IN-91
11808
P.99

NASA Technical Memorandum 102177

JSC Director's Discretionary Fund Program

1990 Annual Report

April 1991

(NASA-TM-102177) JSC DIRECTOR'S DISCRETIONARY FUND PROGRAM Annual Report, 1990 (NASA) 99 p
N91-23012
CSCL 03B
Unclas
G3/91 0011808

Compiled by
New Initiatives Office
Lyndon B. Johnson Space Center

NASA
National Aeronautics and
Space Administration

NASA Technical Memorandum 102177

JSC Director's Discretionary Fund Program

1990 Annual Report

Compiled by
New Initiatives Office
Lyndon B. Johnson Space Center
Houston, Texas

April 1991

Preface

The concept of providing a center director's discretionary fund (CDDF) to support research projects has been very effective at the Lyndon B. Johnson Space Center. The projects described in this report include the results of research that has its roots linked to engineering applications. The reader is provided with invaluable information from a broad experience base. The selection of individual projects also provides an incentive to young engineers for future project development. Funding for FY90 was $1340k which was distributed among twenty-five projects with participation across the Center directorates. By focusing on three Space Exploration Initiative related issues: regenerative life support, human spacecraft design, and lunar surface habitat, a viable program of life sciences, space sciences, and engineering research has been maintained.

The guidelines for selection of proposed projects for funding include an emphasis on in-house work, a project span of 3 years or less at a nominal funding level of $50k per year that is not available from other sources, an early identifiable product, and the potential for a new start with specific funding support. The following is a brief status on some of the projects with broad potential application.

- Artificial intelligence techniques were incorporated into a prototype system to assess the production schedules for Space Shuttle flight software. It has resulted in reducing evaluation personnel by three people.

- Testing of diluent gases in oxygen rich environments showed potential benefits by inhibiting combustion.

- Holographic analysis techniques were successfully applied to the understanding of rocket engine stability and for the detection of defects in metallic systems.

- Testing of antenna performance began on various antenna configurations in order to investigate the advantages of high-temperature superconductors.

- Concepts for analysis of planetary soils are being developed. Thermoanalytic methods are emphasizing a bench test version of a differential scanning calorimeter module mated with a solid state water sensor. A research grade Mossbauer spectrometer is used in backscatter spectroscopy testing.

- Reducing the effects of space flight by developing an optimum protocol for lower body negative pressure and fluid loading solution is continuing.

- The regenerative life support system test bed project outfitted the variable pressure growth chamber with plant growth systems as part of a long-term commitment to the research needed in this vital exploration technology.

- The lunar surface systems habitat test bed is being used to stimulate creative and innovative approaches to human habitation in extreme environments.

- The Targeting and Reflective Alignment Concept, the most significant invention of the year, is being interfaced with machine vision programs to automate grappling with manipulators in space.

- Burn resistant alloys were tested at the White Sands missile range indicating an increased resistance by adding lithium to aluminum alloys.

- Gamma-ray counting facilities developed for the trace element analysis of cosmic dust were used extensively for analysis of radiation effects on the Long Duration Exposure Facility.

The team at the White Sands Test Facility has been particularly efficient in their use of the CDDF. The facilities and individuals that initiated and conducted the follow-up research on the projects included in this report provide a unique capability to the agency.

For additional information on the projects listed in this report, contact the individual investigators or Lyle Jenkins at (713) 283-5405.

William J. Huffstetler
Manager, New Initiatives Office

CONTENTS

Project	Page

TABLES

Table | Page

FIGURES

Figure | Page

Figure Page

TITLE OF INVESTIGATION: Laser-Based Plasma Flow Diagnostics

PROJECT MANAGER: Eric Yuen/ES36/483-5950

TEAM MEMBER: Carl Scott, NASA;
Sivaram Arepalli, Lockheed

INITIATION YEAR: FY88

FUNDING:

	Total prior years	FY90
In-house:	31k	
CDDF:	53k	25k
Total funds:	84k	25k

OBJECTIVE

The Laser-Based Plasma Flow Diagnostics project has been developed in order to gain a better understanding of the hypersonic flow field. This nonintrusive laser-based technique can measure flow parameters such as velocity, temperature, and number densities of the flow constituents. This information is the necessary input for computational fluid dynamics calculations as well as heat transfer analyses. The objective of this project is to demonstrate the feasibility of the laser-based technique in the Atmospheric Reentry Materials and Structures Evaluation Facility (ARMSEF) at the Lyndon B. Johnson Space Center. The feasibility study includes (1) identification of the necessary lasers and detection electronics; (2) procurement of equipment; (3) integration of lasers and electronics into the existing arc-jet facility; and (4) the recording of flow field measurements (temperature, velocity, and number densities) under real test conditions.

ACCOMPLISHMENTS IN FY90

The free-stream velocity and temperature measured in the ARMSEF simulates the atmospheric entry of spacecrafts. The technique of resonance Doppler velocimetry is employed using the laser-induced fluorescence (LIF) of copper atoms in the free-stream flow. Copper atoms sputtered from the anode continuously when there was current between the electrodes of the DC constricted arc heater. These copper atoms were used as tracer atoms to provide information of the free-stream velocity and temperature. The test conditions for these measurements is given in table 1.

TABLE 1.- A SUMMARY OF THE TEST CONDITIONS

Massflow rate k/s	Current A	Pressure N/m2	Enthalpy mJ/kg	Velocity m/s	Temperature K
0.0454	700	4265	13.1	2853	2022
0.0454	500	3546	9.9	2673	1457
0.0454	300	2827	6.5	1952	1017
0.0681	700	5654	11.4	2853	1148
0.0908	700	6900	9.4	2132	1486
0.0908	500	5654	7.2	1952	1478
0.0908	300	4648	4.5	1320	498
0.1135	700	7427	8.7	2492	1076

The setup of the experiment is shown in figure 1. A Nd:YAG (neodynium doped yttrium aluminum garnet) laser, which produced a 350-mJ pulse of 532-nm second harmonic radiation, was used to pump a dye laser resulting in an 80-mJ/pulse of 655 nm radiation. The 655-nm laser pulses were frequency doubled using a KD*P (potassium di-deuterium phosphate) crystal to produce an 8-mJ/pulse of 327.5 nm radiation. By using an intracavity etalon in the dye laser, the linewidth of the 327.5-nm laser pulse is limited to 0.08 cm^{-1} (2400 MHz). The laser beam was then steered into the test chamber at either a right angle or 60° from the flow direction. The LIF signal was collected by a photomultiplier tube (PMT) at 90° to both the laser beam and the flow direction. The PMT operated in the photon counting mode. The output of the PMT was fed directly into two gated channels of a photon counter. The photon counter was then used in a background subtract mode. The photon count and the laser frequency information were sent to an X-Y recorder to construct an LIF spectrum. The basic electronic block diagram is shown in figure 2.

All measurements were made at the centerline of the plasma flow: 12.5 cm from the nozzle exit. The measured Doppler profiles, like the one shown in figure 3, were used to determine the velocity and temperature. The velocity of the plasma flow was obtained by comparing the wavelength shift of the LIF spectrum measured at 60° and the LIF spectrum obtained at 90° using the expression:

$$v = \frac{c}{\nu_0 \cos\theta}\Delta\nu \qquad (1)$$

where v is the velocity of the plasma flow, c is the speed of light in vacuum, ν_0 is unshifted frequency of the transition, θ is the angle between the laser beam and the plasma flow, and Δν is the shift frequency. To determine the temperature of the plasma, a nonlinear least squares curve fit code was used. A quadruplet Gaussian profile was assumed for the four hyperfine levels. The functional form of the quadruplet is

$$I(\nu, T) = \sum_{j=1}^{4} a_j \exp\left[\frac{-m_{Cu}c^2}{2kT\nu_0^2}(\nu - \nu_0 - \nu_j)^2\right] \quad (2)$$

where a_j is the line weight, m_{Cu} is the mass of the copper atom, ν_0 is the line reference wavenumber, ν_j is the offset from the reference for each component, T is the absolute temperature, and c is the speed of light. The least squares determination of the temperature was found by minimizing, with respect to the temperature, the relation

$$S = \sum_{i=1}^{N} [I(\nu_i, T) - I_i]^2 \quad (3)$$

where N is the number of measured points defining the Doppler profile, I_i are the measured intensities suitably normalized, and $I(n_i, T)$ is the calculated intensity formed by folding Eq.(2) with the laser profile and suitably normalizing the result. The relative intensities of the four hyperfine levels (the a_j) was assumed to be 1.0:1.0:0.6:0.3. These were obtained from measurements of a cold copper atom using a single frequency dye laser (ref. 1). The results of the curve fits are shown in figure 4, where the Doppler temperature is plotted against total heat balance enthalpy. The results are compared with calculations made using the 1-dimensional, nonequilibrium flow code NATA (ref. 2) and those obtained by solving the conservation equations (refs. 3, 4, and 5).

$$h_T = \tfrac{1}{2}V_\infty^2 + \alpha_N h_N + C_p T_\infty \quad (4)$$

$$P_{T2} = C_p \rho_\infty V_\infty^2 + P_\infty \quad (5)$$

$$mg = \rho_\infty V_\infty A_{eff} \quad (6)$$

where h_T is the total enthalpy, h_N is the enthalpy of dissociation of nitrogen, V_∞ is the freestream velocity, T_∞ is the freestream temperature, ρ_∞ is the freestream density, P_∞ is the freestream pressure, P_{T2} is the stagnation pressure, α_N is the nitrogen atom mass fraction, C_p is the heat capacity of nitrogen at constant pressure, mg is the massflow rate, and A_{eff} is the area of inviscid core of nozzle flow at the nozzle exit.

The comparison between the NATA code, the solution to the conservation equations, and the measurements are shown in figures 4 and 5. The results do not agree very well, indicating that the assumptions used in the calculations may not be adequate.

PLANNED FUTURE WORK

All of the objectives outlined in this investigation have been met. When the test facilities come back online after the C of F project, the velocity and temperature of the arc jet flow will be measured at various test conditions and at different positions to provide a 3-dimensional picture of the flow field.

PUBLICATION AND PRESENTATION

- AIAA/ASME 5th Joint Thermophysics and Heat Transfer Conference, June 18-20, 1990 / Seattle, WA.
- Sivaram Arepalli, Eric H. Yuen and Carl D. Scott, "Application of Laser Induced Fluorescence for Flow Diagnostics in Arc Jet", to be published in Journal of Thermophysics and Heat Transfer.

REFERENCES

1. Chen, Hao-Lin; and Erbert, G.: Laser Studies of Electronic Energy Transfer in Atomic Copper. Journal of Chemical Physics, vol. 78, April 1983, pp. 4985-4990.

2. Bade, W. L.; and Yos, J. M.: The NATA Code - Theory and Analysis. NASA CR2547, 1975.

3. Scott, C. D.: Catalytic Recombination of Nitrogen and Oxygen on High Temperature Reusable Surface Insulation. Progress in Astronautics and Aeronautics: Aerothemodynamics and Planetary Entry, vol. 77, edited by A. L. Crosbie, AIAA, New York, 1981, pp. 192-212.

4. Scott, C. D.: Catalytic Recombination of Nitrogen and Oxygen on Iron-Cobalt-Chromia Spinel. AIAA Paper 83-0585, January 1983.

5. Scott, C. D.: Survey of Measurements of Flow Properties in Arc Jets. AIAA Paper 90-1795, 1990.

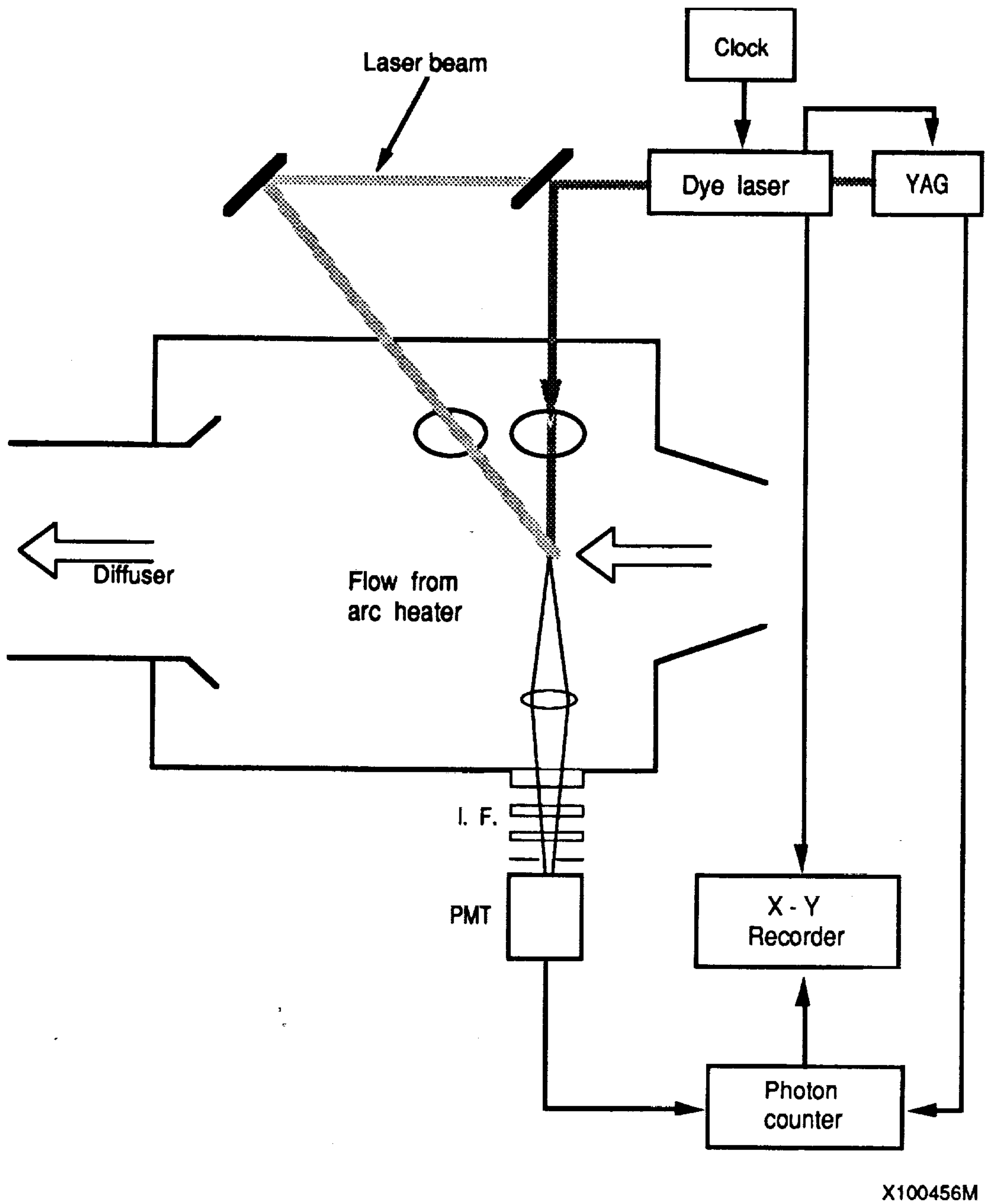


Figure 1. Experimental setup of Doppler velocimetry in ARMSEF.

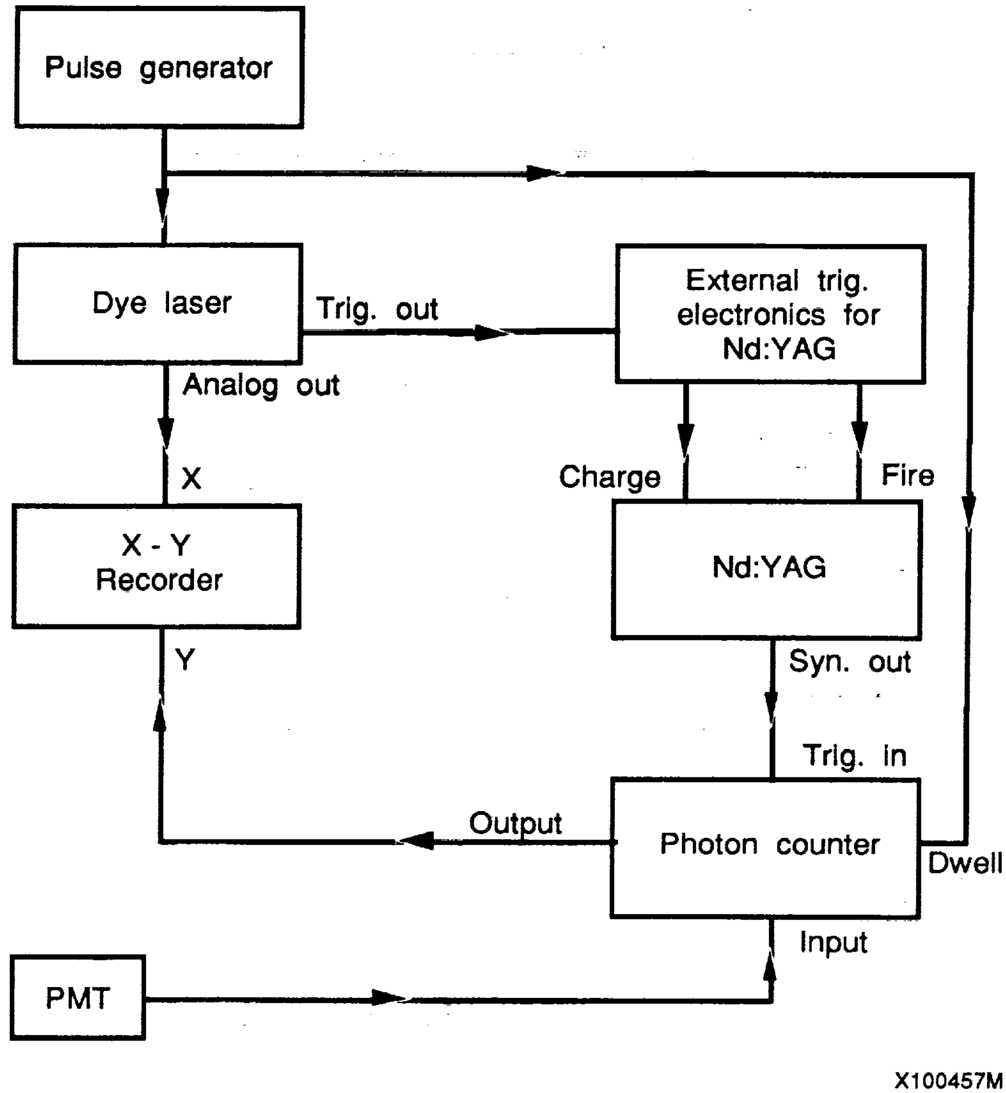


Figure 2. Electronics block diagram of the experiment.

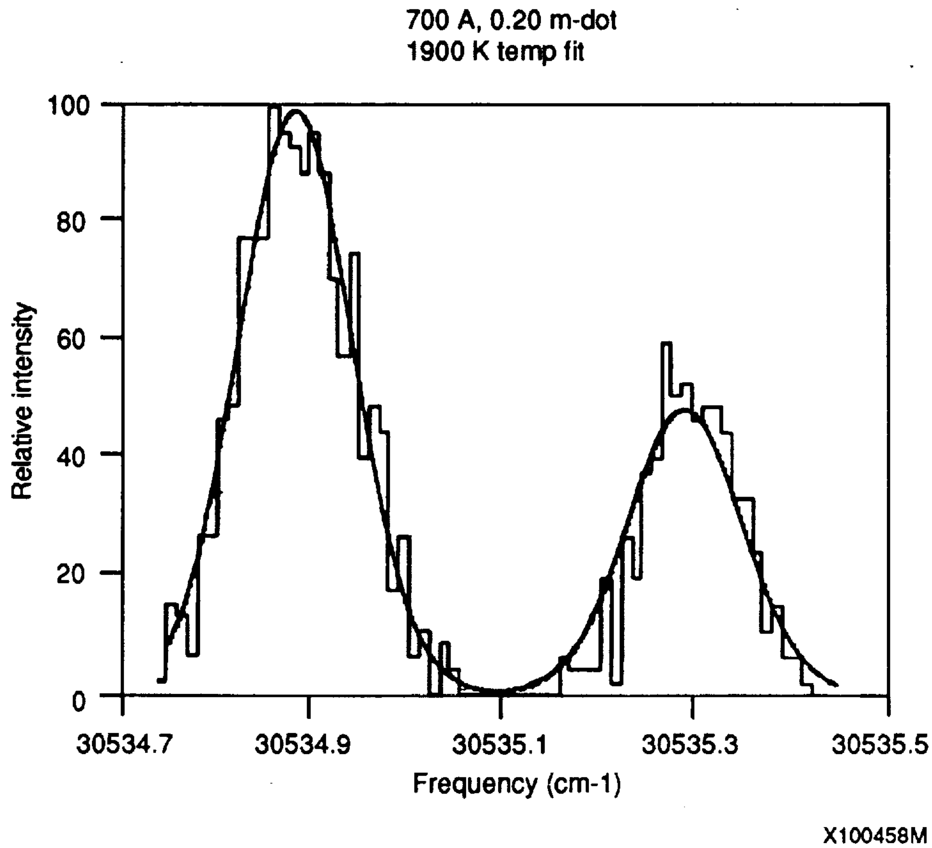


Figure 3. A typical laser induced fluorescence spectrum of copper atom superimposed by the computer spectrum.

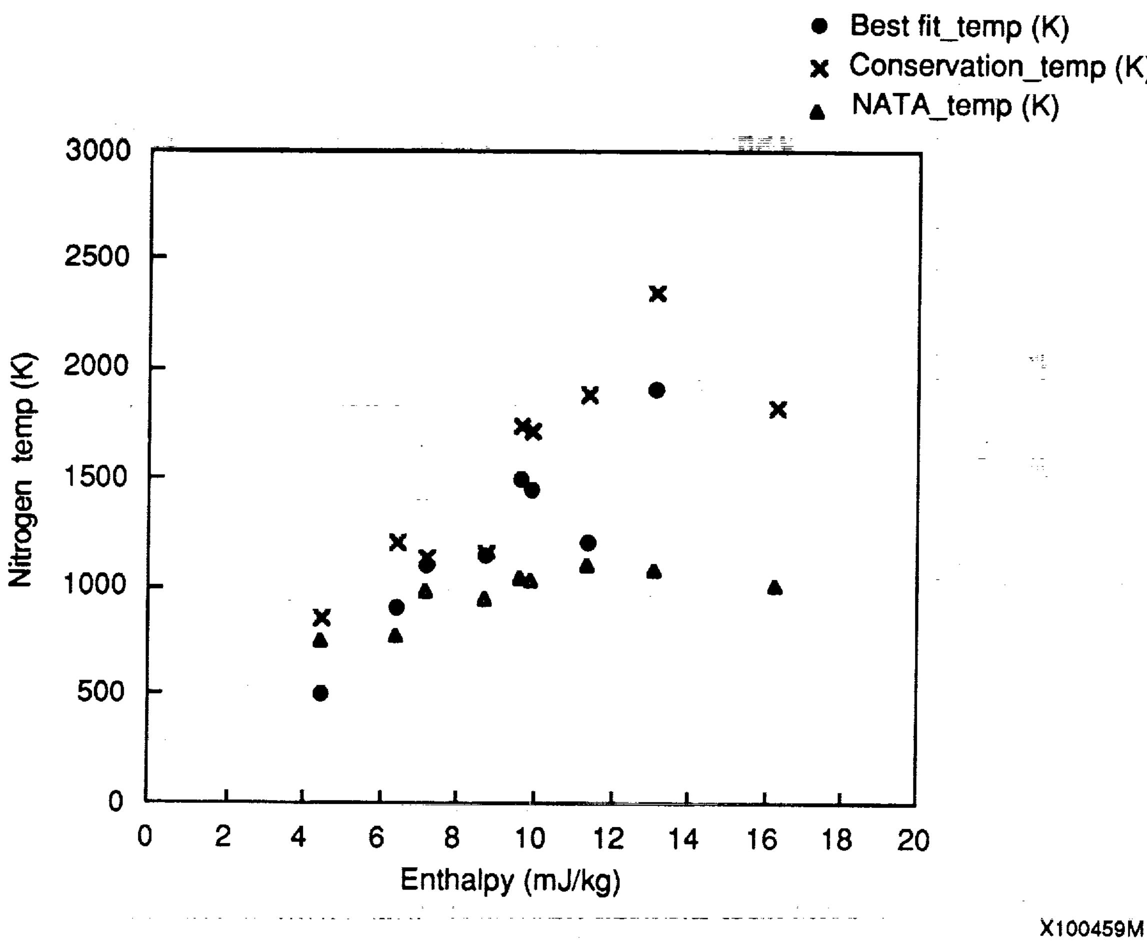


Figure 4. Comparison between measured and computed temperature at different enthalpy (arc jet temperature).

