
Hughes Aircraft Company Contract NAS 9-16581
Rockwell International Contract NAS 9-16399

OAST 4 **Bubble Memory System Development**

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: Edgar A. Dalke/EH4
Task Performed by: Lyndon B. Johnson Space Center

OAST 5 **Multifunction Synthetic Aperture Radar Technology**

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: Kumar Krishen/EE4
Task Performed by: Jet Propulsion Laboratory Contract NAS 7-100
Multiple additional contractors

OAST 6 **Advanced Manned Vehicle Onboard Propulsion Technology**

Funded by: Space Research and Technology Base (UPN-506)
Technical Monitor: William C. Boyd/EP2
Task Performed by: Aerojet Liquid Rocket Company Contracts NAS 9-16639 and NAS 9-15958
McDonnell Douglas Corporation Contract NAS 9-16305

OAST 7 **Lunar Resources**

Funded by: Space Research and Technology Base (UPN-506)
Principal Investigator: Richard J. Williams/SN7
Co-Investigator: William Agosto
Task Performed by: Lyndon B. Johnson Space Center and
Lockheed Engineering and Management Services Company

OAST 8 **Aircraft Fire Safety and Testing**

Funded by: Aeronautics Research and Technology Base (UPN-505)
Technical Monitor: Daniel E. Supkis/ES5
Task Performed by: Chem-Tronics, Incorporated Contract NAS 9-16657
Boeing Commercial Airplane Company Contracts NAS 9-15062, Mod 6S and NAS 9-16400
General Electric Company Contract NAS 9-15533

OAST 9 **In Situ Instrumentation for Nuclear Waste Repositories**

Funded by: Space Utilization System Applications (UPN-775)
Principal Investigator: James E. Keith/SN3
Task Performed by: Lyndon B. Johnson Space Center

Office of Space Sciences and Applications
Lunar and Planetary Sciences

OSSA 1 **Experimental Trace Element Geochemistry**

Funded by: Planetary Geochemistry and Geophysics (UPN-153)
Principal Investigator: Gordon A. McKay/SN7
Task Performed by: Lyndon B. Johnson Space Center

OSSA 2 **Regolith Dynamics from Lunar Cores**

Funded by: Planetary Materials (UPN-152)
Principal Investigator: David S. McKay/SN6
Task Performed by: Lyndon B. Johnson Space Center

Reference Number	Significant Task
OSSA 3	**Cosmic Dust Program** Funded by: Planetary Materials (UPN-152) Principal Investigator: Uel S. Clanton and James L. Gooding/SN2 Task Performed by: Lyndon B. Johnson Space Center
OSSA 4	**Meteorites from Mars** Funded by: Planetary Materials (UPN-152) Principal Investigator: Laurence Nyquist/SN7 Task Performed by: Lyndon B. Johnson Space Center
OSSA 5	**Fluid Inclusions in Meteorites** Funded by: Planetary Materials (UPN-152) Principal Investigator: Everett K. Gibson/SN7 Co-Investigator: Lewis Ashwal, Lunar and Planetary Institute Task Performed by: Lyndon B. Johnson Space Center
OSSA 6	**Laser Microprobe - Gas Chromatograph** Funded by: Planetary Materials (UPN-152) Principal Investigator: Everett K. Gibson/SN7 Co-Investigator: Rama Kotra, Lockheed Engineering and Management Services Company, Inc. Task Performed by: Lyndon B. Johnson Space Center
OSSA 7	**The Earth's Early Crust and Mantle** Funded by: Planetary Materials (UPN-152) Planetary Geochemistry and Geophysics (UPN-153) Principal Investigator: William C. Phinney/SN6 Co-Investigator: Joseph Wooden, Lockheed Engineering and Management Services Company, Inc. Task Performed by: Lyndon B. Johnson Space Center
OSSA 8	**Effect of Aluminum Substitution on the Reflectance Spectrum of Hematite** Funded by: Planetary Geology (UPN-151) Principal Investigator: Richard V. Morris/SN7 Task Performed by: Lyndon B. Johnson Space Center
OSSA 9	**Vertical Impact Facility** Funded by: Planetary Geochemistry and Geophysics (UPN-153) Principal Investigator: Friedrich Horz/SN6 Task Performed by: Lyndon B. Johnson Space Center
	Life Sciences
OSSA 10	**Motion Sickness Test Instrumentation** Funded by: Life Sciences (UPN-199) Technical Monitor: Jerry L. Homick/SD3 Task Performed by: University of Michigan, Contract NAS 9-15244
OSSA 11	**Neutron Activation Laboratory** Funded by: Life Sciences (UPN-199) Technical Monitor: Philip C. Johnson/SD3 Task Performed by: Technology Incorporated, Contract NAS 9-14880
OSSA 12	***In Vivo* Nuclear Magnetic Resonance** Funded by: Life Sciences (UPN-199) Technical Monitor: Philip C. Johnson/SD3 Task Performed by: Baylor College of Medicine, Contract NAS 9-16442
OSSA 13	**Renal and Endocrine Studies During the Early Phase of Antorthostatic Hypokinesia** Funded by: Life Sciences (UPN-199) Technical Monitor: C. S. Leach/SD4 Task Performed by: Northrup Services, Inc., Contract NASA 9-15425 Technology, Inc., Contract NAS 9-14880