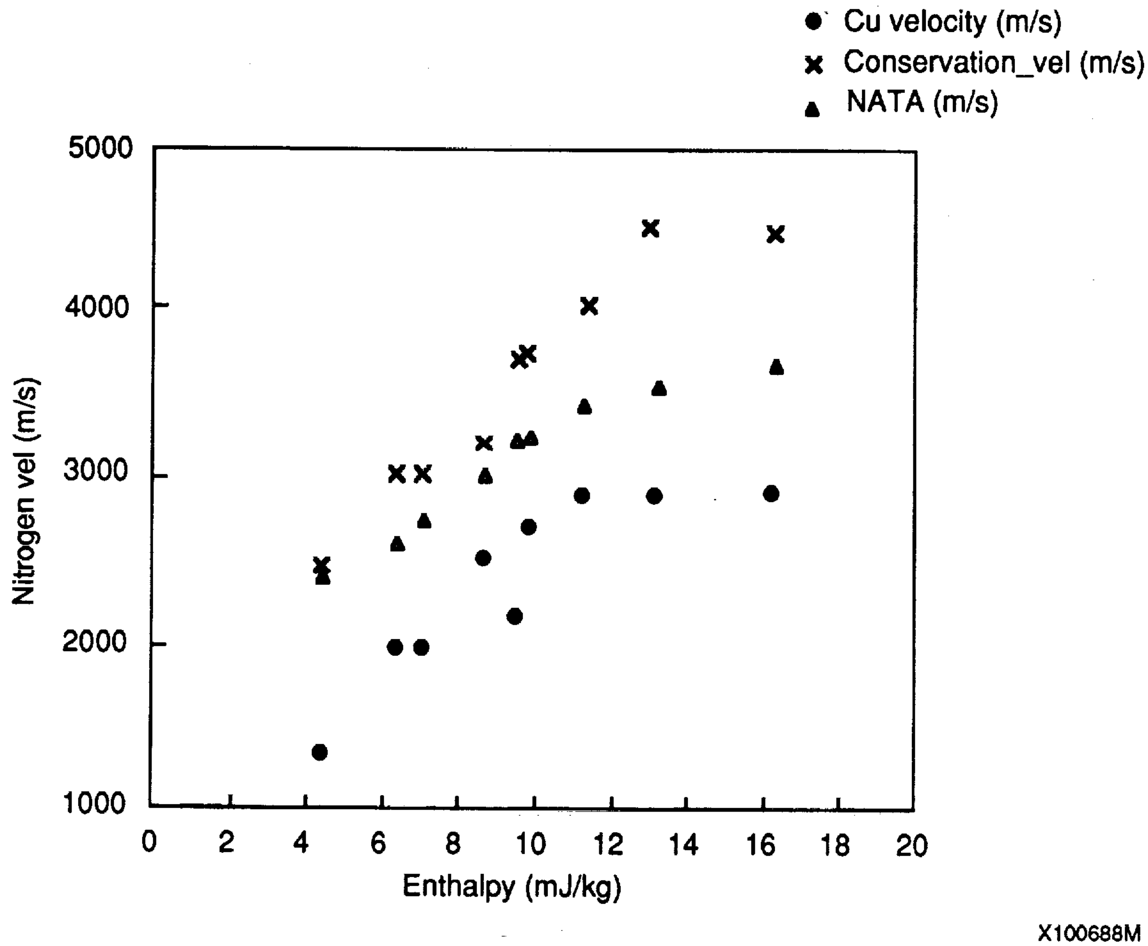


Figure 5. Comparison between measured and computed velocity at different enthalpy (arc jet velocity).

PROJECT TITLE: Distributed Artificial Intelligence Based Schedule Assessment for Space Shuttle Flight Software Production

PROJECT MANAGER: John F. Muratore, DP 483-0796

INITIATION YEAR: FY90

FUNDING:

	FY90	FY91	FY92	Total
Funding:	40k	40k	0	80k
Cost:	13	55(est.)	12(est.)	80
Carryover:	27	12	0	0

OBJECTIVES

The objective of the Distributed Artificial Intelligence Based Schedule Assessment for Space Shuttle Flight Software Production is to develop a tool to assist the Mission Operations Directorate, Reconfiguration Management Division (DP) in coordinating the many schedule details in the production of flight software. The development of multiple options for evaluation is required. The goal of this project is the effective application of new technology to the flight software reconfiguration process scheduling. This local workstation system shall have the capability to perform "what-if" options for evaluation using a combination of conventional and artificial-intelligence-based tools. The final results will be communicated electronically back to the mainframe-based scheduler. These capabilities shall enhance the flight software production process by providing multiple options for evaluation. Quality improvements are expected in the generation of better scheduling, planning, and resource utilization in the flight software production including the integration of multimission planning. Using the local workstation will allow faster response to changes and earlier identification of schedule problems; thus, allowing more time to work resource problems which will become more critical as the flight rate increases.

ACCOMPLISHMENTS IN FY90

A proof of concept prototype system was successfully developed sharing office PCs utilizing Civil Service manpower. Two workstations and a plotter were purchased in order to implement a full up local system and support continued system development. This system is currently being used in a limited way to conduct schedule evaluations. The use of this system has resulted in a manpower savings of three people being required for flight software production schedule assessments.

PLANNED FUTURE WORK

This organization is committed to the continued development of the Distributed Artificial Intelligence Based Schedule Assessment for Space Shuttle Flight Software Production through the maturity of the project. Flight software reconfiguration production electronic interface hardware and software will be purchased to implement a fully integrated scheduling system. Testing and certification of this system will be completed and final upgrades will be identified and implemented as the availability of resources allows. This system will finally be integrated with the Space Station Freedom Program flight software development efforts.

EXPECTED COMPLETION DATE

The current scope of the project will be completed by October 1992.

TITLE OF INVESTIGATION: Diluent Gas Studies in High Pressure Oxygen Systems

PROJECT MANAGER: Radel Bunker/RA/FTS 572-5733

TEAM MEMBER: David Hirsch - Lockheed-ESC White Sands Test Facility

INITIATION YEAR: FY89

FUNDING:

	Total prior years	FY90
In-house:	35k	65k

OBJECTIVE

Considerable effort is expended by NASA to assure that materials used in habitable, oxygen-enriched environments do not present a fire hazard. Even though these efforts have been highly successful, catastrophic system failures have occurred due to fires initiated by polymeric materials. Some limited studies have indicated that small quantities of certain diluent gases can reduce material flammability. If this is the case, safer life support systems and hyperbaric chambers designed for Shuttle and Space Station Freedom which use or will use polymeric materials in high pressure oxygen systems can be designed.

The objective of this project is to determine if there is a physiologically acceptable diluent gas that can be added to oxygen-enriched environments that will significantly reduce the ignition and subsequent combustion of materials.

ACCOMPLISHMENTS IN FY90

Approximately 200 combustion experiments were performed using the White Sands Test Facility Promoted Combustion System shown in figure 6. These experiments were conducted with nitrogen (N_2), helium (He), and argon (Ar) at pressures of 1000 psia and 3000 psia. PTFE Teflon, Kel-F81, and Vitron which are typically used in high pressure O_2 system were selected as the test materials. Some preliminary studies were also conducted with PTFE Teflon at 5000 psia using N_2 and He. The results from these experiments are shown in figures 7, 8, and 9 and indicate the following conclusions:

- Helium, which provides a weight benefit over the other diluent gases tested, was the most effective diluent in inhibiting flame propagation followed by N_2 and then Ar.

- Large quantities of diluent gases, approximately 60 percent or greater, were required to prevent flame propagation of the materials tested; however, the resulting diluent/

oxygen mixtures were still breathable. However, the use of He can present a voice intelligibility problem.

- The effect of pressure on the diluent concentration required to inhibit flame propagation was small at pressures greater than 1000 psia. This result indicates that breathable oxygen mixtures can be stored and used at high pressures (greater than 5000 psi) without increasing fire hazards for the materials tested.

Based on the results for this project, the Kennedy Space Center is planning to use the test methods developed in this project to evaluate material for use in high pressure life support systems.

The last major accomplishment in FY90 was the acceptance for publication of the paper entitled "Effects of Oxygen Concentration, Diluents, and Pressure on Ignition and Flame Spread Rates of Nonmetals: A Review Paper" (ref. 1).

PLANNED FUTURE WORK

Approximately $10k has been requested for FY91 to perform combustion studies with Ne at 1000 psia. The quantity of neon (Ne) required to prevent flame propagation is anticipated to fall between He and N_2; thus making it a better diluent than N_2 but without the voice intelligibility effects of He. These results and the results previously described will then be submitted in a paper to several fire science journals.

EXPECTED COMPLETION DATE

FY91

REFERENCE

1. Hirsch, D.B.; Bunker, R.L.; and Janoff, D.: Effects of Oxygen Concentration, Diluents, and Pressure on Ignition and Flame Spread Rates of Nonmetals. Flammability and Sensitivity of Materials in Oxygen-Enriched Atmospheres: vol. 5, ASTMSTP 1111, edited by Joel M. Stoltzfus and Kenneth McIlroy, American Society for Testing and Materials, Philadelphia, 1991.

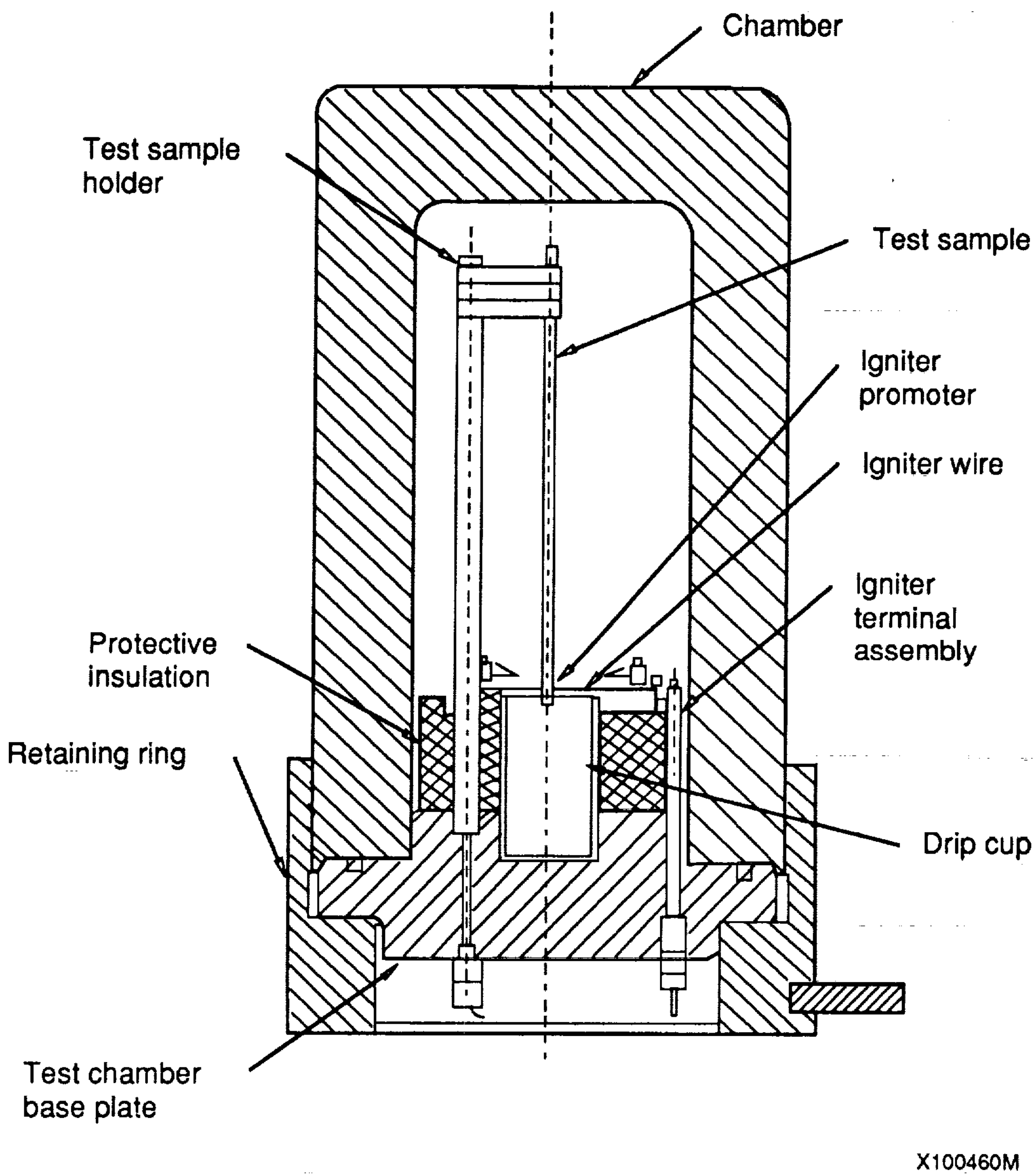


Figure 6. Promoted combustion chamber.

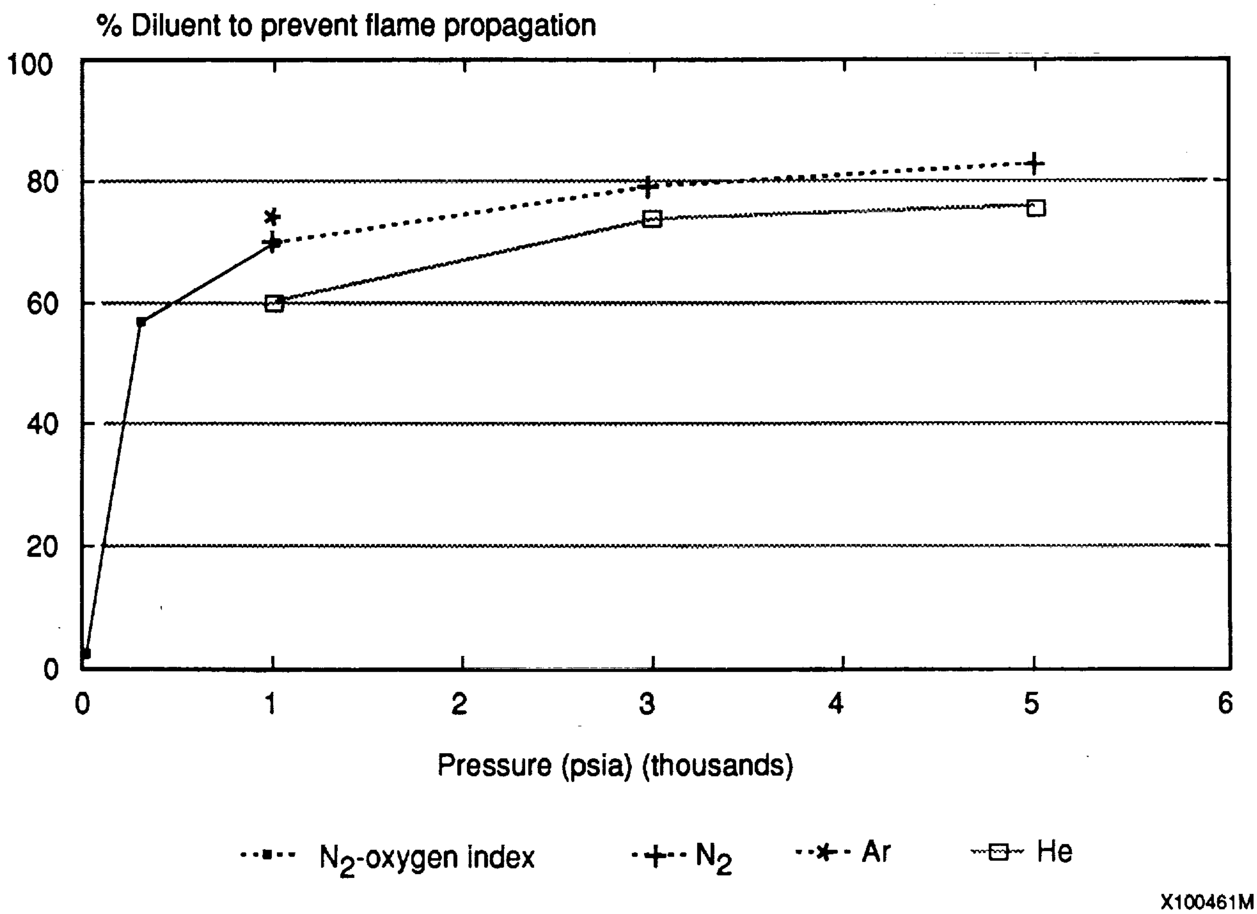


Figure 7. Diluent tests, PTFE teflon.

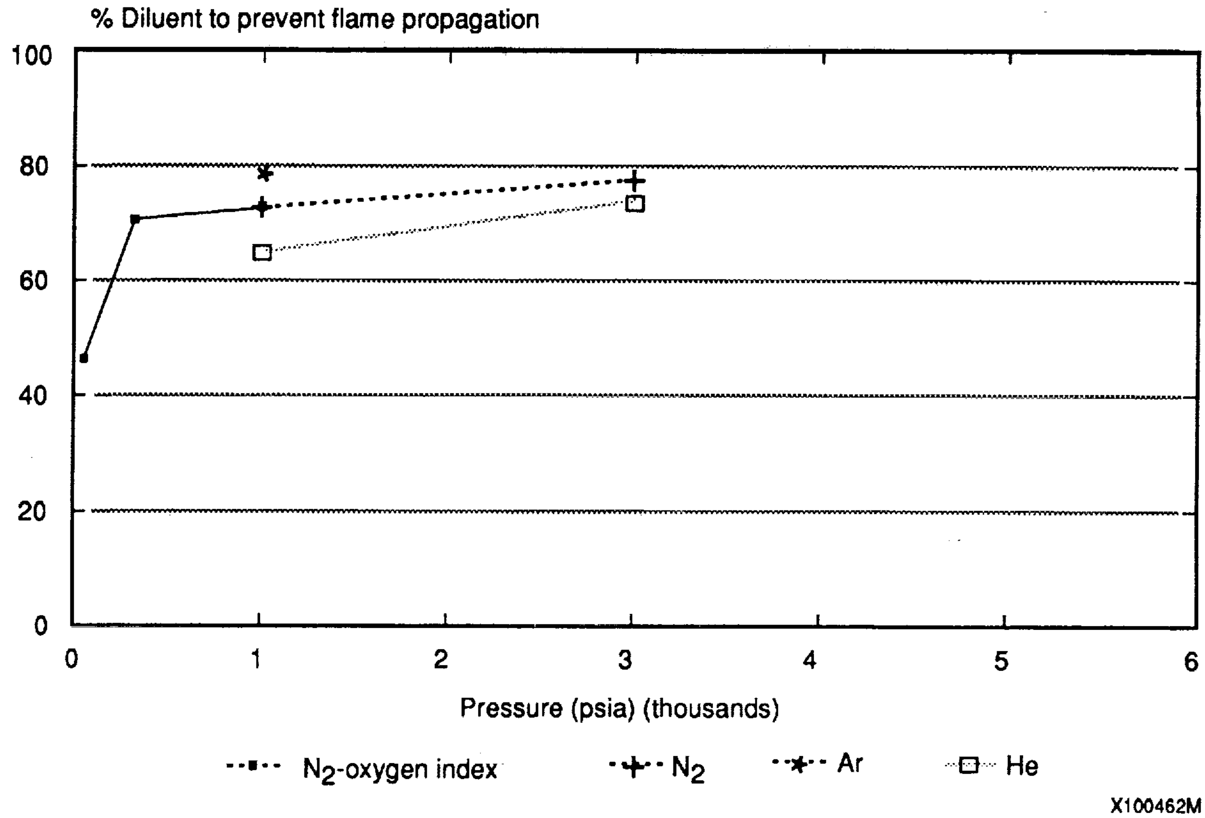


Figure 8. Diluent tests, Vitron.

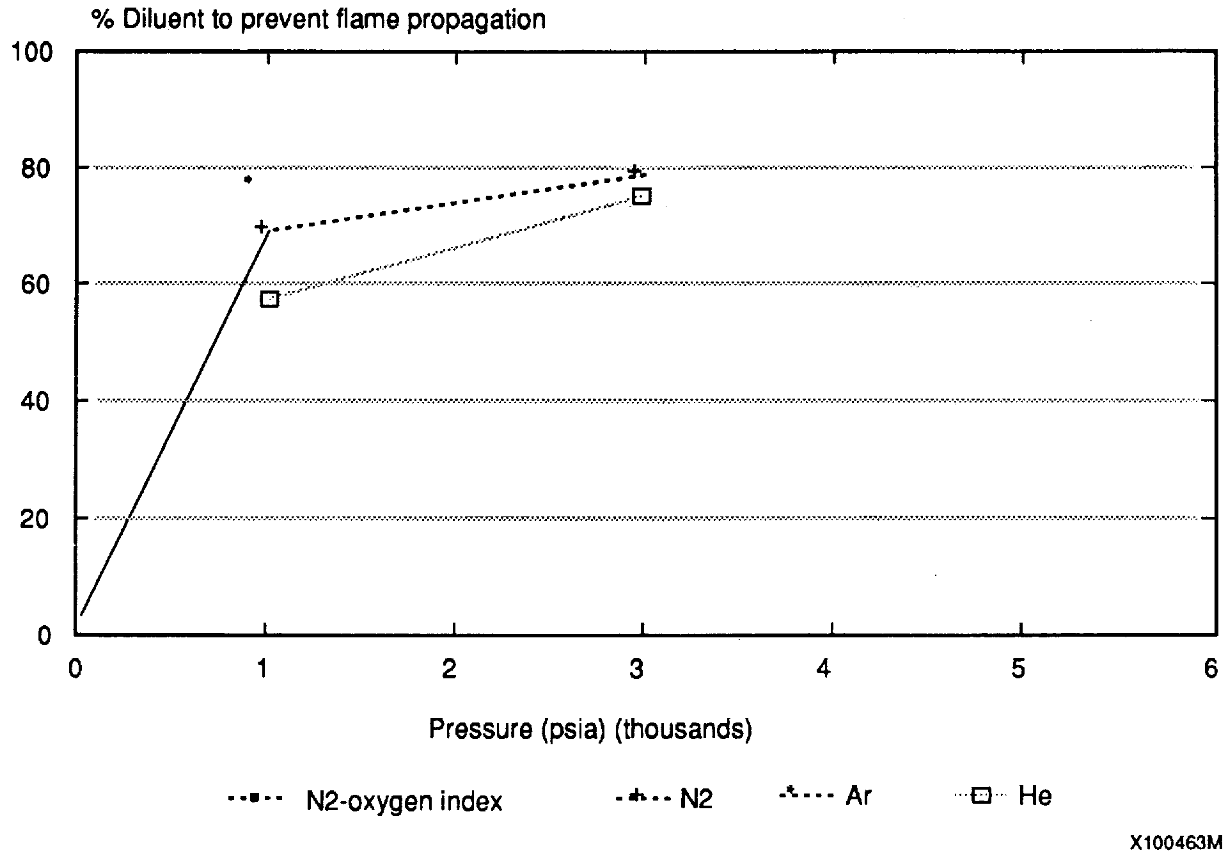


Figure 9. Diluent tests, Kel-F 81.

TITLE OF INVESTIGATION: Holographic Vibration Analysis of a Small Flight-Weight Rocket Engine

PROJECT MANAGER: John Mulholland/RA/FTS 572-5516

TEAM MEMBERS: John Tyrer - Loughborough University of Technology
Robert Cort - Lockheed-ESC White Sands Test Facility

INITIATION YEAR: FY88

FUNDING:

	Total prior years	FY90
In-house:	120k	60k

OBJECTIVE

The objective of this project was to develop an interferometric technique capable of providing nonintrusive, precise stability measurement of a primary reaction control system (PRCS) engine. The relatively new holographic technique that was investigated, electronic speckle pattern interferometry (ESPI) (or TV holography), provides real-time global mapping of small surface displacements using electronic processing and video recording and display. The ESPI system, which is based on laser illumination, allows displacement measurements with sensitivities proportional to the wavelength of light.

ACCOMPLISHMENTS IN FY90

The major goals in FY90 were to conduct hot-fire tests to provide proof-of-concept that ESPI is a viable engine stability analysis method. The test stand fabrication in support of testing was completed in early July followed by a series of PRCS hot-fire tests. Figures 10 and 11 show the test system in firing configuration. The hot-fire testing provided excellent results, and has proven the applicability of ESPI technology for rocket engine vibration analysis. Figure 12 is an actual TV hologram of the PRCS engine during post-test heat soak back. Complete data reduction is still in progress in coordination with Loughborough University of Technology, Leicestershire, England, which has provided support throughout the project. A paper will be presented at the next Society of Photo-Optical Instrumentation Engineering conference.

PLANNED FUTURE WORK

The results of this project were presented to NASA Headquarters, along with a proposal to develop a deliverable package for engine stability analysis. This new project would be a 3-year effort at $300k a year and bridge the gap between the proof-of-concept system and the necessary high-power rugged system required for field testing.

EXPECTED COMPLETION DATE

This project was completed in FY90.

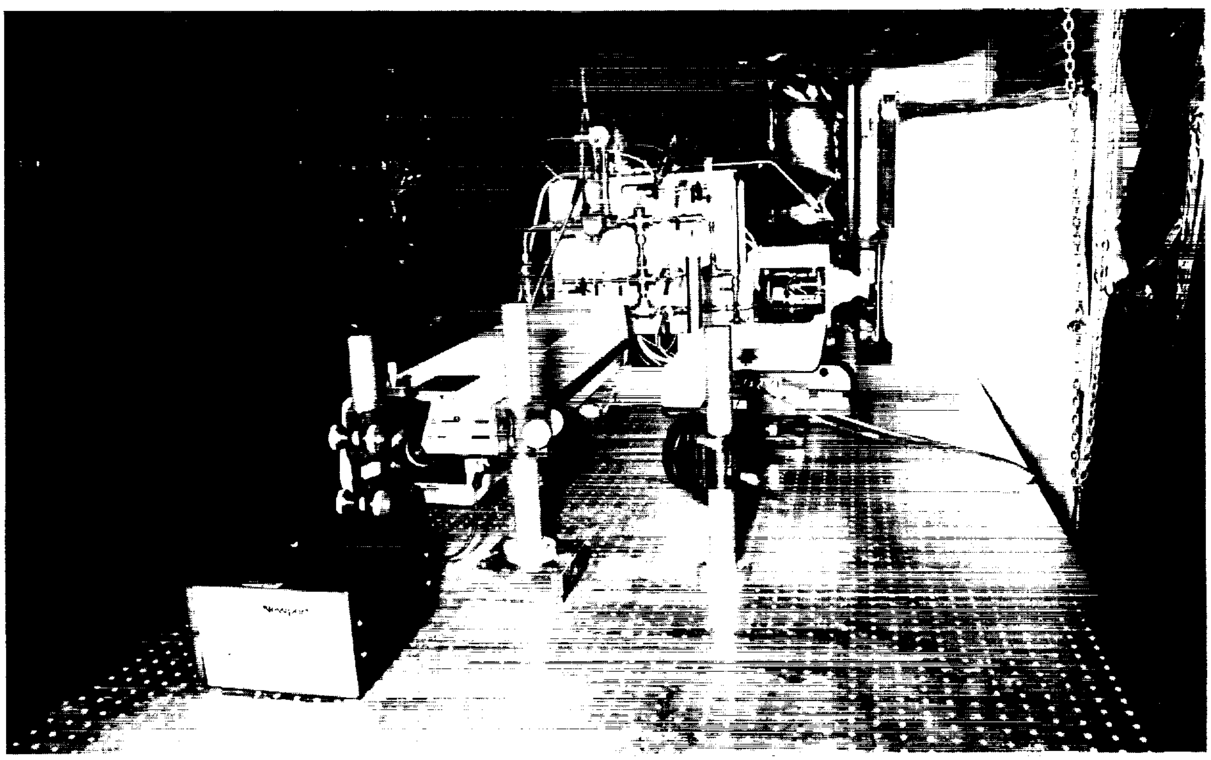


Figure 10. Test system in firing configuration (front view).

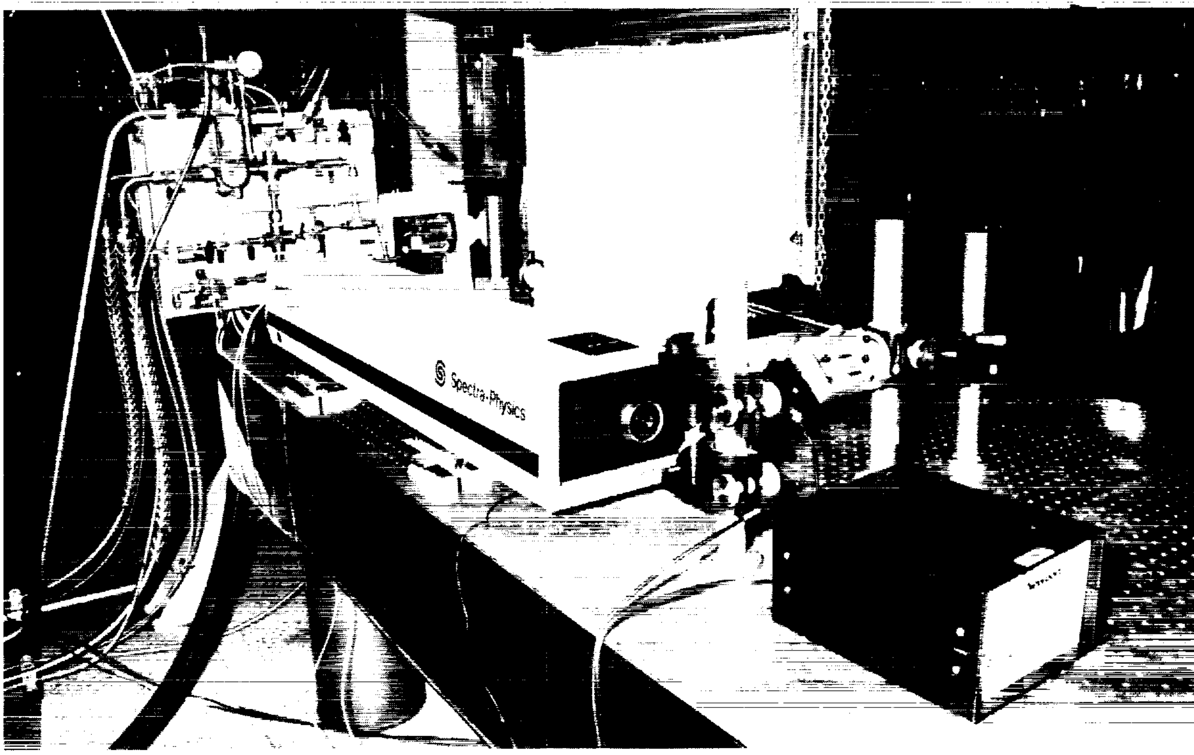


Figure 11. Test system in firing configuration (side view).

Figure 12. TV hologram of PRCS engine during post-test heat soak.

TITLE OF INVESTIGATION: Development of an Optical Analysis System/Technique for Shuttle Component Analysis

PROJECT MANAGER: John Mulholland/RA/FTS 572-5516

TEAM MEMBERS: Larryl Matthews - New Mexico State University
Joseph Genin - New Mexico State University
Mike McNeely - NASA White Sands Test Facility
Lawrence Brooks - Lockheed-ESC White Sands Test Facility

INITIATION YEAR: FY89

FUNDING:

	Total prior years	FY90
In-house:	40k	50k

OBJECTIVE

The objective of this project was to develop self-contained, portable test equipment and procedures for rapid response testing and evaluation of space-related critical components. The specific need for this type of a system became apparent during the STS-26 dynatube leak anomaly investigation. There were no in-place techniques to nonintrusively determine stresses, strains, torque, cracks, etc., on this component while installed in the vehicle. There are many Space Shuttle and Space Station Freedom systems where limited physical access also prohibits the use of traditional test methods such as ultrasonics and x ray. This project is designed to provide holographic test apparatus capable of accessing components in restrictive areas.

ACCOMPLISHMENTS IN FY90

The development of the prototype test system was completed (fig. 13) and tests to demonstrate the feasibility of the concept for aerospace applications were performed.

In one series of tests, an airframe structure was evaluated in a joint effort with New Mexico State University. A disbond in the structure was detected (see TV monitor in fig. 14) which demonstrated the applicability of the holographic methods for health monitoring of such structures.

In another series of tests, welded thin wall tubing was evaluated for flaws. The results proved that holographic methods are capable of detecting flaws in welds and, in some cases, this method was more sensitive than traditional x-ray analysis. The results were presented in a paper entitled "Holographic Analysis as an Inspection Method for Welded Thin Wall Tubing" (ref.1). In addition, preliminary testing was completed to evaluate the capability of this method to detect flaws in composite materials. Test data is presently being analyzed. The overall results to date have indicated that holographic analysis can provide a valuable tool to detect defects in metallic systems. Future test results may prove this method will also detect flaws in composite materials.

PLANNED FUTURE WORK

Planned work for FY91 includes the final system fabrication and software development. Tests will continue to evaluate the capability of holographic methods for detecting flaws in composite materials and metallic pressure vessels.

EXPECTED COMPLETION DATE

This project will be completed in FY91.

REFERENCES

1. Brooks, L.; Mulholland, J.; Genin, J.; and Matthews L.: Holographic Analysis as an Inspection Method for Welded Thin Wall Tubing. Proceedings of the 1990 SEM Spring Conference on Experimental Mechanics, Albuquerque, NM, June 4-6, 1990.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

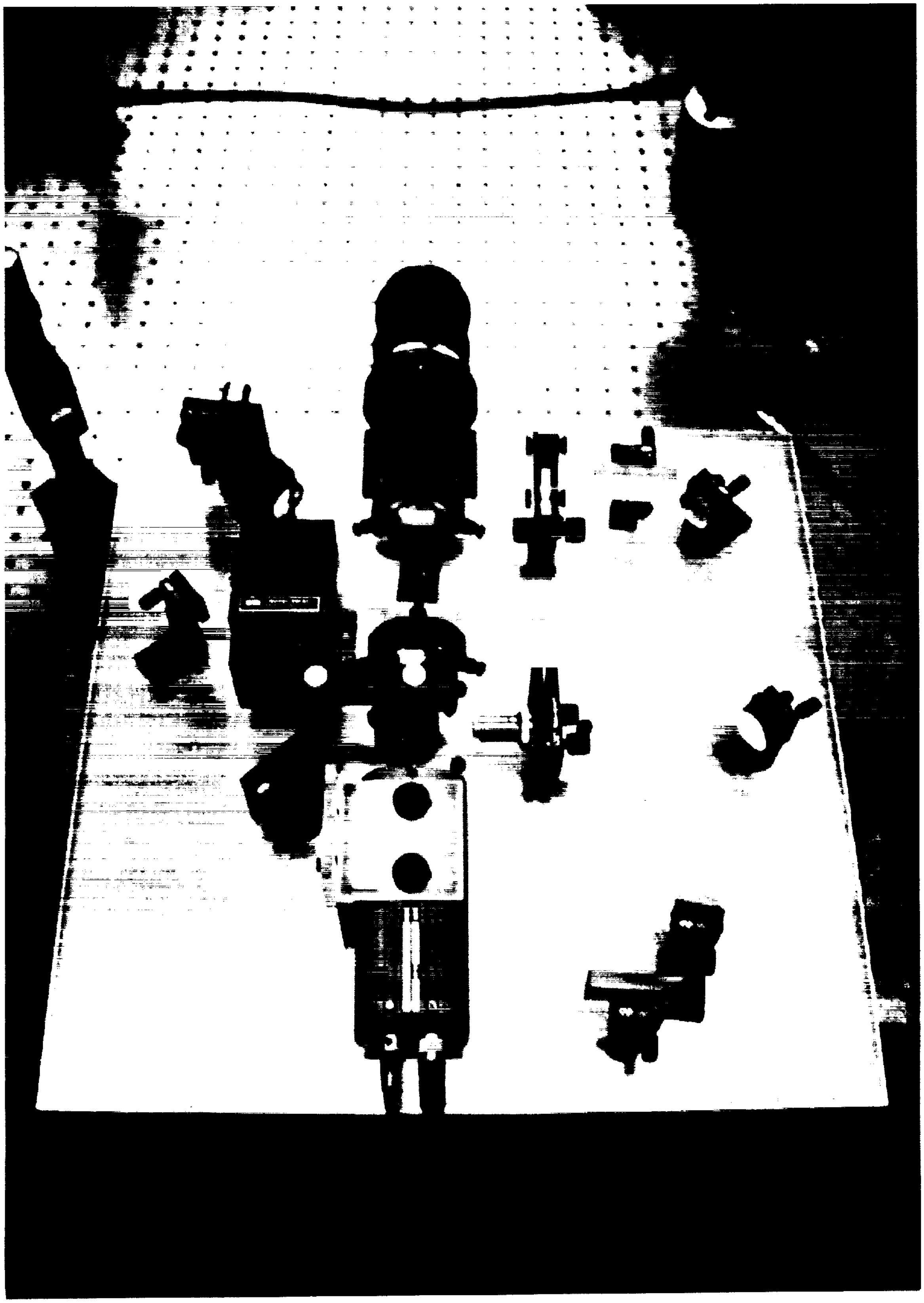


Figure 13. Optical analysis system prototype.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

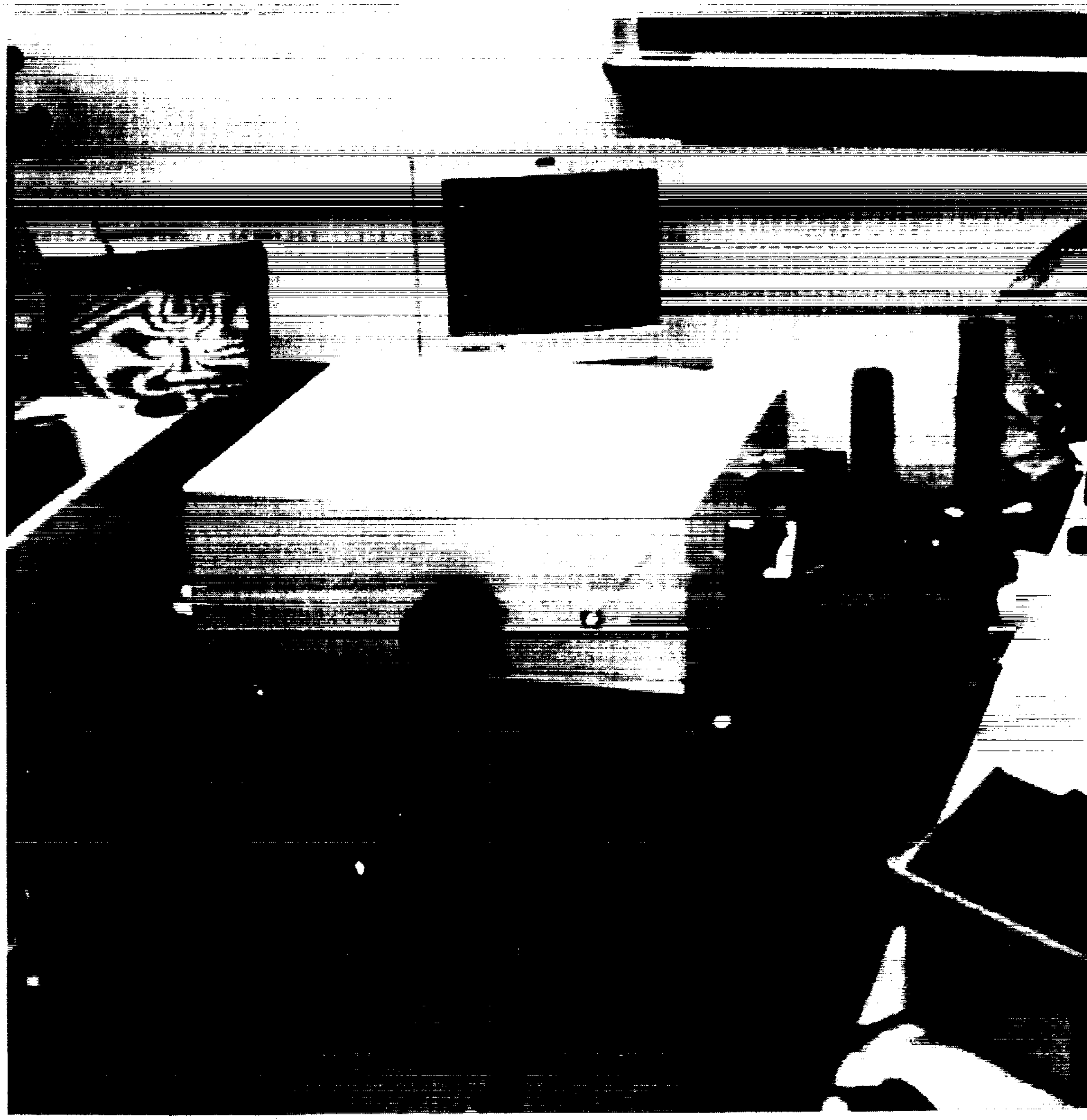


Figure 14. Optical analysis system showing disbond condition on airframe structure.

TITLE OF INVESTIGATION: Orbital Debris Radar Ground Studies

PROJECT MANAGER: G. D. Arndt/EE3/483-1438

TEAM MEMBERS: J. H. Suddath and P. Fink

INITIATION YEAR: 1989

FUNDING:

	Total prior years	FY90
In-house:	40k	45k
Contractors:	0	0
Grants (University):	50	0
Total funds:	90k	45k

OBJECTIVE

Develop and test a low-cost ground demonstration radar system capable of detecting and tracking small, 1-cm particles traveling at high angular rates. The ground system is a precursor to a larger spaceborne radar capable of detecting and tracking orbital debris.

ACCOMPLISHMENTS IN FY90

- Built and tested a 4-element (subarrays) Ku-band antenna as shown in figure 15
- Developed high-speed control software for steering and focusing the phased array antenna
- Initiated Ka-band antenna studies
- Initiated development of a Ku-band radar receiver for subsequent integration of the antenna
- Performed system studies into antenna requirements for scanning spatial sectors with maximum likelihood of incoming debris
- Co-authored paper, "Collision Warning and Avoidance Considerations for the Shuttle and Space Station," AIAA Orbital Debris Conference, Baltimore, MD, 5/90

PLANNED FUTURE WORK

- Complete fabrication of radar receiver, integrate with antenna breadboard, and perform testing in anechoic chamber
- Extend four subarray design into a .5-m by 2.0-m antenna design needed for White Sands testing
- Perform a system level integration study with the antenna and an infrared detection system for initial acquisition

EXPECTED COMPLETION DATE

FY91 will conclude director discretionary funding; Code M RTOP has been submitted for long-term effort resulting in a spaceborne microwave radar tracking system.

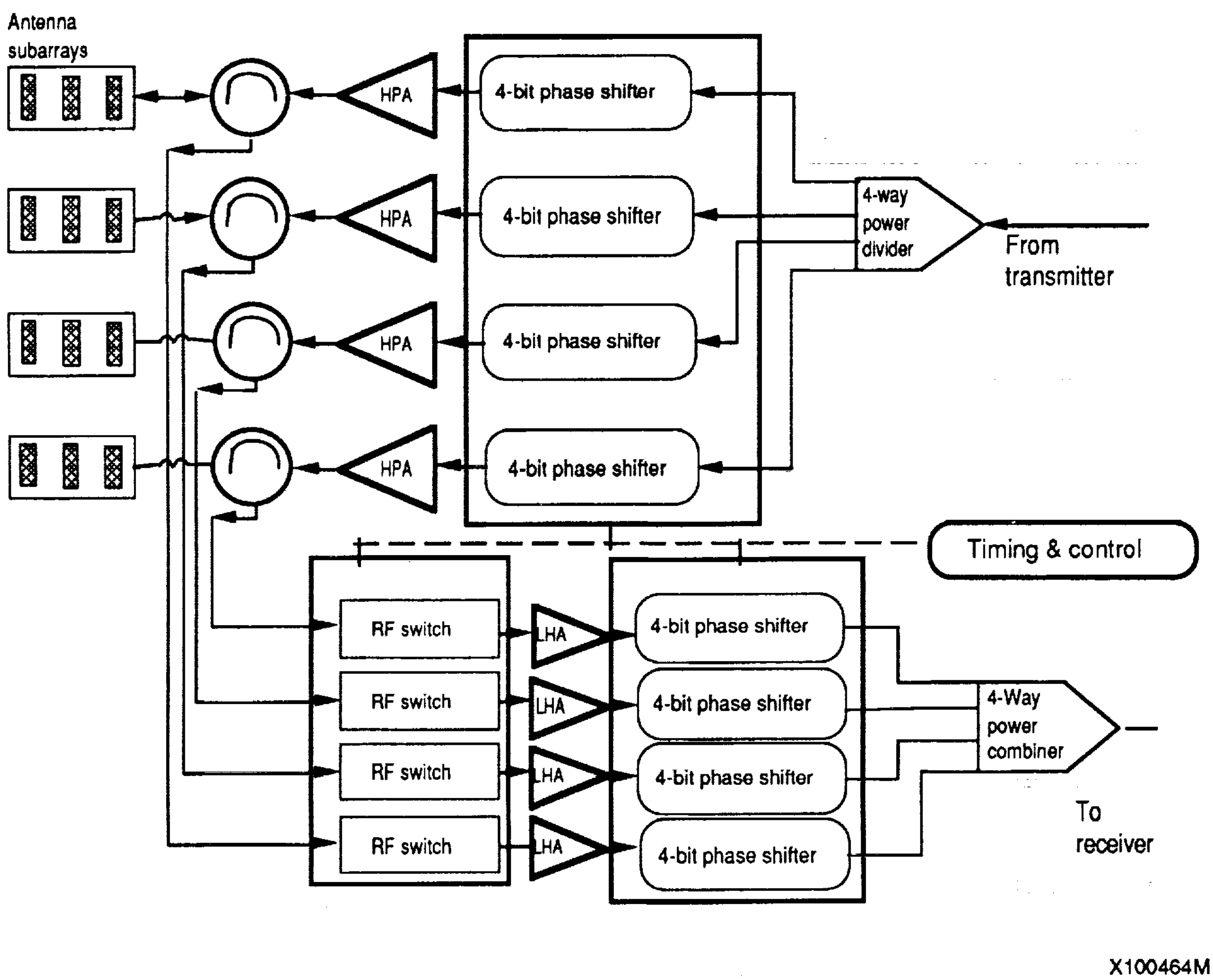


Figure 15. Antenna subsection.

TITLE OF INVESTIGATION: High-Temperature Superconductor Antenna Investigation

PROJECT MANAGER: Phong H. Ngo/EE13/483-7990

INITIATION YEAR: FY89

FUNDING:

	Total prior years	FY90
In House:	50k	50k
Contractors:		
Grants		
Total funds	50k	50k

OBJECTIVE

High-temperature superconductors (HTS) offer the promise of greatly improved tracking and communications system performance. The objectives of this project are to investigate the suitability of applying HTS materials to tracking and communications system components, specifically to develop an antenna array and other useful circuits and methods for characterizing HTS material samples and circuit designs and to integrate these components into a flight experiment (see fig. 16).

ACCOMPLISHMENTS IN FY90

- Laboratory equipment
- Accomplishments for FY90 included a complete checkout of the 4.5 K closed-cycle helium refrigerator. Several problems were found and all have been corrected.
- Modification to the cryogenic cooler was made to allow testing of antennas. This effort includes the extension of the cold-head to reduce the interference caused by the walls of the chamber and replacing the top lid with several radomes to allow radiation measurements.
- One all-metal aperture coupled microstrip patch antenna was fabricated and is being tested.

SPIE Symposium Presentation

An analytical study comparing radiation efficiency and bandwidth of HTS and normal metal antennas was presented at the SPIE Symposium.