Reference Number	Significant Task
OSSA 14	**Physiological Testing of the Ambulatory Lower Body Negative Pressure Apparatus** Funded by: Life Sciences (UPN-199) Technical Monitor: M. W. Bungo/SD3 Task Performed by: ILC Dover, Technology Inc., Contract NAS 9-14880
OSSA 15	**Shuttle Solid Sorbent Air Sampler** Funded by: Life Sciences (UPN-199) Technical Monitor: Howard C. Schneider/ES22 Task Performed by: Northrup Services, Inc., Contract NAS 9-15690
OSSA 16	**Microbial Contamination Control and the Centrifugal Microbiological Analyzer** Funded by: Life Sciences (UPN-199) Technical Monitor: Duane L. Pierson/SD4 Task Performed by: Northrup Services, Inc., Contract NAS 9-15425
OSSA 17	**Multiwire Proportional Counter Gamma Camera (MPCGC)** Funded by: Life Sciences (UPN-199-20) Technical Monitor: J. L. Lacy/SD3 Task Performed by: Lockheed Engineering and Management Corporation Contract NAS 9-15800
	Space Applications
OSSA 18	**AgRISTARS: Early Warning/Crop Condition Assessment Project** Funded by: Resource Observation (UPN-691) Project Manager: Victor S. Whitehead/SH3 Task Performed by: NASA, U. S. Department of Agriculture, and U.S. Department of Commerce
OSSA 19	**AgRISTARS: Inventory Technology Development** Funded by: Resource Observation (UPN-691) Project Manager: Jon Erickson/SH Task Performed by: NASA, U. S. Department of Agriculture, and U.S. Department of Commerce
OSSA 20	**Rangeland Biomass Estimation** Funded by: Resource Observation Applied Research and Data Analysis (UPN-691) Project Manager: Kenneth J. Hancock/SH2 Task Performed by: Texas Agriculture and Mechanical University, Contract NAS 9-15369
OSSA 21	**AgRISTARS: Supporting Research** Funded by: Resource Observation (UPN-691) Project Manager: Forrest G. Hall/SG3 Task Performed by: NASA, U.S. Department of Agriculture, and U.S. Department of Commerce
OSSA 22	**TEXAS Natural Resources Inventory and Monitoring System** Funded by: Applications Systems Verification Test (UPN-658) Project Manager: Leo F. Childs/SK Task Performed by: Lyndon B. Johnson Space Center Department of Water Resources, Contract T-3499H
OSSA 23	**SIR-A Antenna Mission Deintegration** Funded by: Resource Observation (UPN-666) Technical Monitor: H. A. Nitschke/EE6 Task Performed by: Lyndon B. Johnson Space Center Ball Aerospace Systems Division, Contract NAS 9-15512

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16. Abstract

The 1982 Research and Technology Annual Report of the Johnson Space Center highlights accomplishments in new and advanced concepts within the last 12 months. The report encompasses research funded by the Office of Aeronautics and Space Technology; the Advanced Programs accomplishments funded by the Office of Space Flight; and Lunar and Planetary Sciences, Life Sciences, and Space Applications research funded by the Office of Space Sciences and Applications. The report is intended to present these accomplishments in a format suitable for external consumption, free of technical jargon, and illustrated with pictorial representations to increase ease of comprehension. It includes summary sections which describe the role of the Johnson Space Center in each program, followed by individual one-page descriptions of the significant projects.

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