PLANNED FUTURE WORK

- In the FY91 year, fabrication, test and characterization of a 30-GHz, 4 by 4 antenna array utilizing HTS materials in the feed network will be completed.
- Pending RTOP funds, a flight experiment is planned for late 94.

EXPECTED COMPLETION DATE

The CDDF portion of the HTS research should be completed in October 1991.

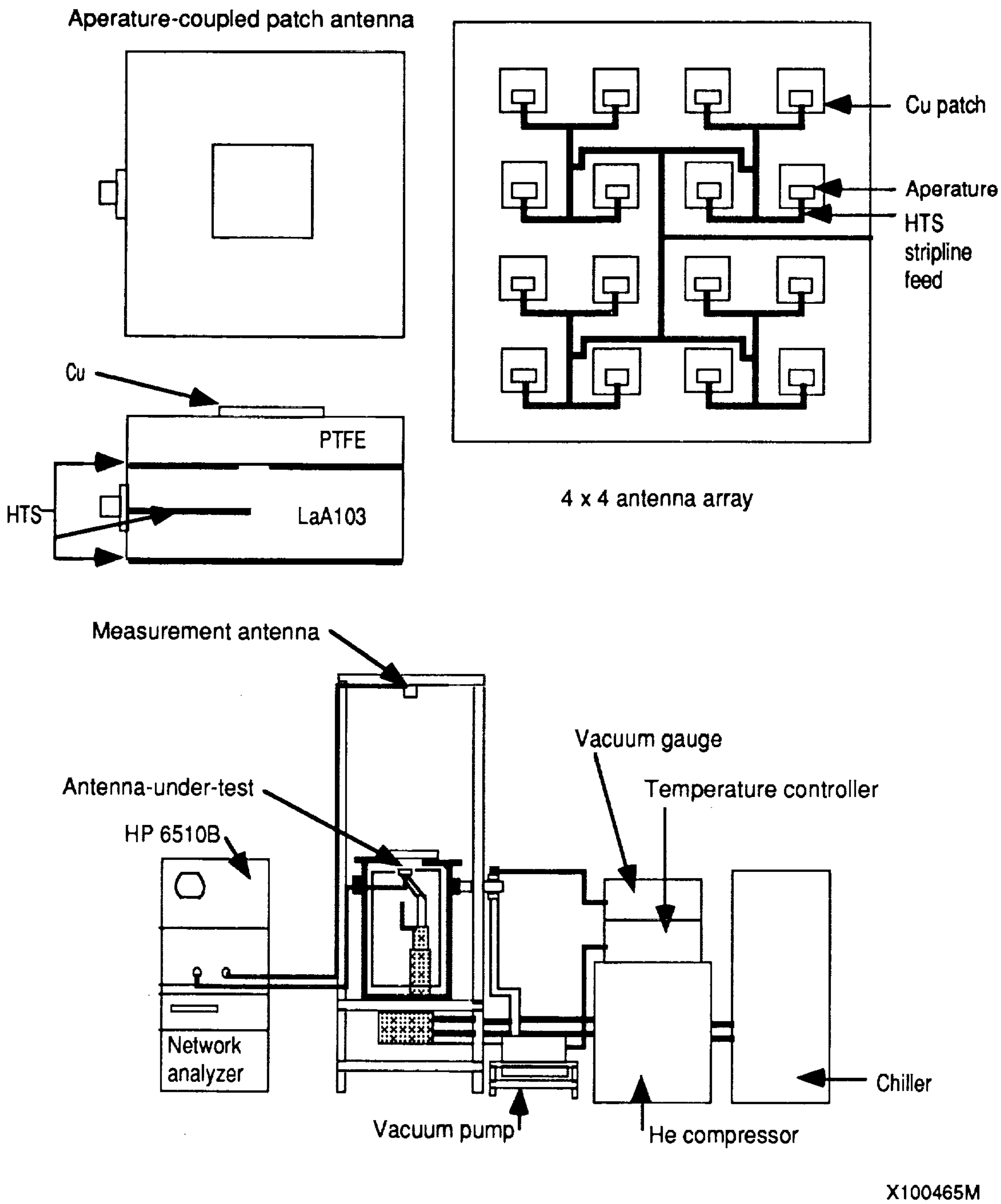


Figure 16. Complete antenna test set-up.

TITLE OF INVESTIGATION: Thermal Analyzer for Planetary Soils (TAPS)

PROJECT MANAGER: James L. Gooding/SN21/FTS 525-5126

TEAM MEMBERS: Judith H. Allton, Lockheed Engineering Space Corporation, (LESC)
Terry B. Byers, LESC
Keith J. Draper, LESC
Howard V. Lauer Jr., LESC
A. James Kettle (University of Newfoundland, Canada; Summer Intern sponsored by Lunar and Planetary Institute, Houston, Texas)

INITIATION YEAR: FY1989

FUNDING:

	FY89	FY90
In-house (incl. LESC):	45k	43k
Contractors (not LESC):	0	2
Grants:	0	0
Total funds:	45k	45k

OBJECTIVE

Exploration of the solar system requires compact instruments for in-situ analysis of water and related substances in planetary geologic materials. Motivations for such analyses include scientific investigation of the nature and histories of planetary surfaces as well as evaluation of the resource potential of planetary materials. Possible applications are as follows:

*Moon: Reconnaissance for ices at the poles and ore minerals elsewhere

*Mars: Identification of ices, water-bearing minerals, carbonates, and nitrates

*Asteroids or Comets: Identification of ices and water-bearing minerals; "fingerprint" comparison with meteorites

*Venus: Identification of sulfide, oxide, and carbonate minerals

The TAPS project is intended to define the scope, purpose, and design considerations for miniaturized, automated instruments that would perform, through thermoanalytic methods, in-situ identification of ices, water-bearing minerals, and related substances in planetary surface soils. This early definition work is necessary before development of flight experiments can be usefully sponsored by other mainline NASA programs.

ACCOMPLISHMENTS IN FY1990

The three important functions embodied in TAPS are acquisition of a solid sample, thermodynamic analysis of the solid sample, and analysis of gases evolved from the sample during heating (fig. 17). For the analytical functions, several different sensor types were identified with recognition that actual sensor selections will be influenced by the choice of planetary target and the instrument mass, volume, and power available on a specific mission. Our published results included detailed descriptions of the functions, design considerations, and candidate sensor methodologies (refs. 1 and 2) as well as actual test data for prototype systems (refs. 3, 4, 5, and 6).

To focus various elements of the design process, we selected a differential scanning calorimeter (DSC) as the thermodynamic analyzer and a single-function water sensor as the evolved-gas analyzer. The DSC represents the most versatile and powerful choice for the thermodynamic analyzer; whereas the water sensor represents a simple approach to analyzing a single (but arguably the most important), volatile compound. Choices of sample inlet-and-purge systems are varied and are more dependent on the scope or limitations of individual missions. To facilitate the design and test process, however, we selected a single rotary paddle design (denoted as the TAPS Mark-1 sample probe) that was created specifically to support the DSC.

Using laboratory instruments, we demonstrated that DSC is a useful material "fingerprinting" method for possible martian and cometary applications (refs. 4 and 5). In addition, we showed that, for prospective martian applications, DSC is a sensitive method that can detect and quantitatively measure hydrated silicate, carbonate, sulfate, and oxides minerals at concentrations as low as 0.5 weight percent (see fig. 18) (ref. 6).

We computed the sensitivity required for a water analyzer that could be mated with a DSC and found that, for a 10 mg sample containing 1 weight percent water as a single mineral, the minimum acceptable dynamic range for the sensor would be 180 to 2100 ppm (by volume); an even wider range would be highly desirable. Based on that estimate, we evaluated published descriptions of various water-sensor technologies and found five different sensor types that might be suitable for TAPS. Previous studies of possible planetary water analyzers (by other workers in the 1970s) emphasized phosphorous pentoxide electrolytic cells; but we found that newer, solid-state sensors hold significant promise for TAPS applications. Although further evaluation of prospective water sensors will be pursued, we exercised our design and implementation concepts by constructing a simple, bench-top system based on a piezoelectric quartz oscillator chilled by a small Peltier-effect electric cooler. A sensor with heating and cooling capacity would be expected to enhance specificity for water in mixed-gas samples. We note that, for applications on cold planets such as Mars, cooling by the ambient-environmental heat sink might be achieved without additional power consumption. Test data from our experimental system (fig. 19) were encouraging and showed that simple sensors of this general category deserve further study.

Laboratory tests of the Mark-1 sample probe functional model (which was designed and fabricated in FY89) showed that the current design is effective in acquiring DSC samples (10 to 100 mg) from sand-sized materials but that it will require modifications for silt-sized materials (fig. 20). This sampling mechanism may not be suitable for all conceivable versions of TAPS but demonstrates that an analytical instrument with self-contained sampling capability should be feasible. This approach stands in contrast to conventional assumptions that a TAPS-style experiment would require an independent, spacecraft- or vehicle-furnished sampling mechanism.

PLANNED FUTURE WORK

Work in FY91 will focus on assembling a bench-top TAPS analyzer based on a DSC module mated with a solid-state water sensor. No attempt will be made, at this early stage, to design an optimized or flight-qualified instrument. Instead, this work will explore coordinated operation of the two different sensor systems and evaluate the degree to which theoretical sensitivities of each analyzer can be achieved.

Accomplishments during this 3-year project constitute the pre-Phase A stage of experiment development. The progress we have demonstrated will be carried forward as a proposal to NASA Headquarters for a Phase A definition and development of a version of TAPS that would be suitable for specific flight opportunities. At present, the most reasonable pre-project candidate is the Mars Environmental Survey (MESUR) mission although recently emerging opportunities in the Comet Rendezvous and Asteroid Flyby mission will also be explored.

EXPECTED COMPLETION DATE

The third year (FY91) will complete the definition phase supported by the discretionary fund. All sponsored work should be finished by the end of December 1991.

REFERENCES

1. Gooding, J. L.: Differential scanning calorimetry (DSC) and evolved-gas analysis (EGA) applied to planetary surface exploration. In I. R. Harrison (Ed.), Proc. 18th North American Thermal Analysis Society (NATAS) Conference, vol. 1, 1989, pp. 222-228.

2. Gooding, J. L.: Thermal Analyzer for Planetary Soils (TAPS) experiment: Functions and design options. To appear in Lunar and Planetary Science XXII, Lunar and Planetary Institute, Houston, Texas, March 1991.

3. Allton, J. H.; Lauer, H. V. Jr.; Draper, K. J.; and Gooding, J. L.: Thermal Analyzer for Planetary Soils: Results of Initial Testing of Mark-1 Sample Probe Prototype. JSC 24572, NASA Johnson Space Center, Houston, Texas, 1990, pp. 1-16.

4. Gooding, J. L.; and Allton, J. H.: Water/rock interactions in carbonaceous chon drites: Possible fingerprints for in-situ comet-nucleus analysis. To appear in Lunar and Planetary Science XXII, Lunar and Planetary Institute, Houston, Texas,March 1991.

5. Gooding, J. L.; Kettle, A. J.; and Lauer, H. V. Jr.: DSC signatures of water-bearing geologic materials relevant to Mars and comets. In I. R. Harrison (Ed.), Proc. 19th North American Thermal Analysis Society (NATAS) Conference, vol. 1, pp. 9-15.

6. Gooding, J. L.; Kettle, A. J.; and Lauer, H. V. Jr.: DSC sensitivity to hydrated miner als in planetary samples. To appear in Lunar and Planetary Science XXII, Lunar and Planetary Institute, Houston, Texas, March 1991.

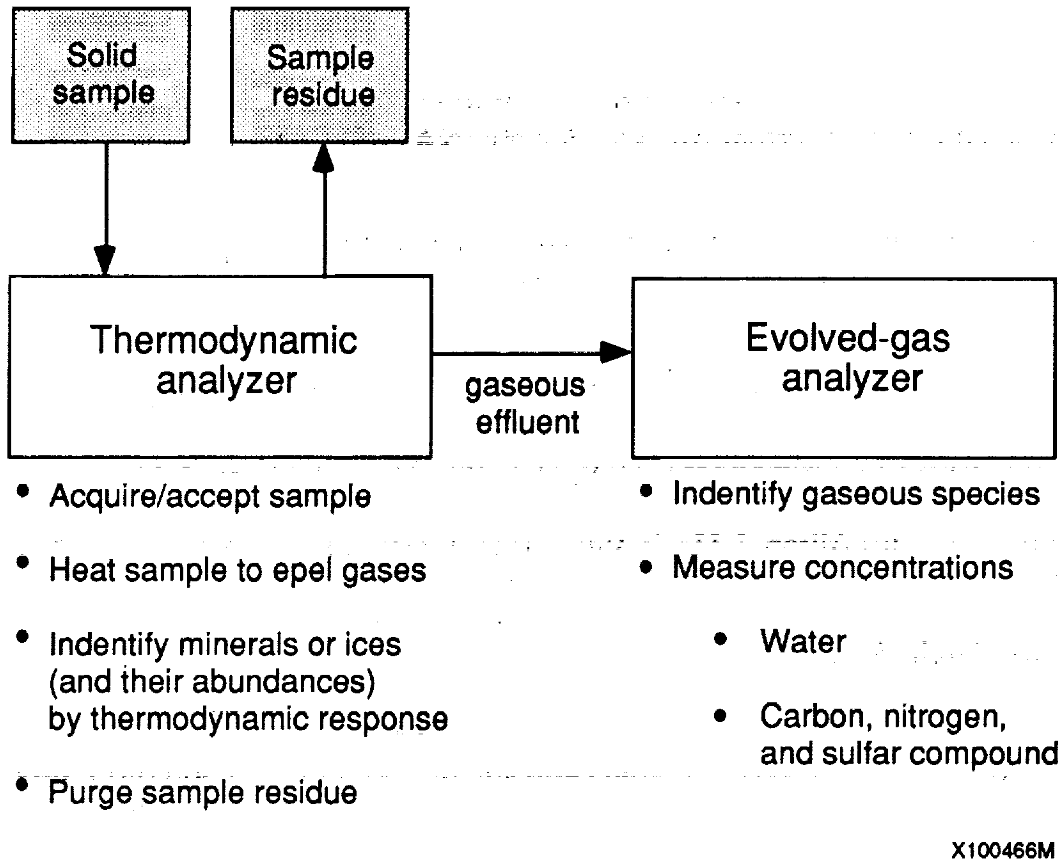


Figure 17. TAPS functional diagram (experiment functions).

Thermal Analyzer for Planetary Soils (TAPS)

Bench-level tests of piezoelectric water sensor
(9 MHz quartz oscillator with Peltier cooler).

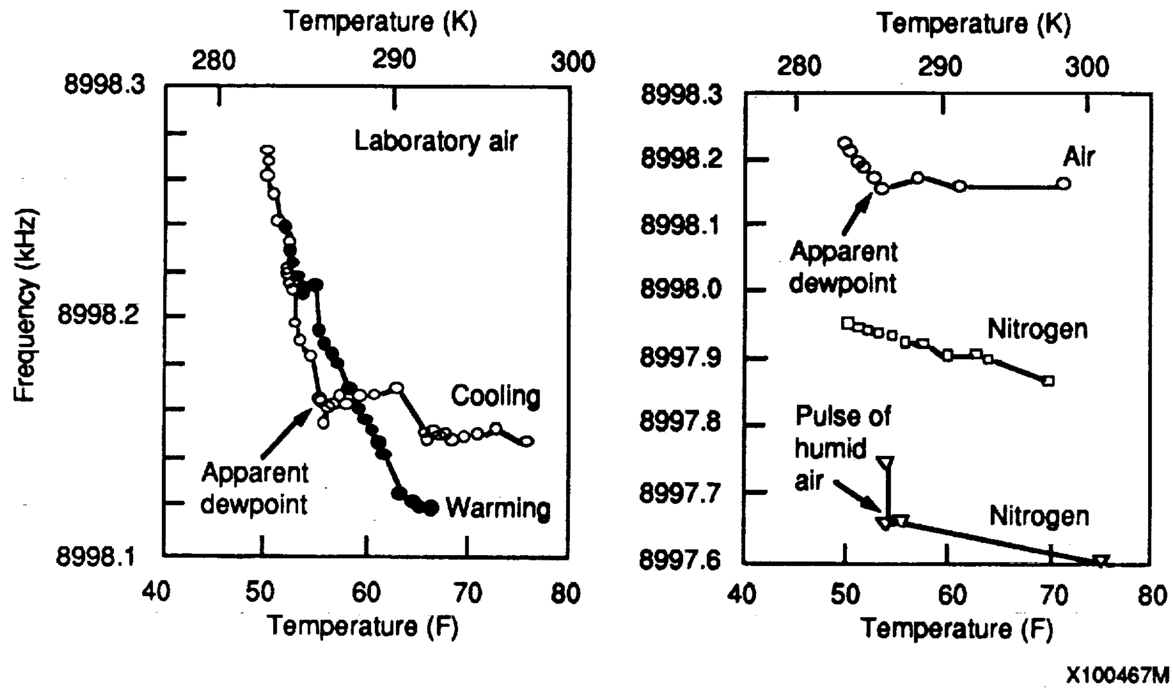
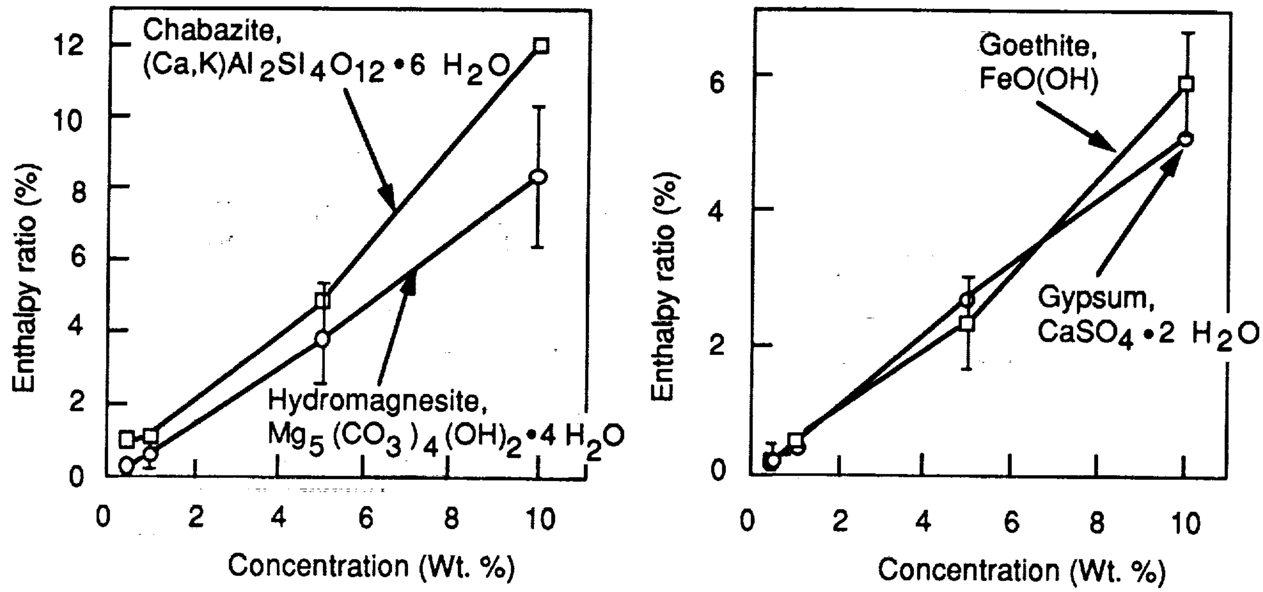


Figure 18. Experimentally determined DSC sensitivities.

Thermal Analyzer for Planetary Soils (TAPS)

DSC detectablility of hydrated minerals in basalt matrix.

- Analyses made in JSC Thermal Analysis and Calorimetry Laboratory (TACL)
- DSC-2C instrument operated at 10 K/min and 5 cc Ar/min; no cold sink
- Enthalpy of dehydration (relative to pure phase); 1 std. dev. from 3 analyses
- Ordinary data analysis (without benefit of deconvolution anaysis)
- Conclusion: Sensitivity at least 0.5 wt. % (equiv. 0.1 wt. % water for gypsum)



X100468M

Figure 19. Experimentally determined response of a candidate solid-state TAPS water sensor to cooling below dewpoint (left) and sudden exposure to a pulse of humid air (right), as simulations of evolved-gas analysis.

Thermal Analyzer for Planetary Soils (TAPS)

- Work performed at JSC (> 120 individual tests)
- Test material: Cheto (Arizona, USA) bentonite (crushed and sieved)
- Variables: particle size, sample packing density, speed (rpm) of rotary paddle
- Conclusions: Performance in sand acceptable; redesign needed for silt

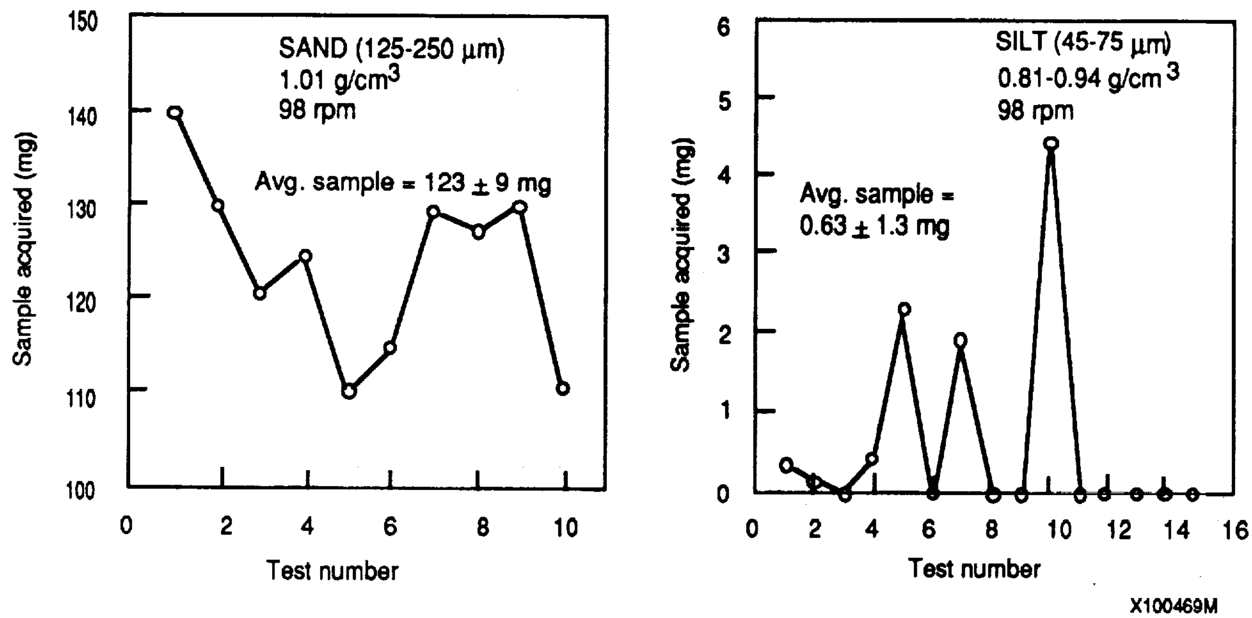


Figure 20. Experimentally determined sample-acquistion performance of the TAPS Mark-1 sample probe which is based on a spinning-paddle design.

TITLE OF INVESTIGATION: Lymphocyte Activation in Simulated Microgravity and Hypergravity

PROJECT MANAGER: Clarence F. Sams, Ph.D./SD4/483-7160

INITIATION YEAR: 1989

FUNDING:

	Total prior years	FY90
In-house:	50k	35k
Contractors:	0	0
Grants:	0	0
Total funds:	50k	35k

OBJECTIVE

A decrease in mitogen-induced activation has been observed in vitro with peripheral lymphocytes during space flight or in clinostats. This decreased activation may be due to alterations in cellular signaling or to environmental changes in the hypogravity cell culture environment. The focus of this basic research activity is to determine the molecular and cellular mechanisms responsible for the apparent gravity sensitivity of lymphocyte activation previously reported for cells in culture. This major objective has been reduced to the following specific tasks: (1) to characterize potential alterations in the cell culture environment as a function of gravity, (2) to determine the response of lymphocytes to these environmental alterations, and (3) to examine the cellular and molecular mechanisms involved in these responses. The influence of the cell culture environment on lymphocyte function in vitro will be evaluated with particular emphasis on those aspects which are changed in nonunit gravity. The events associated with the activation process, such as cell-cell communication, cell signal transduction, and alterations in transcriptional and synthetic activity will be examined to assess their relative contribution to gravity-induced changes in lymphocyte responses.

These studies will provide basic information concerning the impact of gravitational changes on specific cellular functions and will provide the preliminary data supporting development and submission of an original research proposal.

ACCOMPLISHMENTS IN FY90

The initial characterization of the cell culture environment in simulated microgravity was performed in FY89 using a lymphocytic cell line (SP2 from the American Type Culture Collection) and a JSC cell culture clinostat (slow turning lateral vessel). These experiments indicated limitations in metabolic transfer as well as apparent alterations in cellular response. The environmental limitations were examined and a redesigned vessel was produced which provided improved gas exchange. Metabolic support of high-density cell cultures was possible with the new vessel, though the persistence of a lag phase upon inoculation in the vessel suggested the influence of cell-cell contact in the growth response of this cell line. A patent application for the redesigned culture vessel (high aspect ratio vessel) was filed in FY90. These studies represent collaborative efforts between the Biotechnology Labs and the Cell Image Analysis Lab of the Medical Sciences Division.

The observations with the cell lines suggested that the effective cell concentration in the suspended state may also have an impact on mitogen-induced activation of peripheral lymphocytes. Lymphocytes were treated with various mitogens while suspended by gentle mixing or while static. Activation was followed by the appearance of CD69 protein. CD69 appears on the surface of activated lymphocytes within 2 hours after treatment with mitogens and represents the earliest surface activation marker. A significant decrease in CD69 expression was observed for suspended lymphocytes activated with the surface active mitogen phytohemagglutinin (PHA) as compared to cells activated in static culture (fig. 21). Activation with a phorbol ester, which bypasses the cell surface receptor mediated events and directly activates intracellular signaling pathways, resulted in equivalent activation of suspended or static cells. These findings indicate simple dispersion of cells may play a significant role in the response of cells to culture in microgravity. In addition, these data demonstrate the utility of using different mitogens to isolate specific processes or functions in the activation cascade.

PLANNED FUTURE WORK

The results to date suggest that the initial events in lymphocyte activation are influenced by alterations in cell culture environment similar to those occurring in nonunit gravity. Further studies will examine the early responses in the activation cascade to determine the molecular mechanisms influenced by gravity. Specific experiments will examine the function of the intracellular signaling pathways including the inositol phosphate second messenger system, changes in intracellular calcium concentration, and the activation and translocation of protein kinase C. In addition, the role of cellular adhesion receptors in the initial cell surface events will be explored. Changes in transcription of cellular oncogenes associated with activation/proliferation (such as c-myc and c-fos) will be quantitatively determined. The role of the cell cytoskeleton in the integration of these molecular responses will be evaluated.

EXPECTED COMPLETION DATE: 1991

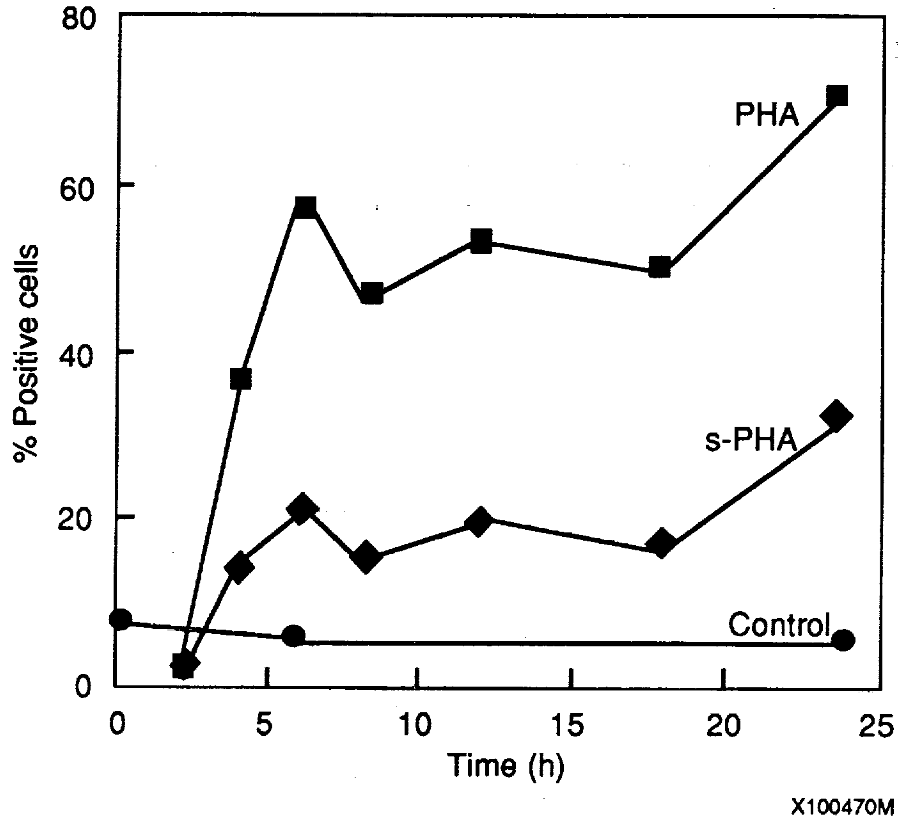


Figure 21. Activation of lymphocytes. Lymphocytes were activated with 2µ/ml phytohemagglutinin for 24 hours in sealed tubes which were static (PHA) or placed on a blood rocker to gently suspend cells (s-PHA). Activation was measured by the percentage of CD69 positive cells as determined by immunofluorescent labeling and flow cytometry. Data area presented as percent CD69 positive cells vs. time after mitogen addition.

TITLE OF INVESTIGATION: Plasma Volume and Orthostatic Tolerance

PROJECT MANAGER: Suzanne M. Fortney, Ph.D/SD5/37213

INITIATION YEAR: 1989

FUNDING:	FY89	FY90
In-house:	60k	60k
Contractors:	0	0
Grants:	50k	50k
Total funds:	110k	110k

OBJECTIVES

Hyatt and West (ref. 1) have shown that 4 hours of continuous exposure to -30 mm Hg lower body negative pressure (LBNP) and the simultaneous ingestion of 1 liter of an isotonic salt solution will restore plasma volume and orthostatic responses for up to 18 hours during bed rest. The objective of this project is to develop the optimum protocol (LBNP profile and fluid loading solution) which restores plasma volume and orthostatic responses with a minimum time commitment, discomfort, and risk.

FLUID SOLUTIONS

An effective fluid solution must expand plasma volume for at least 24 hours during simulated weightlessness (bed rest) and result in an improvement of orthostatic responses. The solution must be palatable. Plain water and weak salt solutions or solutions containing glucose have been found to stimulate a diuresis with only transient expansion of plasma volume and no improvement of orthostatic responses. Riedesel et. al. (ref. 2) have demonstrated the ability of glycerol when added to water, to cause fluid retention without provoking a diuresis. Glycerol promotes fluid movement across cell membranes, resulting in fluid retention. However, fluid retention occurs in all fluid compartments of the body, not just the plasma volume. One goal of this proposal is to determine whether glycerol ingestion during bed rest will significantly expand body fluids and improve orthostatic responses to a greater degree than isotonic saline. (This part of the study is being performed in Albuquerque, New Mexico by Dr. Riedesel with extended duration orbiter funding.)

LBNP EXPOSURE

Although the 4-hour LBNP protocol of Hyatt and West (ref. 1) has been demonstrated to effectively improve orthostatic responses for up to 18 hours, this protocol is very cumbersome to perform inflight. It was recently flown during the STS-32 mission and was reported to cause considerable subject discomfort as well. This flight LBNP treatment protocol is shown in figure 22. One objective of this study is to modify the negative pressure profile to allow equal improvement of orthostatic responses during bed rest in less time – a total daily exposure duration of less than 2 hours. Exposure to a fluctuating pressure profile rather than a continuous profile at -30 mm Hg, is thought to be more efficient in provoking fluid retention and cardiovascular responses which may result in improved orthostatic responses.

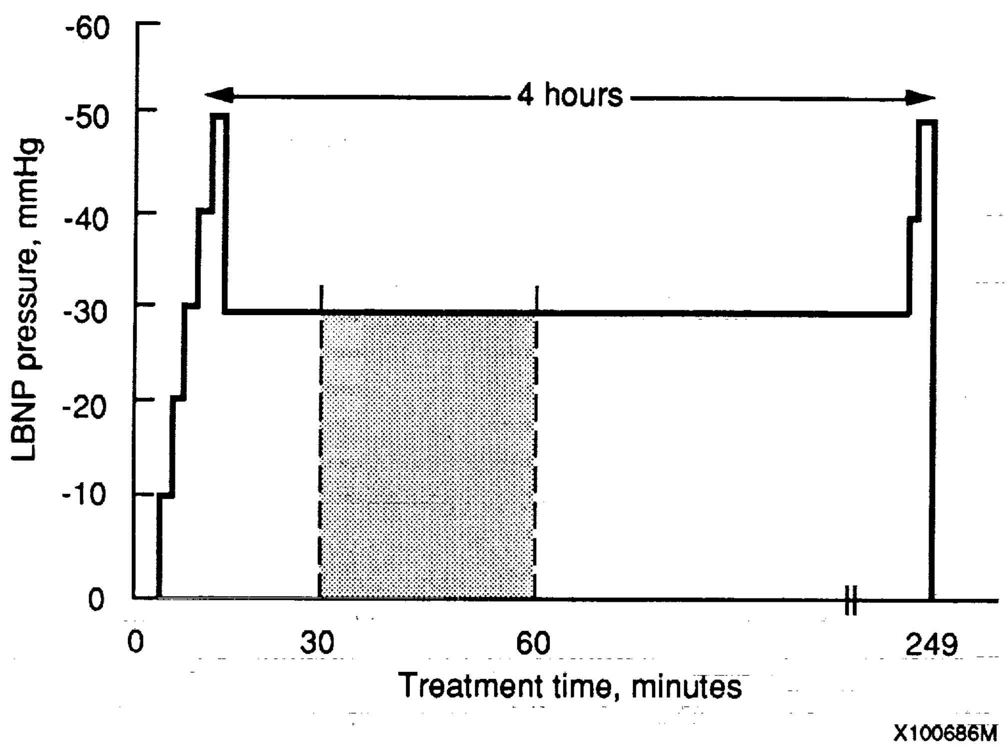


Figure 22. LBNP treatment pressure profile.

ACCOMPLISHMENTS IN 1990

- Completion of a bed rest study in 10 male subjects with duel objectives to, first, validate the effectiveness of a 4-hour continuous -30 mm Hg LBNP profile and simultaneous ingestion of 1 liter of isotonic saline to restore plasma volume and orthostatic responses during bed rest. Second, to determine whether this LBNP and fluid ingestion protocol may be shortened to 2 hours and remain effective in restoring orthostatic responses. The 4-hour protocol was validated in this ground-based study and found to still be effective 24 hours after treatment. The 2-hour profile expanded plasma volume but was not effective as a countermeasure for orthostatic intolerance 24 hours after treatment.

- A second bed rest study of female subjects to determine, first, whether the 4-hour continuous -30 mm Hg LBNP and isotonic saline treatment will be as effective in women as it was shown to be in men. Second, a 2-hour sinusoidal LBNP profile (LBNP pressure continuously fluctuating between 0 and -60 mm Hg once each minute) and simultaneous ingestion of 1 liter of isotonic saline was tested as a countermeasure to restore orthostatic responses during bed rest. The 4-hour treatment improved orthostatic responses in only 3 out of 8 of the first eight women studied. Likewise, the sinusoidal LBNP profile improved orthostatic responses in only 3 of the eight subjects tested so far.

APPLICATIONS MADE OF INVESTIGATORS RESULTS DURING FY90

The results from the study of the male subjects was used to finalize the LBNP protocol used in STS 32 as shown above. The LBNP profile flown was the full 4-hour, 30-mm Hg continuous LBNP and saline countermeasure.

PATENTS

N/A

REPORTS, JOURNAL ARTICLES, OTHER PUBLICATIONS

- Fortney, S.M. and Cintron, N.M. Plasma volume and orthostatic tolerance. Center Director's Discretionary Fund, Research and Technology Report, 1990.

- Fortney, S.M. Development of lower body negative pressure as a countermeasure for orthostatic intolerance. Submitted to the Journal of Clinical Pharmacology, 1990.

- Fortney, S.M.; Dussack, L.; Rehbein, T.; Wood, M.; and Steinmann, L. Effect of prolonged LBNP and saline ingestions on plasma volume and orthostatic responses during bed rest. Conference Report from the Joint ARC/JSC Cardiopulmonary Workshop, December 6 and 7, 1990.

PAPERS FOR PRESENTATION AT PROFESSIONAL SOCIETY MEETINGS

- Bondar, R.L.; Kassam, M.S.; Stein, F.; Dunphy, P.T.; Fortney, S.; and Charles, J. The usefulness of transcranial doppler in predicting loss of orthostatic tolerance during lower body negative pressure. Abstr. submitted to Aerospace Medical Association Meeting, 1991.
- Fortney, S.M.; Troell, M.; Dussack, L.; and Cintron, N.M. Plasma volume, fluid balance, and endocrine responses to prolonged lower body negative pressure (LBNP) during bed rest. Abstr. submitted to Federation of Experimental Biology and Medicine Meeting, 1991.

PLANNED FUTURE WORK

- Finish female bed rest study. (Two more subjects expected to be tested January 31, 1991 until February 16, 1991.) Data analysis and manuscript preparation for rest of the year.
- Perform short, 7-day bed rest study in men to evaluate the effectiveness of sinusoidal LBNP 2-hour protocol in men. (Begin this summer.)

EXPECTED COMPLETION DATE

Studies completed by October 1, 1991.
Data analysis and manuscript preparation done by October 1, 1992.

REFERENCES

1. Hyatt, K.H.; and West, D.A.: Reversal of bedrest-induced orthostatic intolerance by lower body negative pressure and saline. Aviat. Space Environ. Med. 48: 1977, pp. 120-124.
2. Lyons, T.P.; Riedesel, M.L.; Meuli, L.E.; and Chick, T.W.: Effects of glycerol-induced hyperhydration prior to exercise in the heat on sweating and core temperature. Med. Sci. Sports Exercise 22: 1990, pp. 477-483.

TITLE OF INVESTIGATION: Neural Network Modeling of Postural Control

PROJECT MANAGER: Millard F. Reschke, Ph.D./SD5/483-7210

TEAM MEMBER: James A. Villarreal

INITIATION YEAR: FY89

FUNDING:

	FY89	FY90
In-house:	15k	15k
Contractors:	15	35
Grants:	0	0
Total funds:	30k	50k

OBJECTIVE

The goal of this project is to develop a neural network (NN) model of postural equilibrium control that can map sensory input signals from the visual, vestibular, and proprioceptive systems into appropriate motor control strategies for maintenance of stable, upright stance. When the model is sufficiently developed, it will be trained using pre- and postflight postural equilibrium data to simulate the course of neurosensory adaptation to microgravity and readaptation to the terrestrial environment. It may then be useful in predicting untoward responses to normal crew activities and aid in developing appropriate countermeasures to these responses.

ACCOMPLISHMENTS

The following is a brief summary of the significant work performed during FY90. For more details consult the Center Director's Discretionary Fund Final Report "Neural Network Modeling of Postural Control" published November 30, 1990, which is available upon request.

Methods

The project focused on analyzing posture data obtained from 10 normative subjects who spent 30 minutes in the Tilt Translation Device (TTD), which is one of several preflight adaptation trainer (PAT) simulators available in the Johnson Space Center (JSC) Neurosciences Laboratory. The PAT devices were designed to produce a sensory conflict similar to the conflict caused by microgravity. The TTD operates by presenting a visual scene to a subject which can be translated back and forth and by tilting the subject forward and backward. The TTD generates a sinusoidal tilting and translation motion with an adjustable phase lag between the separate motions. Previous studies have revealed that exposure to microgravity generates a sensory conflict which the central nervous system attempts to resolve by reinterpreting tilt as translation. The subjects underwent a battery of posture sensory organization tests (SOTs) using a commercially available posture platform, before and after exposure to the TTD (fig. 23).

To perform the analysis, an NN architecture was chosen that was especially suitable for the task. The spatiotemporal neural network (STNN) is a variant on the well known backpropagation (BP) algorithm. The BP algorithm is used in multilayered feedforward networks and works via supervised learning; i.e., the network is presented with input/output (I/O) pairs in which the network is trained to produce the output. The training consists of adjusting weights between neurons in different layers to satisfy a minimum training error criteria. The STNN architecture was conceived by the Software Technology Branch at JSC to address the task of analyzing several channels of time series data simultaneously. The STNN architecture and learning rule are very similar to BP; the only real difference is that in place of a single scalar weight between two neurons, there is now a vector of weights. The components of this weight "vector" consist of adjustable coefficients similar to those in a digital filter with "pole" and "zero" coefficients available. In addition to the coefficients, the network contains delays which store samples of the time series so that one has a "history" of the time series "spread out" between the network layers (fig. 24).

Pre- Post-PAT Prediction Using Heteroassociative Mapping

The rationale for mapping pre to post PAT data was to find out if it was possible for a neural network to be used to predict the performance of a subject for a given sensory test after exposure to the PAT TTD. The implication being that if a network, using only minimally processed subject data, could capture the essential changes inherent between the pre- and post-PAT data and successfully generalize to new data, a basis for predicting postflight astronaut performance would exist.

In previous prediction tasks using BP NNs, typically a single-channel time series was used in which a portion containing a "sufficient" number of samples was mapped on to the input layer and the network attempted to predict the next sample which was generated by a single output unit. The criteria for knowing how many samples were "sufficient" was dependent on the characteristics of the data. The network was trained by using a large (about 7/8) portion of the data set in this incremental fashion. The trained network was tested on the remaining portion. While this method has worked well for single-channel time series, extensions to the multiple channel case would be difficult using BP. Also, for our purposes, this prediction method (which could have been implemented on STNN) would have dubious utility since we required the network to represent a change brought on by sensory rearrangement. Taking pre-PAT data and using it to predict future samples of data based on a pre-PAT sensory condition would not be valid for predicting post-PAT responses.

We decided to construct I/O pairs by taking the 1st trial of pre-PAT data and pairing it with the 1st trial of post-PAT data for SOT #6. While it can be argued that there was not a functional relationship between the two trials per se, the PAT TTD produces a sensory rearrangement that is fairly robust (based on the comparison of pre- and post-center of gravity (CG) sway) for a short duration after TTD exposure. Since the STNN (and BP as well) performs a mapping from the input data to the output data, it seemed a reasonable idea that a net trained on pre- and post-PAT I/O pairs could deduce the functional relationship between the two states (based solely on the data) and reproduce it for an arbitrary input. Two different treatments were done; the first used all 11 channels of filtered raw data (fig. 25) and the second used derived CG sway data only.

The result for the 11-channel case was that the network reproduced the training set fairly accurately but did not perform as well on the test set. Average training errors were 1 to 2 percent while average testing errors were in the 13 to 15 percent range. The number of hidden units were varied from 6 to 50 without significant change in the results. A 6-hidden unit, 5-second window version failed to produce significantly different results. Another series was run using Subject #2 data only and produced similar results. A network that performs this way is experiencing some degree of generalization failure. Ideally the network test error would be identical to the training error; however this target is not easy to attain when real data is used. The network was able to learn the training set (which usually occurs), but for one of several reasons could not generalize at an optimum level.

The CG sway data was generated by taking the four force transducers under the support surface and, based on a formula provided by the posture platform manufacturer, combining these channels into a single channel which measures CG sway over time. Longer time windows were tried for this portion of the study since it was anticipated that longer duration training samples and windows would result in better network performance. The testing error results were comparable to the 11 channel version, although training error was higher for CG version (8 percent). A three subject version was tried and had better training error but worse testing error. This version was also tried with Subject #2 alone and produced a training error of 7 percent and test error of 12 percent. Our goal was to get the error close to the same level as the autoassociator network. Again, a degree of generalization failure existed. Compared to other NN pattern recognition and classification tasks found in the literature where biological experimental data was analyzed, our test data error percentages were comparable. However, the performance of the network is not yet adequate to justify its use as a prediction tool for postflight postural responses.

Hidden Unit Analysis of Autoassociated CG Data

Another method we tried which has shown promise is to perform an analysis of the hidden units of a trained autoassociative (identical input and output) NN. The network is trained with a data set until its error is at an acceptable level, at which point the weights are fixed. The network is then input with the training set again, but instead of changing the weights, the activation values of the hidden units are recorded for each member of the training set. The justification for this procedure is that the hidden units generate an internal representation of the mapping between input and output spaces. By examining the hidden units activation patterns as different members of the training set are input, some insight can be gained into how the network is performing the mapping. If the activations cluster in this space for similar data, a basis for classification and/or discrimination may exist. The activations of the hidden units are typically displayed (for 2 and 3 hidden units) in 2- and 3-dimensional graphs where each hidden unit's activation level is represented on one axis in the plot. Higher numbers of hidden units (greater than three) are usually analyzed with attendant loss of visualization (and insight).

We used an autoassociator of CG data from two sensory tests at the opposite extremes of the posture testing battery, SOT #1 and SOT #6 (fig. 23). Discriminating between the two extremes should be the easiest task the NN has to perform. Two different network architectures, STNN and BP, were used for this experiment. This was done to provide a point of comparison and, in part, because BP hidden unit analysis is better understood than its STNN counterpart. In the case of STNN, a 200-point trajectory was generated representing the duration of the training sample (i.e., 20 seconds). The BP will map the 200-point sample across the input and output layers. Since there is no temporal history in a BP net, only a single point will be generated for each training sample. In both cases, three hidden units were used (for ease of visualization) and all members of the training and test sets were 20 second trials of SOT #1 and SOT #6.

The STNN results revealed easily distinguishable differences between SOT #1 and SOT #6 based on gross features of the trajectories. SOT #1 had a very small trajectory relative to SOT #6. A feature common to all STNN versions of the autoassociator was an initial trajectory appeared that was subject dependent (but similar across subjects) which later developed into a quasielliptical trajectory pattern for the remainder of the sample. The STNN results for a single subject in which the network discriminated between three distinct classes of data also revealed differences between the three trials based on gross features of the trajectories (fig. 26).

The BP version for SOT #1 and SOT #6 behaved rather closely to expectations as definite clustering occurred and the clusters and locations seemed reasonably consistent. The plot shown is two dimensional since the activation of the third hidden unit was very small relative to the other two, hence it was suppressed as it supplied no useful information. All the SOT #1 trials (odd numbers on the graph) had partial activations of both hidden units, while the SOT #6 trials (even numbers) tended to ride the axes, the exception being data point #4 (fig. 27). Why this deviation occurred is unknown.

Based on the results that we had obtained from the FY90 work, we felt some promising lines of research were discovered and that the appropriate mechanism for continuing the work would be under the aegis of RTOP funding (see below). A DDF Final Report has been prepared for submission to the New Initiatives Office and is attached to this technical summary. The report contains more detailed information regarding the work performed and discussion of the results obtained.

PLANNED FUTURE WORK

After evaluating the DDF work results, we feel that the most promising line of research is to pursue the classification task. NNs will be developed to perform explicit classification of postural sway data into distinct states based on the standardized posture sensory tests and distinct physiological states that are known to be represented in the data. Our expectation is that NN-based classifiers should have sufficient discriminative ability to allow the use of a previously trained network to classify new data obtained from either normative or astronaut populations.

A spinoff benefit of this research would be the development of a basis for automated classification of postural sway of clinical patient populations using NNs. Since patients with various CNS lesions display distinct alterations in postural control which appear in posture platform testing, NN-based classifiers trained on patient data should perform as well as NN posture classifiers trained on normative and astronaut populations. Discrimination of distinct postural control states is more challenging in normative (versus patient) populations since the variation in performance is smaller; hence, the NN algorithms, which are successful with normative subjects, should be able to spot these changes in patient populations.

We are presently in the beginning stages of writing an RTOP proposal to pursue the development of NN-based posture maintenance classifiers. This research effort would focus on evaluating the classification performance of several NN architectures applied to the PAT posture data. An integral part of this effort would also involve analyzing the network's operation as it performed this task. By understanding what features the network used to classify the data, we hope to gain some insight into underlying physiological mechanisms that generated the data. This information should aid in achieving the goals stated in the objective.

EXPECTED COMPLETION DATE

The DDF phase of this project was completed on November 30th, 1990.

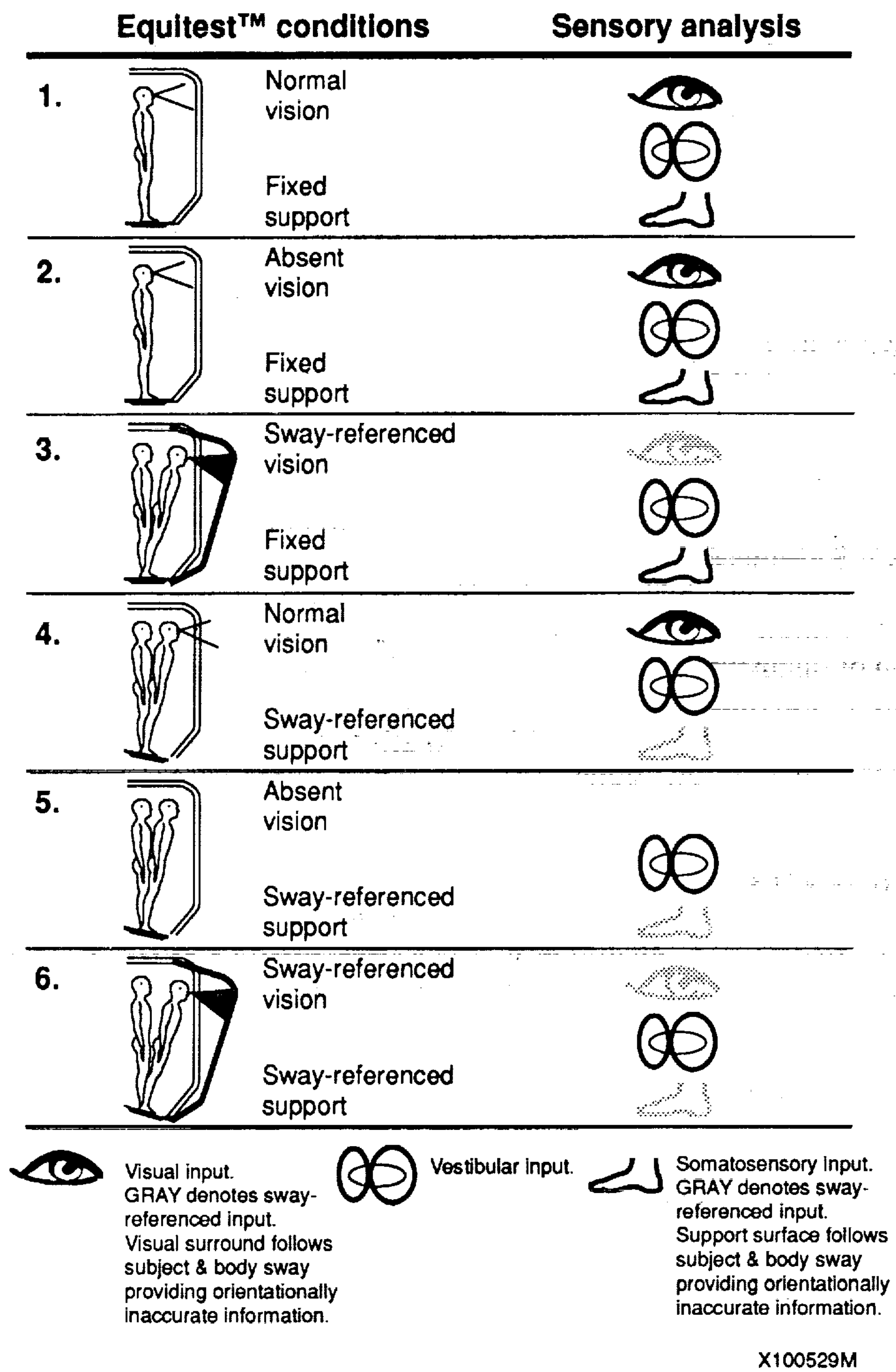
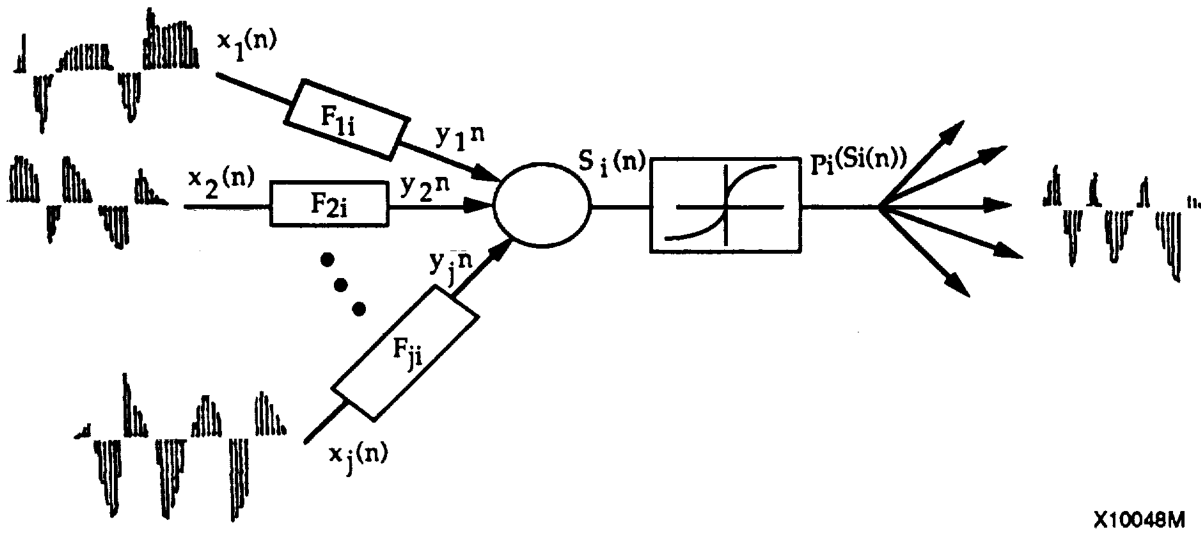
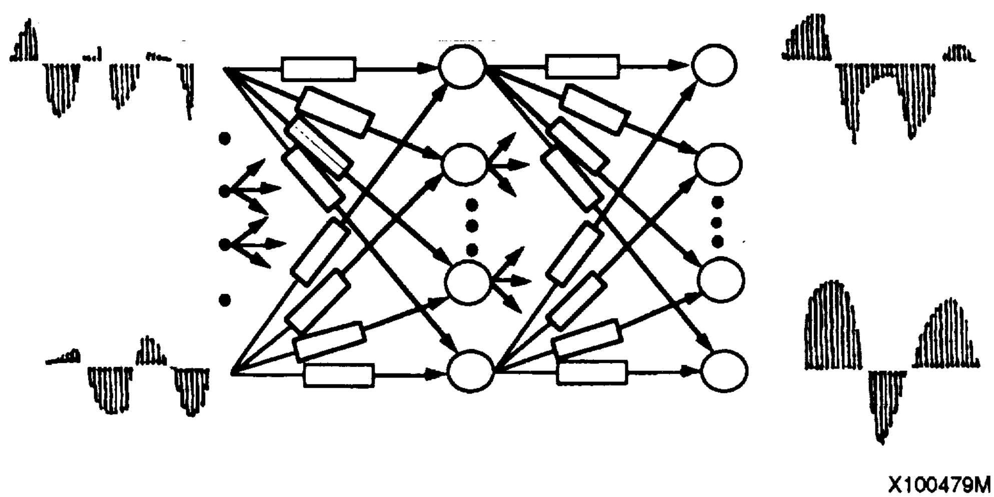


Figure 23. Sensory Organization Test conditions. The symbols on the right indicate the visual, vestibular, and ankle proprioceptive senspory inputs used during that test condition. Sway referenced conditions are those in which the visual surround and/or support surface are directly servo controlled to body sway thereby providing orientationally inaccurate information. (Figure copyright by Neurocom, Inc.; used with permission.)



a) STNN processing element comparable to standard BP network except for the weight vector which replaces the BP weight scalar.



b) Representation of STNN emphasizing the weight vectors interconnections between layers of processing elements.

Figure 24. STNN architectural features; in both cases note the mapping of input time series to output time series.

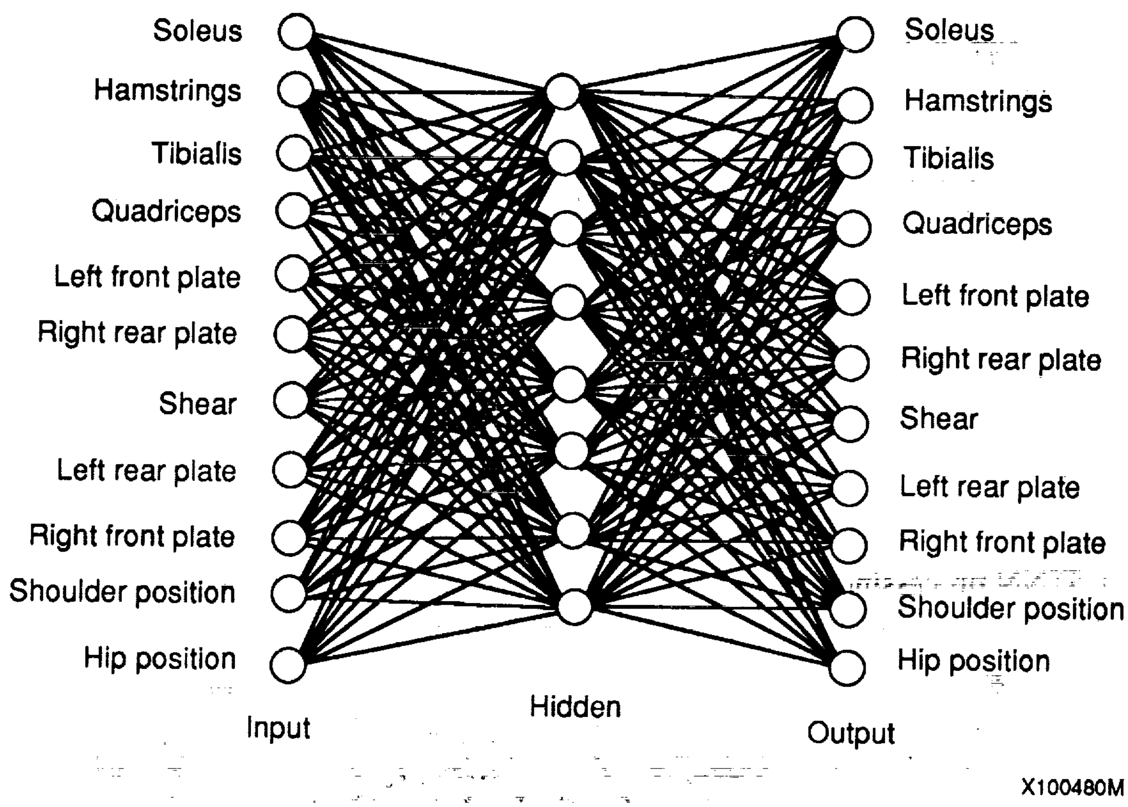


Figure 25. Topology of 11-channel STNN network (auto- and heteroassociator). Note that (for clarity) each weight vector is represented by a single line and that the number of hidden units is variable as described in the text.

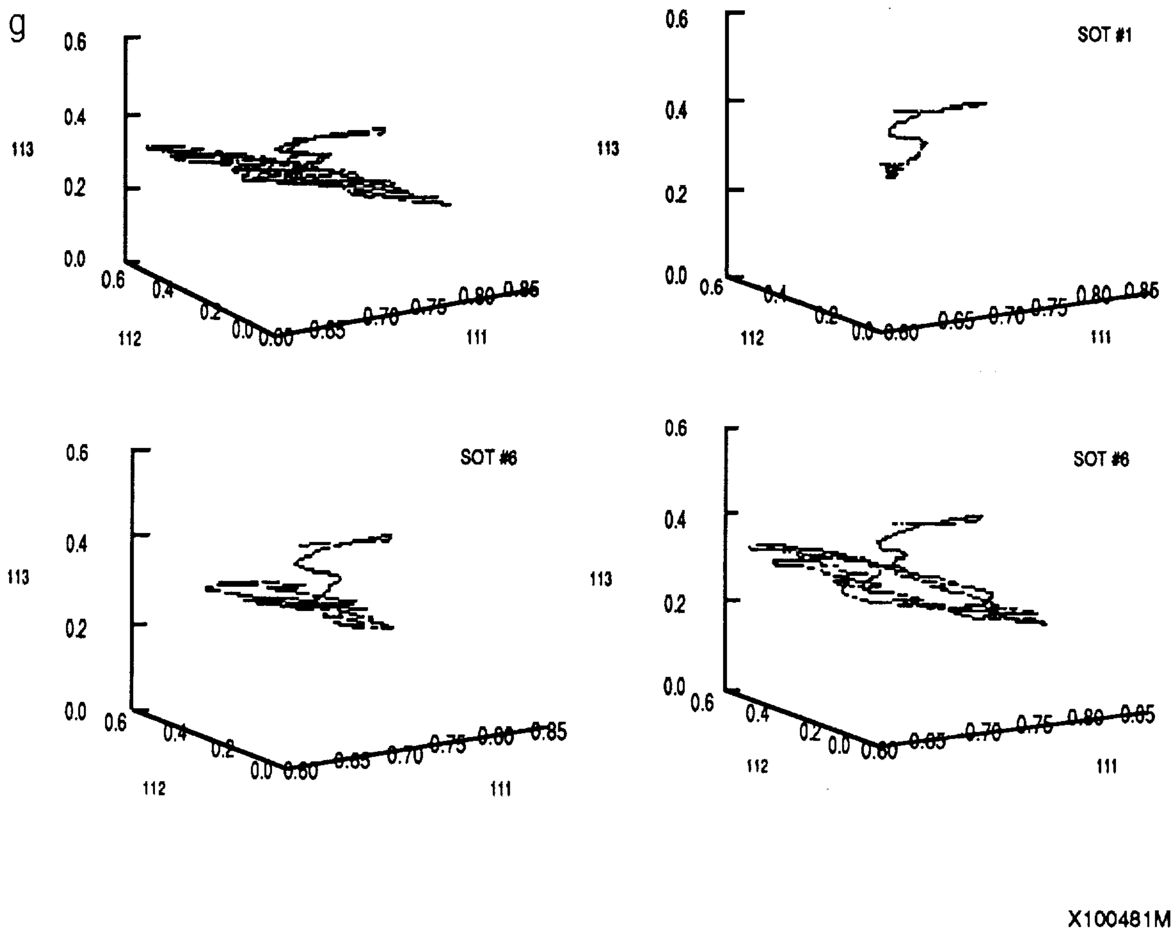


Figure 26. A 3-D plot of STNN autoassociator hidden unit activation values for network trained with subject #2 SOT #1, SOT #6 (pre-PAT), and SOT #6 (post-PAT) data only. Note the 200-point trajectories in each case.

a) Composite plot. b) SOT #1. c) SOT #6 (pre-PAT). d) SOT #6 (post-PAT).

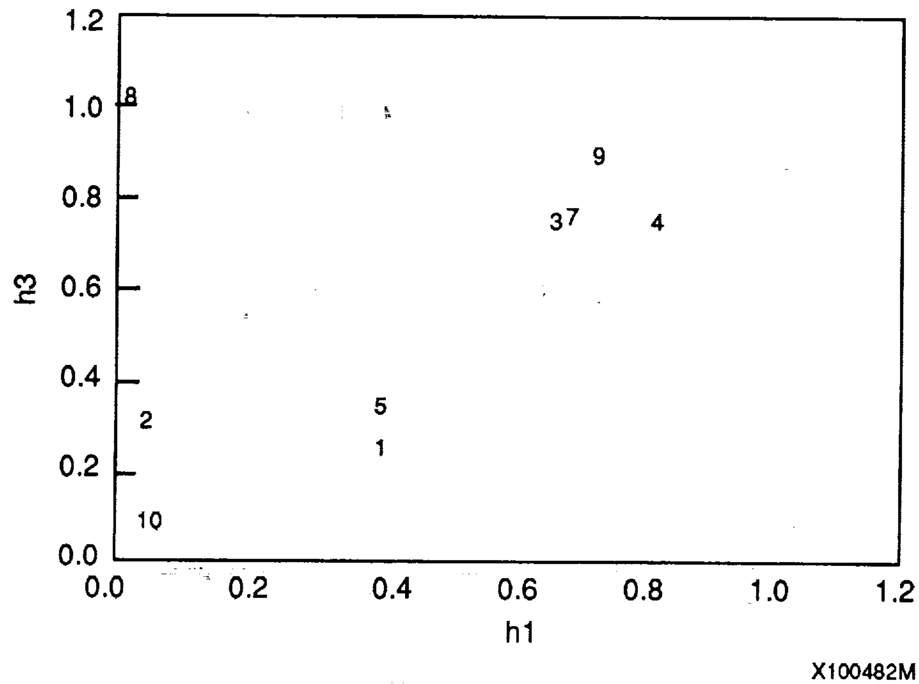


Figure 27. A 2-D plot of BP autoassociator hidden unit activator values for network trained with SOT #1 and SOT #6 (pre-PAT) data for five subjects. Note distinct clustering and segregation of data points.

TITLE OF INVESTIGATION: Backscatter Mossbauer Spectroscopy (BaMS) for Analysis of Planetary Surface Materials

PROJECT MANAGER: Richard V. Morris/SN2/FTS 525-5040

INITIATION YEAR: FY89

FUNDING:

	Total prior years	FY90
In-house:	18k	30k
Contractors:	0	0
Grants:	12	
Total funds:	30k	30k

OBJECTIVES

Spacecraft missions with landers to the Moon, Mars, asteroids, and other solid solar-system objects require instrumentation for analysis of surface materials. Analysis provides characterization of the surface materials and, for sample return missions, a basis for selection of representative samples. Operation of a lunar base requires similar instrumentation for *in situ* resource utilization. Iron Mossbauer spectroscopy is specific for the element and sensitive to its oxidation states and chemical environment. The technique provides quantitative information on the mineralogy of iron-bearing phases and on the relative proportions of those phases. On the Moon, for example, it is an ideal probe for the mineral ilmenite, which is a source of O_2 for life support and He^3 for nuclear fusion. Because of this high selectivity to mineralogy, the inherent simplicity of the instrumentation, and no requirements for sample preparation, a BaMS (fig. 28) is a highly viable candidate for inclusion on a surface lander. This project is to (1) document that BaMS can provide the necessary mineralogical data (proof-of-concept) and (2) build a brassboard instrument. Technology development areas for brassboard subsystems include miniaturization of the velocity transducer, incorporation of solid-state detector, and testing of detector arrays (both solid state and proportional counter). This project is the basis for proposals to the Planetary Instrument Definition and Development Program for full development of a flight instrument. The project is conducted by the Solar System Exploration Division of the Johnson Space Center.

ACCOMPLISHMENTS IN FY90

For the proof-of-concept phase of the project, a research-grade Mossbauer spectrometer, capable of operation in both the normal transmission mode and in backscatter mode, was obtained during FY89. Analysis of samples pertinent to planetary applications of Mossbauer spectroscopy is underway. Transmission Mossbauer spectra for a martian meteorite, a palagonitic soil (an analogue of weathered martian material), and a lunar simulant are shown in figure 29. The sensitivity of the technique to iron mineralogy is clearly apparent. Computer programs have been developed to parameterize the Mossbauer spectra. For the brassboard phase of the project, a piezoelectric (PZ) velocity transducer was tested as an alternative to the bulky and heavy velocity transducer present in laboratory systems. A miniaturized version of a conventional velocity transducer is also being constructed. A list of publications and talks associated with this project are listed in the bibliography.

PLANNED FUTURE WORK

Samples appropriate to martian and lunar applications of a BaMS instrument will continue to be analyzed. Several velocity transducer designs (PZ and conventional) will be completed and competed against each other. Detector arrays will be built and tested. A brassboard instrument employing optimum detector and transducer designs will be built and tested.

EXPECTED COMPLETION DATE

September 30, 1991.

BIBLIOGRAPHY

1. Morris, R.V.; Agresti, D.G.; Shelfer, T.D.; and Wdowiak, T.J.: Mossbauer backscatter spectroscopy: A new approach for mineralogical analysis on planetary surfaces. In *Lunar and Planetary Science* vol. XX, The Lunar and Planetary Institute, Houston, 1989, pp. 723-724.

2. Agresti, D.G.; Wills, E.L.; Shelfer, T.D.; Iwanczyk, J.S.; Dorris, N.; and Morris, R.V.: Development of a solid-state Mossbauer spectrometer for planetary missions. In *Lunar and Planetary Science,* vol. XXI, The Lunar and Planetary Institute, Houston, 1990, pp. 5-6.

3. Morris, R.V.; Gooding, J.L.; Lauer, H.V.; and Singer, R.B.: Origins of Marslike spectral and magnetic properties of a Hawaiian palagonitic soil. *J. Geophys. Res. 95,* 1990, pp. 14427-14434.

4. Shelfer, T.D.; Pimperl, M.M.; Agresti, D.G.; Wills, E.L.; and Morris, R.V.: Backscatter Mossbauer spectrometer (BaMS) for planetary applications: Transducer design considerations. In *Lunar and Planetary Science,* vol. XXII, The Lunar and Planetary Institute, Houston, accepted, 1991.

5. Agresti, D.G.; Shelfer, T.D.; Pimperl, M.M.; Wills, E.L.; and Morris, R.V.: Mossbauer spectrometer for planetary surfaces, *Am. Phys. Soc. An. Mtg.,* accepted, 1991.

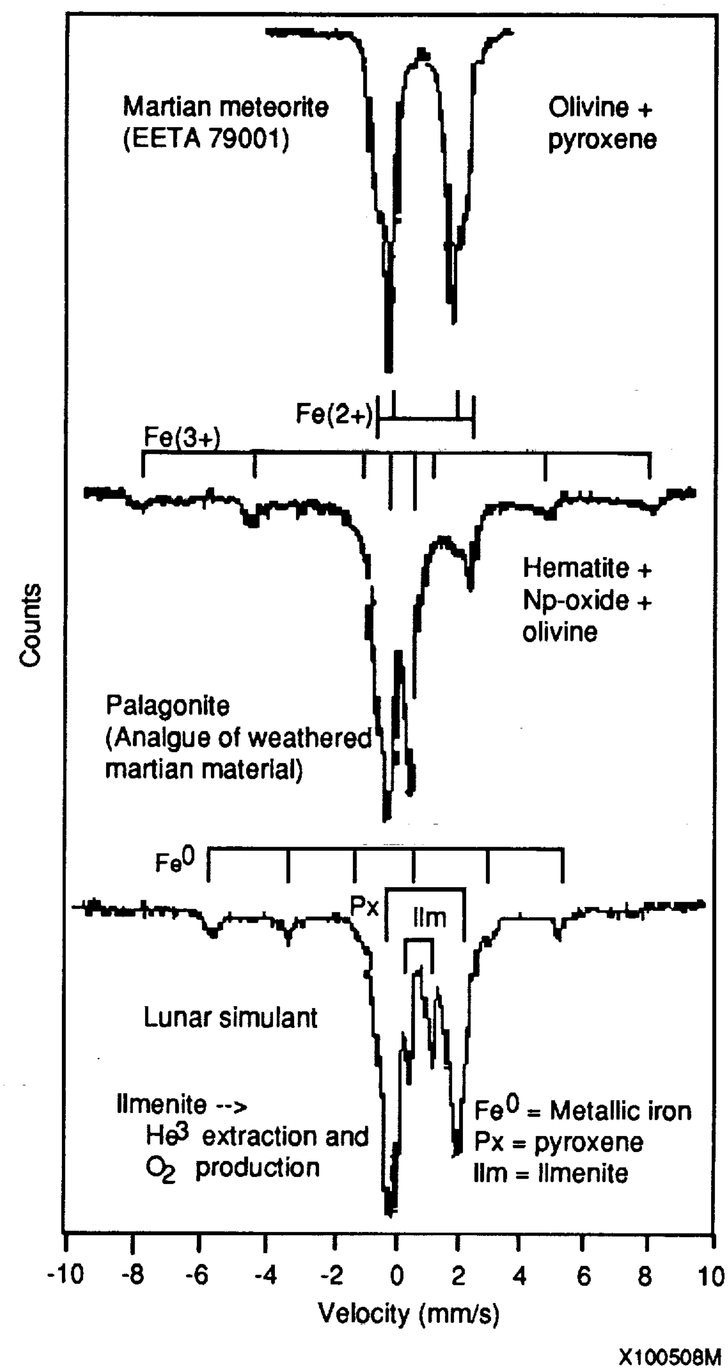


Figure 28. Transmission Mossbauer spectra.

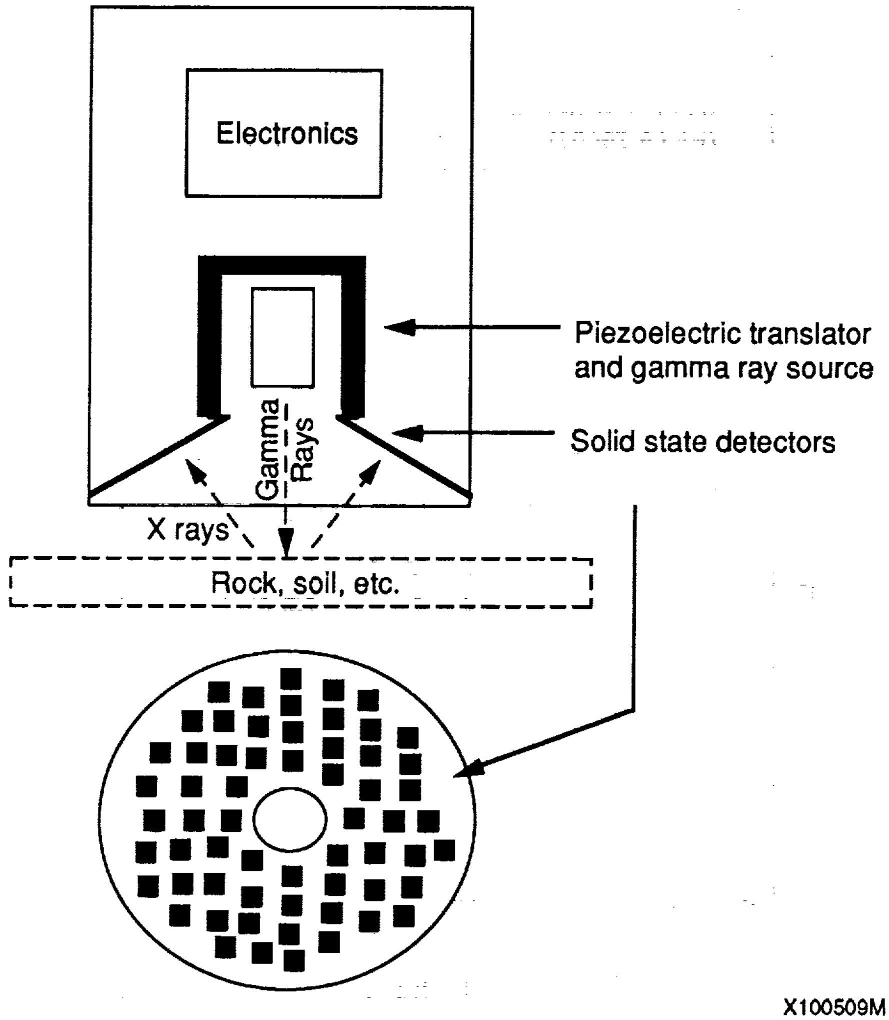


Figure 29. Backscatter Mossbauer spectrometer (BaMS).

TITLE OF INVESTIGATION: Regenerative Life Support Systems (RLSSs) Test Bed Project

PROJECT MANAGER: Albert F. Behrend/EC3/483-9241

PRINCIPAL INVESTIGATOR: Donald L. Henninger/EC3/483-5034

PROJECT ENGINEER: Terry O. Tri/EC3

INITIATION YEAR: FY90

FUNDING:	Total prior years	FY90	FY91 (est.)	FY92 (est.)
In-house:	0	283k		
Contractors:	0	17		
Grants:	0	0		
Total funds:	0	300k	300k	400k

OBJECTIVE

The objective of the RLSS Test Bed Project is to use higher plants grown in a closed, controlled environment in conjunction with physicochemically based life support systems to provide an integrated biological/physicochemical RLSS test bed. A human metabolic simulator, or "canned man," also will be integrated into the test bed, which will supply variable metabolic loads to the system to simulate the presence of a crew. The integrated RLSS test bed will be fully automated to grow crops from seed to harvest without the need for human intervention. One of the test bed's two growth chambers (see fig. 30) will be operable at both ambient and reduced atmospheric pressures to more closely duplicate candidate lunar and martian habitat environments (ref. 1). Major objectives of the test bed include quantification of life support capabilities of higher plants (i.e., oxygen production, carbon dioxide uptake, and water conditioning via transpiration), determination of interactions between the biological and physicochemical life support system components, and definition of the integrated control system approach for providing variable life support capabilities on demand. Data from the RLSS Test Bed Project will be used to define requirements for a future human-rated RLSS test facility to be developed at JSC (ref. 2).

ACCOMPLISHMENTS IN FY90

The RLSS Test Bed Project achieved several key accomplishments during FY90, including development of an overall systems design for the test bed and outfitting the variable pressure growth chamber with plant growth systems. The chamber outfitting activities consisted of constructing an internally-located atmospheric conditioning system, a fluorescent lighting system, four independent fluid delivery systems for deionized water irrigation and nutrient solution delivery, and various other supporting subsystems. Other key activities accomplished in FY90 included constructing the ambient pressure growth chamber, outfitting a centralized control room for monitoring and control of the test bed, and developing an initial supporting research laboratory in which off-line plant growth experiments and biomass production analysis can be peformed.

PLANNED FUTURE WORK

Anticipated FY91 accomplishments include performing functional testing of the existing plant growth systems, growing several test crops of lettuce and wheat in various solid support substrate media, outfitting the ambient-pressure growth enclosure with hydroponically-based plant growth systems, fabricating the metabolic simulator, and preparing an existing physico-chemical air revitalization system for eventual integration into the test bed.

EXPECTED COMPLETION DATE

The Center Director's Discretionary Fund (CDDF) portion of this project is scheduled to be completed in October 1992 (i.e., 3 years of CDDF support). After this date, continuation of this project is anticipated to be funded by the Research and Technology Objectives and Plans program.

REFERENCES

1. Henninger, D. L., et al.: Regenerative Life Support Systems (RLSS) Test Bed Performance Characterization of Plant Performance in a Closed, Controlled Test Chamber. To be presented at the 21st Intersociety Conference on Environmental Systems, Society of Automotive Engineers, 1991 (in work).

2. Tri, T. O., et al.: Regenerative Life Support Systems (RLSS) Test Bed Development at NASA Johnson Space Center. To be presented at the 21st Intersociety Conference on Environmental Systems, Society of Automotive Engineers, 1991 (in work).

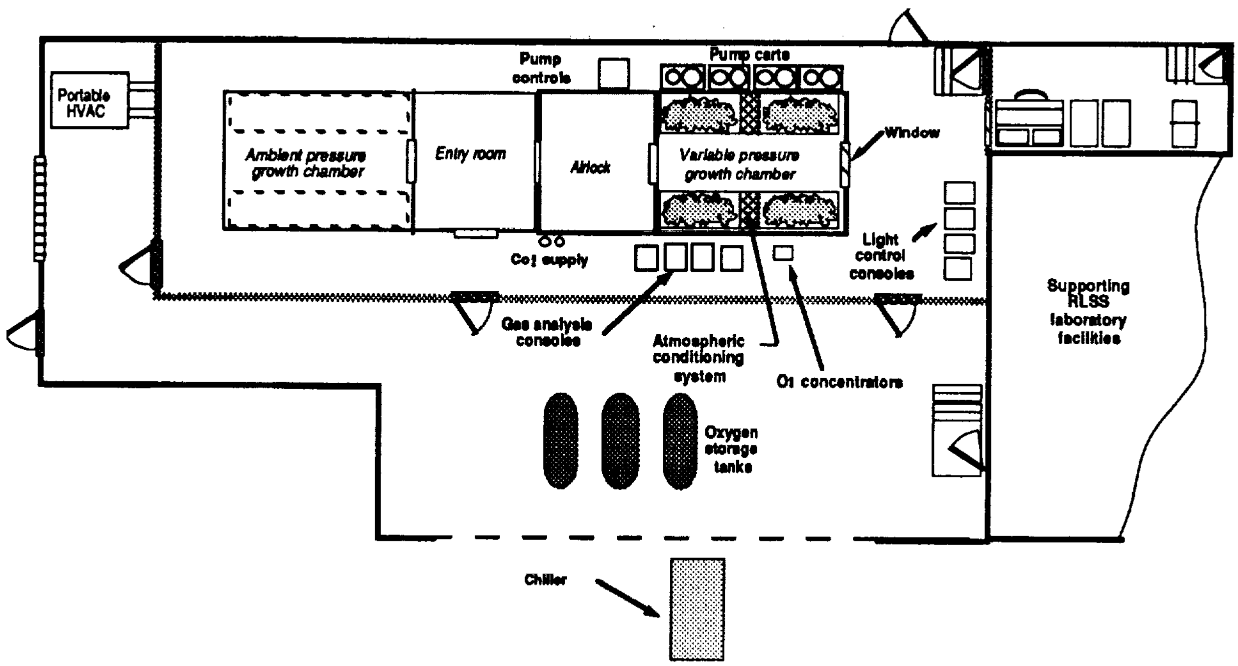


Figure 30. The RLSS Test Bed Facility layout.

TITLE OF INVESTIGATION: Mockup of a Constructible Lunar Habitat

PROJECT MANAGER: Michael Roberts/ET2/483-6632

INITIATION YEAR: FY90

FUNDING:

	Total prior years	FY90
In-House:	0	135k
Contractors:	0	0
Grants:	0	0
Total funds:	0	135k

OBJECTIVE

The Center Director's Discretionary Fund (CDDF) activity will result in the construction of a full-scale mockup of a constructible lunar habitat. The near-term goal of the project is to evaluate the habitability of a 10-m spherical habitat. The long-term goal is to develop a facility for the rapid creation and modification of habitat mockups, so that architectural trade studies in support of the Space Exploration Initiative may be performed in a timely manner.

ACCOMPLISHMENTS IN FY90

- A modular structural framework has been procured. The framework is currently configured as a four-story hexagonal cylinder, 38 ft tall and 36 ft in diameter. This framework is designed for rapid assembly and disassembly, and may be reused to support other habitat or vehicle mockup configurations.

- A complete interior design for a 10-m diameter spherical habitat has been completed. This design was performed by a team of four university space research associate students under the direction of NASA personnel. The design is documented in a report titled, "Design of an Inflatable Habitat for NASA's Proposed Lunar Base" (see ref. 1).

- The funding for this project was shared with another CDDF project, a mockup of an initial lunar habitat. This second project was directed by SP personnel and is the subject of another report item.

PLANNED FUTURE WORK

The actual construction of the mockup interior elements and external cover are underway, with completion expected in early 1991. The resulting spherical configuration will be evaluated by such architectural criteria as efficient utilization of space, available stowage, and ease of movement within the habitat. The evaluation will be documented in a report.

A vertical cylindrical habitat configuration has been proposed as a follow-on study. Construction of the follow-on is expected to begin in the fall of 1991.

EXPECTED COMPLETION DATE

May 1991

REFERENCES

1. Connell, R. B., et. al.: Design of an Inflatable Habitat for NASA's Proposed Lunar Base. August 1990.

TITLE OF INVESTIGATION: Adaptive Control of a Robot Arm Using an Artificial Neural Net with Stereo Vision Input

PROJECT MANAGER: Timothy F. Cleghorn, Ph.D/PT4/483-8090

ASSOCIATED PROJECTS: Leo Monford/IC
Les Theard/LEMSCO, Texas A&M University

INITIATION YEAR: FY90

FUNDING:

	Total prior years	FY90
Contractors:	0	50k
Total funds:	0	50k

OBJECTIVE

Development of artificial neural net techniques for the adaptive control of robot arms.

ACCOMPLISHMENTS IN FY90

The mode of operation currently proposed for space and planetary surface robotics is teleo-peration. While this may prove satisfactory for tasks in the immediate vicinity of a manned spacecraft, it is clear that there will be numerous occasions for which more autonomous robotic behavior will be required. Examples of such tasks include satellite servicing, for which the transmission time delays are unacceptable; routine inspections, requiring intense human concentration for long periods, thus raising the probability of error due to fatigue or boredom; and planetary surface rover operations for which the round trip transmission times exceed the real time requirements.

Similar tasks have been addressed usually by what can be called "automatic" robotics; i.e., the arm or vehicle is preprogrammed to carry out a specific operation. It has little or no sense of its environment, and if an unanticipated event occurs, at best, it shuts itself off and waits for a human to restart it. What will be needed in order to carry out the more demanding tasks is the development of "autonomous" robotics in which the computer attached to the arm or vehicle has a wealth of sensory input about the environment, and the ability to respond to that input without human intervention. The system thus adapts to the environment, and can continue to function in the face of unforeseen events or obstacles.

Until recently, there have been two major factors which have limited the development of autonomous robotics. The first of these was the lack of sufficient computing power. This is no longer seen as a limiting problem, especially with the advent of parallel architectures. Even serial computers are now becoming fast enough, and have sufficient memory and storage capabilities to handle some of these problems. The other limiting factor was the lack of success of the "classical" artificial intelligence techniques. Combinatorial explosions usually derailed the attempts to teach computers about their environments. With the rediscovery and development of artificial neural net technology in the 1980's, this problem is also being addressed. One class of network, adaptive resonance theory (ART), is particularly suitable for the environment sensing and response problem.

A simulation has been developed on a Silicon graphics computer, which demonstrates the Robotics Research Corporation K-1607 robot arm learning to reach out and touch a spherical target object. The learning process occurs with an ART-like net similar to one developed by Neurogen, Inc. for a microbot arm. The inputs to these networks are stereo images of the target and arm. There are two phases: a learning phase and a production phase. During the learning phase, the arm manipulates the target sphere within the field of view of the cameras, similarly to how a baby observes his or her hands moving in front of its face. This allows the weights of the neural net to make an association between the view and the position and motion of the arm. During the production phase, the target is placed at random within the field of view of the cameras, and depending upon the degree of learning, the arm reaches out and touches it. Initially, learning occurred quite rapidly. After about 20 000 learning manipulations, the arm could touch the target in more than half of its attempts. The system continued to learn less rapidly for up to 200 000 manipulations, at which point it was able to touch a randomly placed target more than 90 percent of the time. The time needed for 200 000 learning trials was about 10 hours.

This demonstrates the potential for neural network technology for solving problems involving unstructured or dynamic environments, as are likely to be encountered in both space and planetary surface robotics operations.

A graphics demonstration was developed and delivered, including source code, which illustrates a 7-degree-of-freedom robot arm using stereo machine vision as input to its neural net controller to locate and grapple a target object. The neural network is adaptive and exhibits unsupervised learning.

PLANNED FUTURE WORK

The demonstration will be enhanced and refined to include obstacle avoidance and additional classes of target objects. The system is written so that the output can be used to control actual hardware robots. This will be performed for robot arm configurations of increasing complexity during the period FY91 to FY95. The long-term goal is to be able to include dynamic targets and obstacles in the neural net controller system.

EXPECTED COMPLETION DATE

The estimated completion date at this time is 1995.

TITLE OF INVESTIGATION: Psychosocial Support for Long-Duration Missions

PROJECT MANAGER: Patricia A. Santy, M.D./SD5/483-7111

TEAM MEMBERS: A. W. Holland, Ph.D. and Roy Marsh, M.D.

INITIATION YEAR: 1989

FUNDING:

	Prior year	FY90
	35k	32k

OBJECTIVES:

- Review the literature and Soviet data on methods of providing psychosocial support in various environments.
- Develop several operational strategies for psychosocial support for long-duration space missions.
- Develop RTOP/operational proposals for future funding

ACCOMPLISHMENTS

Santy, Patricia A.; Psychosocial Support for Long-duration Space Missions. Presented at the IAF meetings in Tashkent, USSR, November, 1989.

Santy, Patricia A.; Psychological Health Maintenance on Space Station Freedom. Journal of Spacecraft and Rockets 1990, vol. 27,pp. 482-85.

PLANNED FUTURE WORK

Drs. Marsh and Holland are currently working on developing individual support plans for extended duration orbiter missions. Funding for this activity will be coming from medical operations.

EXPECTED COMPLETION DATE

This project is ongoing.

TITLE OF INVESTIGATION: Evaluation of New Body Composition Techniques in Variable Gs

PROJECT MANAGER: Steven F. Siconolfi, Ph.D./SD5/483-7110

INITIATION YEAR: FY89

FUNDING:

	Total prior years	FY90
In-house:	35k	32k
Contractors	0	0
Grants	0	0
Total funds:	40k	30k

OBJECTIVES:

Development of new methodologies that can measure changes in body fluids and lean mass (muscle) is the cornerstone for evaluating microgravity-induced changes in body composition.

This project has been divided into four main phases.

- Characterize the bioelectrical responses of the body with different skin temperature, input frequencies, and electrode configurations relative to body positions (FY89/90).
- Data for Phase I and II is currently being collected (25 percent of the subjects are completed). These phases are examining the relationships between bioelectrical responses to low voltage, mutifrequency electrical inputs and body fluid compartments (total body water, extracellular fluid volume, and plasma/ blood volume).
- Phases II and III include the engineering of a compliance volumometer and the physiological evaluation of the volumometer.

ACCOMPLISHMENTS IN FY90

- Completed skin temperature and input frequency analyses.
- National presentations (refs. 1 and 2) of the characterization of the input frequency responses.

- Input frequency responses evaluated with bedrest (ref. 3).
- Skin temperature analysis abstract accepted for 1991 presentation (ref. 4).
- Started Phases I and II September, 1990.

PLANNED FUTURE WORK

- Complete Phases I and II by March 1, 1991.
- Complete engineering checkout of compliance volumometer for both pressure and gas dilution) March 1, 1991 (n=60 subjects. 30 males, 30 females).

REFERENCES

1. Harris, J.; Smith, R.; Reynolds, M.; and Siconolfi, S.F.: Frequency-resistance responses for bioelectrical analysis in humans. Aviation, Space and Environmental Medicine (abstract), 1990.

2. Smith, R.; Harris, J.; Reynolds, M.; and Siconolfi, SS.F.: Bioelectrical responses of humans to input frequencies between 50 and 240 kHz. Medical Science Sports Exercise (abstract), 1990.

3. Wogan, C.F.; Moore, A.D.; Barrows, L.H.; Harris, B.A.; and Siconolfi, S.F.: Assessing Fluid Shifts with Bioelectrical Resistance During Bedrest. Aviation, Space and Environmental Medicine, 1990.

4. Barrows, L.H.; Stricklin, M.D.; and Siconolfi, S.F.: The relationship between bioelectrical resistance and fat-free mass under conditions of different frequency, temperature, and time. Aviation, Space and Environmental Medicine (abstract), 1991.

PROJECT TITLE : Automated Grappling Control for the Space Shuttle Remote Manipulator System Utilizing the Magnetic End Effector and the Targeting and Reflective Alignment Concept (TRAC)

LEADER: Timothy F. Cleghorn, Ph.D./PT4/483-8090

ASSOCIATED PROJECTST: Leo Monford/IC
Les Theard/LEMSCO, Texas A&M University

INITIATION YEAR: FY90

FUNDING:

	Prior years	FY90
Contractors:	0	50k
Total funds:	0	50k

OBJECTIVE

Automation of the TRAC system using machine vision techniques and development of similar machine vision techniques for space and terrestrial robotics operations.

ACCOMPLISHMENTS

An Aspex, Inc. PIPE Processor PSI/100 was delivered and installed. Several machine vision programs were written or ported to this machine. Cooperation set up between NASA and Texas A&M University for development of machine vision routines for the magnetic end effector.

PLANNED FUTURE WORK

The long-term goal is the development of a flight demonstration using real-time machine vision techniques and the TRAC system to control grappling by the Space Shuttle remote manipulator system with the magnetic end effector. Near-term work will include development of demonstrations in the manipulator development facility and elsewhere of the real-time machine vision techniques. Funds will be used to procure additional hardware and software to develop and enhance the lab's real-time machine vision capabilities.

EXPECTED COMPLETION DATE

1997

TITLE OF INVESTIGATION: Doubly Labeled Water Technique

PROJECT MANAGER: Helen W. Lane/SD4/483-7188

INITIATION YEAR: FY90

FUNDING:

In-house:	50k
Contractors:	0
Grants:	
Total funds:	50k

OBJECTIVES:

To develop a scientifically valid method, doubly labeled water, for determination of energy requirements during space flight.

ACCOMPLISHMENTS

- Key accomplishments including reference to:

  Built purification systems for hydrogen and CO_2 from biological samples (urine and saliva)

- Reports, journal articles, other publications

  Submitted to: Analytical Chemistry
  Socki, R.A.; Karlsson, H.R.; and Gibson, E.K.:
  A rapid and inexpensive extraction technique for the 0 - 18 determination of water using pre-evacuated glass vials.

- Papers for presentation at professional society meetings, seminars, symposia, and other important forums

  Paper presented at International Congress of Geochemistry and Geochronology, Canberra, Australia in September 1990.

PLANNED FUTURE WORK

- Validate manifold built to purify hydrogen and oxygen.

- Use data from flight detailed supplement objective on fuel cells and Orbiter water to refine in flight doubly labeled water methods.

- Use data to develop models.

EXPECTED COMPLETION DATE

First stage of Center Director's Discretionary Fund completed in 3 years (FY91 - FY92).

TITLE OF INVESTIGATION: Development of Alloys with Improved Burn Resistance

PROJECT MANAGER: Joel Stoltzfus/RA/FTS 572-5731

TEAM MEMBER: Subhashish Sircar - Lockheed-ESC White Sands Test Facility

INITIATION YEAR: FY89

FUNDING:	Total prior years	FY90
In-house:	40k	25k
Other fund sources:	30	150
Total funds:	70k	175k

OBJECTIVE

The selection of burn-resistant metal alloys for use in oxygen systems has long been an important issue for designers of ground support and flight systems. Fires in oxygen systems are usually catastrophic and may result in loss of hardware and human life. Recent advances in the testing methodology have led to the ability to rank metals and alloys with respect to their flammability in oxygen. However, the alloys that have the greatest resistance to burning do not always have the best mechanical and physical properties. This has led to the need to develop new alloys with improved burn resistance and more favorable mechanical and physical properties. The objective of this project is to develop the technology to formulate and test alloys with these advanced properties.

ACCOMPLISHMENTS IN FY90

Equipment for formulating new alloys and producing test specimens has been purchased and installed, and 25 elemental metals have been purchased. The alloy formulation facility is being activated. Other sources of funds to supplement this project were obtained which contributed $150k in FY90. These funds were used to perform most of the flammability testing discussed below.

Extensive flammability testing of pure metals and existing commercial and experimental alloys in oxygen has been accomplished and is ongoing (refs. 1 to 8). Tests with pure metals configured as wire meshes have indicated that nickel has a superior resistance to combustion compared to the other metals (ref. 1). This led to the investigation of 17 nickel-binary alloys in which the flammability of nickel alloyed with aluminum, cobalt, chromium, molybdenum, titanium, and manganese was determined (see table 1) (ref. 2). These elements are added to nickel to produce more favorable mechanical and physical properties. Of all the alloys tested, only Ni-50 Cr was found to be flammable at an oxygen pressure of 10 000 psig. This result indicates that further investigation of more complex nickel-base alloys may indeed produce burn-resistant alloys which are lighter and stronger than alloys currently available.

Tests have also been conducted on relatively flammable aluminum and titanium-base alloys that are light and strong with the objective of making them more burn resistant. Tests on aluminum alloys have revealed that the addition of lithium, which is highly reactive, increased the minimum pressure required to support combustion from 30 to 200 psia (ref. 3) but slightly increased the likelihood of ignition by mechanical impact (ref. 4). Flammability tests on commercially available and experimental titanium-base alloys are currently underway. To date, no improvement in the burn resistance of titanium alloys has been observed.

PLANNED FUTURE WORK

The activation of the alloy formulation facility will be completed, new alloys will be formulated, and test samples will be produced. Flammability tests on existing metals and alloys will continue and tests on newly formulated alloys will be performed; this will include more complex nickel-base alloys. Work to understand why lithium had a favorable affect on the flammability of aluminum-base alloys will be investigated and the results will be applied to new alloy development. Further testing on titanium-base alloys will continue. Supplementary fund sources amounting to $75k have been identified for FY91.

EXPECTED COMPLETION DATE

The Center Director's Discretionary Fund objective of implementing the formulation facility will be completed in FY91. Flammability testing and new alloy development will continue as supported by supplementary fund sources.

REFERENCES

1. Stoltzfus, J. M.; Lowrie, R.; and Gunaji, M. V.: Burn Propagation Behavior of Wire Mesh Made From Several Alloys. Flammability and Sensitivity of Materials in Oxygen Enriched Atmospheres, vol. 5, ASTM STP 1111, edited by J. Stoltzfus and K. McIlroy, American Society for Testing and Materials, Philadelphia, 1991.

2. Kazaroff, J.; Stoltzfus, J.; Gunaji, M.: Flammability of Nickel-Binary Alloys in Oxygen. Presentation to be made at the ASTM Committee G04 Fifth International Symposium on the Flammability and Sensitivity of Materials in Oxygen Enriched Atmospheres, Noordwijk, The Netherlands, 1991.

3. Tack, W.T.; McNamara, D. K.; Stoltzfus, J. M.; and Sircar, S.: Aluminum-Lithium Alloys: Mechanical Property and Composition Effects on Liquid Oxygen Compatibility. Flammability and Sensitivity of Materials in Oxygen Enriched Atmospheres, vol. 5, ASTM STP 1111, edited by J. Stoltzfus and K. McIlroy, American Society for Testing and Materials, Philadelphia, 1991.

4. Simon, N.J.; McColskey, J. D.; Reed, R. P.; and Gracia Salcedo, C. M.: Reaction Sensitivities of Al-Li Alloys and Alloy 2219 in Mechanical-Impact Tests. Flammability and Sensitivity of Materials in Oxygen Enriched Atmospheres, vol. 5, ASTM STP 1111, edited by J. Stoltzfus and K. McIlroy, American Society for Testing and Materials, Philadelphia, 1991.

5. Schoenman, L. and Franklin, J.E.: Flame Propagation Rate of Unalloyed Beryllium and Silicon Nitride in Oxygen. Flammability and Sensitivity of Materials in Oxygen Enriched Atmospheres, vol. 5, ASTM STP 1111, edited by J. Stoltzfus and K. McIlroy, American Society for Testing and Materials, Philadelphia, 1991.

6. Sircar, S.; Stoltzfus, J. M.; and Gunaji, M. V.: The Relative Ignitability and Flammability of Lead-Tin Binary Alloys. Flammability and Sensitivity of Materials in Oxygen Enriched Atmospheres, vol. 5, ASTM STP 1111, edited by J. Stoltzfus and K. McIlroy, American Society for Testing and Materials, Philadelphia, 1991.

7. Steinberg, T. A., and Benz, F. J.: Iron Combustion in Microgravity. Flammability and Sensitivity of Materials in Oxygen Enriched Atmospheres, vol. 5, ASTM STP 1111, edited by J. Stoltzfus and K. McIlroy, American Society for Testing and Materials, Philadelphia, 1991.

8. Steinberg, T. A.; Mulholland, G. P.; Wilson, D. B.; and Benz F. J.: The Combustion of Iron in High Pressure Oxygen. Combustion and Flame, (to be published).

TABLE 2. RESULTS OF FLAMMABILITY TESTS ON NICKEL-BINARY ALLOYS

Material	Test pressure (psig)	Number of tests	Results
Ni-1Al	10 000	5	NB
Ni-3Al	10 000	5	NB
Ni-5Al	10 000	5	NB
Ni-5Co	10 000	5	NB
Ni-10Co	10 000	5	NB
Ni-20Co	10 000	5	NB
Ni-25Co	10 000	5	NB
Ni-2Mo	10 000	5	NB
Ni-6Mo	10 000	5	NB
Ni-10Mo	10 000	5	NB
Ni-10Cr	10 000	5	NB
Ni-20Cr	10 000	5	NB
Ni-50Cr	10 000	1	CB
Ni-50Cr	7 500	1	CB
Ni-50Cr	5 000	1	CB
Ni-50Cr	3 000	1	CB
Ni-50Cr	2 000	1	CB
Ni-50Cr	1 500	1	CB
Ni-50Cr	1 000	1	CB
Ni-50Cr	500	1	CB
Ni-50Cr	300	1	NB
Ni-50Cr	200	2	NB
Ni-1Ti	10 000	5	NB
Ni-3Ti	10 000	5	NB
Ni-5Ti	10 000	5	NB
Ni-1Mn	10 000	5	NB
Ni-2.3Mn	10 000	5	NB

NB The sample was ignited but no sustained burning occurred.
CB The sample burned completely.

TITLE OF INVESTIGATION: Trace Element Analysis of Individual Cosmic Dust Microparticles

PROJECT MANAGERS: Michael E. Zolensky/SN2/483-5128
David J. Lindstrom/SN2/488-5012
Marilyn M. Lindstrom/SN2/483-5135

INITIATION YEAR: FY88

FUNDING:

	Total prior years	FY90
In-house:	130k	40k
Contractors:	0	0
Grants:	0	0
Total funds:	130k	40k

OBJECTIVE

New techniques are being developed to determine trace element abundances in microscopic particles. Instrumental Neutron Activation Analysis techniques are being extended to smaller sample sizes by utilizing the extremely low gamma-ray background of JSC's unique Radiation Counting Laboratory and high-efficiency gamma ray detectors to allow detection of small amounts of radioactivity induced in the samples during intense neutron bombardment in a high-flux nuclear reactor. Samples smaller than one nanogram (10^{-9} g) have been analyzed for a variety of elements, some of which are detected at concentrations less than 1 ppm. We are initially employing this technique to analyze single grains of cosmic dust as well as spacecraft debris and putative martian samples.

ACCOMPLISHMENTS IN FY90

The technique development phase is essentially complete and has been described in a paper (ref. 1) presented to the Seventh Symposium on Radiation Measurements and Applications that is now in press. A second paper (ref. 2) describing low-level counting facilities is also in press. Several irradiations of cosmic dust particles have been completed, and the results have been presented orally at the Lunar and Planetary Science Conference and the abstracts published (refs. 3 and 4). Some related work on meteorite samples was the subject of another abstract (ref. 5). In addition, projects utilizing these techniques have begun on samples of possible martian weathering products in the shergottite meteorite EETA 79001 (ref. 6), and on volcanic glass inclusions in 500-million year old terrestrial quartz grains. This technique may also be employed to aid in the characterization of particle residues from impact craters on surfaces of the Long Duration Exposure Facility (LDEF). All these results are being written up for publication. This year, the gamma-ray counting facilities developed for this project have been used extensively for analysis of radiation effects on LDEF. Nearly one hundred samples, mostly metals, have been counted for gamma-ray activities induced by the space radiation environment. The amounts of different isotopes produced, depending on the target materials and location on the spacecraft, will be used to construct better models of the radiation environment to which astronauts are exposed.

PLANNED FUTURE WORK

These techniques will be used on a variety of materials, in order to solve a variety of scientific problems. The main focus is likely to remain cosmic dust and other fine-grained extraterrestrial materials because of the scientific importance of these materials and the powerful combination of these nondestructive trace element analysis techniques with electron microscopy and other work. We are preparing manuscripts describing scientific results from the initial analyses. A proposal to the Office of Space Science and Applications (OSSA) was funded at a start-up level in FY89, and a new proposal to fund this work fully is to be submitted this spring.

EXPECTED COMPLETION DATE

Technique development is essentially complete, although further optimization to solve specific problems will continue. Further work is expected to be funded by OSSA.

REFERENCES

1. Lindstrom, D.J.: Analysis of Submicrogram Samples by INAA. Nuclear Instr. Meth. Phys. Res., in press and oral presentation, (1991).

2. Lindstrom, R.M.; Lindstrom, D.J.; Slaback, L.A.; and Langland, J.K.: A Low-Back ground Gamma Ray Assay Laboratory for Activation Analysis. Nuclear Instr. Meth. Phys. Res., in press, (1991).

3. Lindstrom, D.J.; Zolensky, M.E.; and Martinez, R.R.: INAA of Cosmic Dust Par ticles from the Large Area Collector (abstract and oral presentation). Lunar and Planetary Science XXI, 700-701, (1990).

4. Lindstrom, D.J.; and Martinez, R.R.: Trace Element Analysis by INAA of Possible Martian Weathering Products in Shergottite EETA 79001 (abstract). Lunar and Planetary Science XXII, in press, (1991).

5. Lindstrom, D.J.; Zolensky, M.E.; and Martinez, R.R.: Compositional Variations in Cosmic Dust-sized Pieces of Murchison Matrix (abstract). Lunar and Planetary Science XXI, pp. 698-699, (1990).

6. Lindstrom, D.J.; Zolensky, M.E.; and Martinez, R.R.; INAA of Large Interplanetary Dust Particles from Collector L2005 (abstract). Lunar and Planetary Science XXII, in press, (1991).

TITLE OF INVESTIGATION: Human Spacecraft Design

PROJECT MANAGERS: Clarence A. Bell/ER/483-4644
Ann Bufkin/ET/483-6619

TEAM MEMBERS: Kathy Daues, Trish Petete, Mariann Brown, Diana Villarreal, Joe Riccio, Don Allison, Ed Robertson, Jim Masciarelli, David Rodriquez, Scott Simmons, Nathan Moore, Robert Trevino, Scott Wright, Don Nelson, Jeff Hein, Elaine Stephens, Tom Moore, George Strouhal, Howard Ashley, James Schornick, Don Morrison, Jeri Brown, Palmer Chiu, Ginger Pack, Mike Eubanks, Irene Verinder, Don Donohoe, Barbara Hernandez, Jon Kahn, Mike Langan, Jim Lee, Angie Law, Dane Russo, Jeff Davis, Karen Mathes, and Jim Waligora

INITIATION YEAR: 1990

FUNDING :

	Total prior years	FY90
In-house :	0	75k
Contractors:		
Grants:		
Total funds:	0	75k

OBJECTIVE

To develop manned spacecraft design options for the initial lunar missions (low Earth orbit (LEO) to lunar surface and back to LEO).

ACCOMPLISHMENTS IN FY90

- Formed a multidirectorate design team to support the future manned spacecraft design for lunar and Mars exploration
- Developed and documented lunar transportation system (LTS) requirements
- Designed two alternative LTSs
- Created desktop models for both LTS designs (construction begun in December)
- Initiated a spacecraft design data base

- Created project brochure and computer animation (both in final stages of completion)

PLANNED FUTURE WORK

- Continue lunar work and begin Mars issues, requirements, and vehicle definition

- Specific interest in: radiation protection, gravity effects, health care and biological effects, viewing requirements definition/pilot ergonomics, systems integration, concept development, mass properties assessment, costing, etc.

EXPECTED COMPLETION DATE

The estimated completion date at this time is December 31, 1991.

REFERENCES

Final report due out in February 1992.

TITLE OF INVESTIGATION: High Resolution Optical Rate Sensor

PROJECT MANAGER: Joseph Thibodeau/ EG1/483-8232
Indulis Saulietis/EG4

TEAM MEMBERS: Tony Pham/EG4
Jo Uhde-Lacovara, Ph.D., Stevens Institute, UHCL
Don Downing, Lockheed Engineering

INITIATION YEAR: 1988

FUNDING:

	FY88	FY89	FY90
In-house:	50k	40k	40k
Contractor:	0	0	0
Grants:	0	0	0
Total funds:	50k	40k	40k

OBJECTIVE

Investigate the performance of image processing algorithms for implementation in a high-resolution, optical, attitude rate sensor.

ACCOMPLISHMENTS IN FY90

Applied digital filtering methods to the image processing of high resolution digital signals from a megapixel charge coupled device (CCD) video camera. An algorithm to provide attitude rate information by directly manipulating the sensor pixel intensity output was developed and tested (refs. 1 and 2).

The rate algorithm works well for simulated star images. When zero mean Gaussian noise with a standard deviation of 5 is added to the simulated data of a star image moving at a constant rate, the algorithm derives the rate with an error of 1.9 percent at a rate of 1.28 pixels per frame. When camera data were collected for a moving image from a fiber optic light source (fig. 31), unexpected systematic intensity errors corrupted the derived rate measurements.

The Kodak CCD large-scale integrated array exhibits a sixteen pixel periodicity in measurement intensity due to the physical layout of the array. More work is required in the camera electronics to eliminate the systematic errors, or the errors must be adequately described and modeled as part of the system software and implemented in the rate derivation algorithm. In addition, the studies indicate a need for more dynamic range than that offered by the Kodak chip and the need for a cooled camera to reduce thermally generated noise. These considerations would be part of any future study efforts.

PAPERS

Uhde-Lacovara, J.: High Accuracy Optical Rate Sensor. NASA/ASEE Summer Faculty Fellowship Program, August 17, 1990.

PLANNED FUTURE WORK

None.

EXPECTED COMPLETION DATE

Algorithm development task completed.

REFERENCES

1. Uhde-Lacovara, J.: Analysis of the Continuous Stellar Tracking Attitude Reference (CSTAR) Attitude Rate Processor. NASA/ASEE Summer Faculty Fellowship Program, vol. 2 (N87-25884) pp. 19-85, 1986.

2. Uhde-Lacovara, J.: Optical Rate Sensor Algorithms. NASA/ASEE Summer Faculty Fellowship Program, vol. 2 (N90-24985) pp. 18-80, 1989.

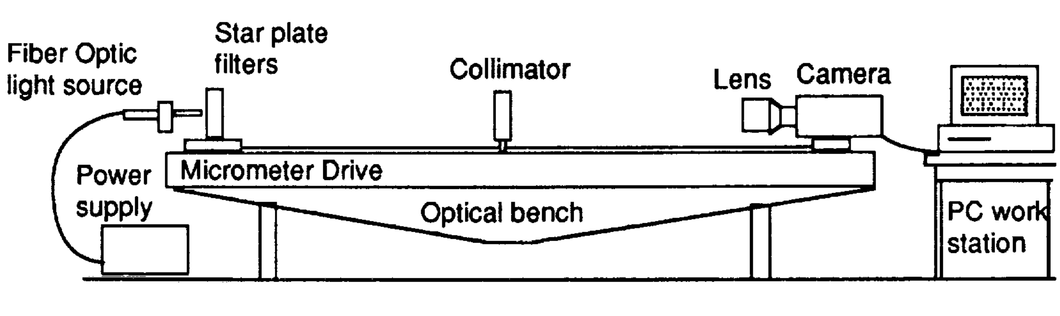


Figure 31. Optical rate sensor experiment.

TITLE OF INVESTIGATION: Network-Based Video Image Link

PROJECT MANAGER: Charles R. Price/ER4/483-1523
University Space Automation and Robotics Consortium

TEAM MEMBERS: Dr. Donald Johnson, Rice University
Dr. Richard Volz, Texas A&M University
Dr. Delbert Tesar, University of Texas at Austin
Dr. George Kondraske, University of Texas at Arlington

INITIATION YEAR: 1990

FUNDING:

	Prior years	FY90
In-house	0	0
Contractors	0	0
Grants	0	50k
Total funds	0	50k

OBJECTIVE

The purpose of this project is to provide video interface hardware to a new robotics network being developed to link the robotics laboratories of the Lyndon B. Johnson Space Center (JSC), Rice University, Texas A&M, University of Texas (UT) at Austin, and UT at Arlington. The network is being established to provide access to a pooled set of very expensive robotics equipment, to greatly increase the efficiency of the use of this equipment, to promote technical communications among the institutions regarding robotics, and to provide a realistic environment for the study of transport lag and other aspects of ground control of multiple space robots. The video interface hardware (frame grabbers and video compression boards) allows for the use of commonly available communications links (e.g., Internet) to transmit slow scan video images of the robotic workspace to the operator and to the performance monitoring node workstations.

ACCOMPLISHMENTS IN FY90

- Video interface hardware was specified and procured to link Texas A&M and Rice University over the Susquinet network (the State version of Internet) which was also used to link the UT at Austin and the UT at Arlington.

- A graphics workstation was procured also to host the Austin kinematic robotics graphics package developed at JSC in order to provide commonality of robotics modelling software.

- A highly impressive demonstration of the concurrent control of three robots and simulations at three schools with performance monitoring at a fourth was given to JSC representatives of the New Initiatives Office, Engineering Directorate, Missions Operations Directorate, and the Space Station Program Office on February 1, 1991. The video interface hardware functioned to confirm that predictive simulations of the robotics workspace presented at the operator's workstation can be successfully used to control remote robotics to perform orbital replacement unit changeout tasks in spite of a variable time lag in command and feedback signals of 3 to 5 seconds between the operator and the robots.

PLANNED FUTURE WORK

A command and control node will be established in Building 9C and added to the newwork as well as the JSC robotics laboratories. Expansion of the robotics network to include all NASA centers and external national and international academic and industrial institutions is currently being proposed to Code R. Applications studies of the ground control of robots for Space Station maintenance and for lunar/Mars operations are being proposed to the appropriate project offices.

EXPECTED COMPLETION DATE

The Network-Based Video Image Link effort funded by the Director's Discretionary Fund will be completed by June 1991. The use of the equipment will continue in the expansion and application of the robotics network.

REFERENCES

Formal documentation is expected by June 1991.

TITLE OF INVESTIGATION: Lunar Based Mockups

PROJECT MANAGER: Nathan Moore/SP/483-4308

TEAM MEMBERS: Nick Pausbeck, Chip Walters, Lindsay Gupton

INITIATION YEAR: FY90

FUNDING:

	FY90
In-house:	
Contractors:	50k (Johnson Engineering)
Grants:	
Total funds:	50k

OBJECTIVES:

The study described by this report was commissioned to develop concepts pertaining to the design of an initial lunar outpost. This habitat would serve as a point design for use in the verification of habitat parametrics and as the source design for fullsize mockup documentation. The three products produced by this study were (1) the design of an initial lunar habitat topology; (2) hypermedia documentation of the design, intended to run on Macintosh workstations; and (3) a full-size mockup of the habitat.

ACCOMPLISHMENTS IN FY90

This study provided one of many data points required for parametric analysis of habitats in Lunar and Mars mission initiatives. This reference design along with detailed subsystem information serves as a habitation systems database for use by program offices, mission planners, and line organizations in sizing habitats for mission architectures. The study also provides presentation mediums (full-size mockups and hypermedia) that allow understanding of the habitat by all viewers.

The study also identified new levels of technology which must be attained before missions can be successfully conducted. Examples of this are partial-gravity, human habitability, and performance parameters. Knowledge gained in these new technologies will be used in further iterations of design studies such as this one.

This design study, due to its indepth look at lunar base habitability, has been very effective in documenting current habitat configurations and in identifying areas of further study needed to fill knowledge gaps in habitability research. The hypermedia presentation produced by this study has received wide attention by most agencies currently performing lunar base habitation studies. The mockup, recently completed, provides the opportunity to experience the design in full scale. The initial lunar outpost construction module (figs. 32-35) is designed around the Space Station Freedom module pressure hull and is 4.2 by 12m in length. The interior is substantially different, both in principal and execution, in order to better accommodate the scope of its mission and the partial-gravity environment present on the lunar surface. The exterior contains structure both for module support/leveling, and for radiation shielding support. The radiation shielding material used is lunar soil.

The module is intended to accommodate up to six crewmembers for periods of 30 to 60 days. This single unit must provide for all aspects of living and working during this extended period, and the module is therefore subdivided into five distinct "activity zones": sleep station/crew quarters; wardroom/galley/exercise (living area); hygiene/waste management; stowage; and operations/workstations. These zones are intended to be distinct from each other both operationally and architecturally to give a sense of purpose to each as well as provide variety.

PLANNED FUTURE WORK

Planned events for FY91 include work on the mockup to improve the fidelity after elements of the design are revisited. A detailed report on this design is in the process of being written for submission to NASA for publication as a technical paper. Expected completion schedule depends on resources allocated to this project.

REFERENCES

1. Initial Lunar Habitat Design Control Specification. Prepared by Design Edge Inc. (for Johnson Engineering Corp.), June 19, 1990.

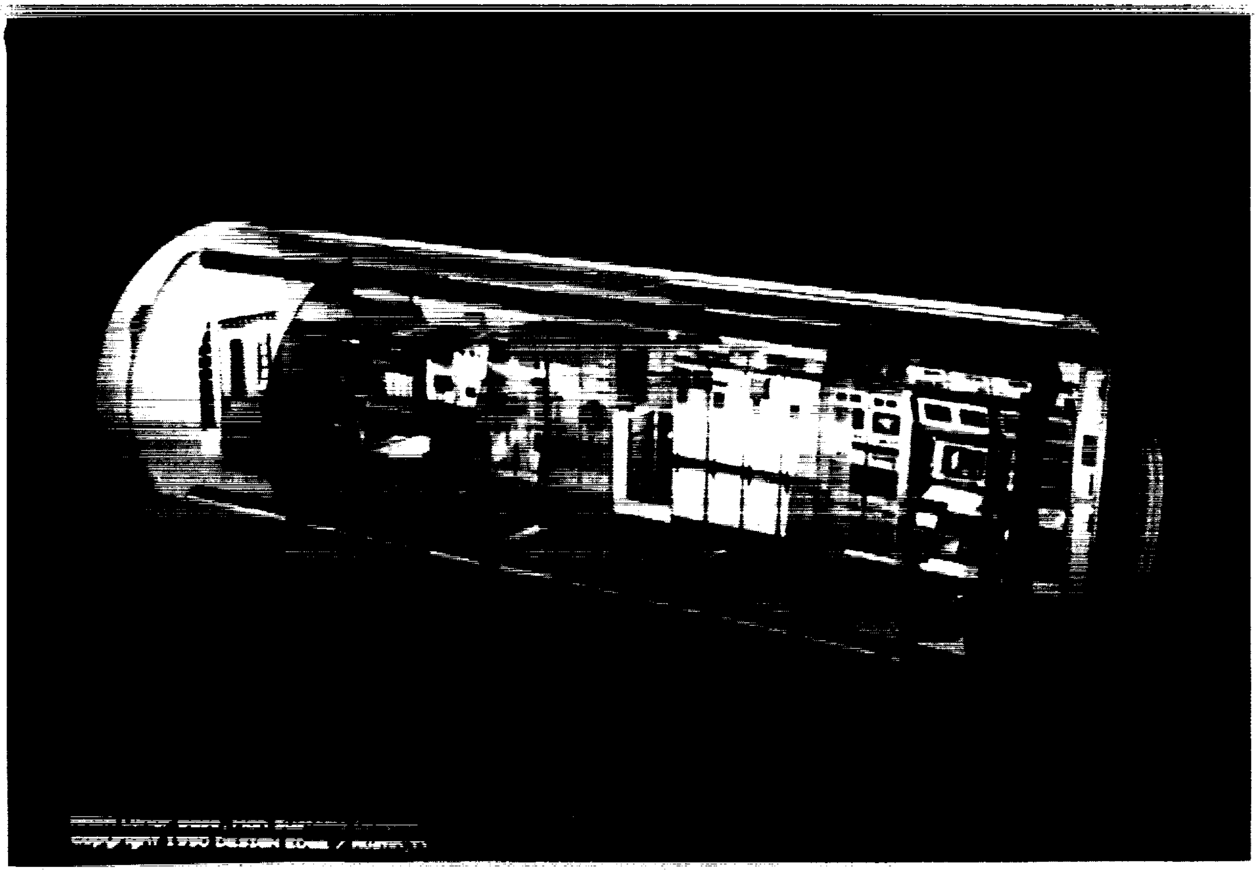


Figure 32. Interior view of telerobotic workstations.

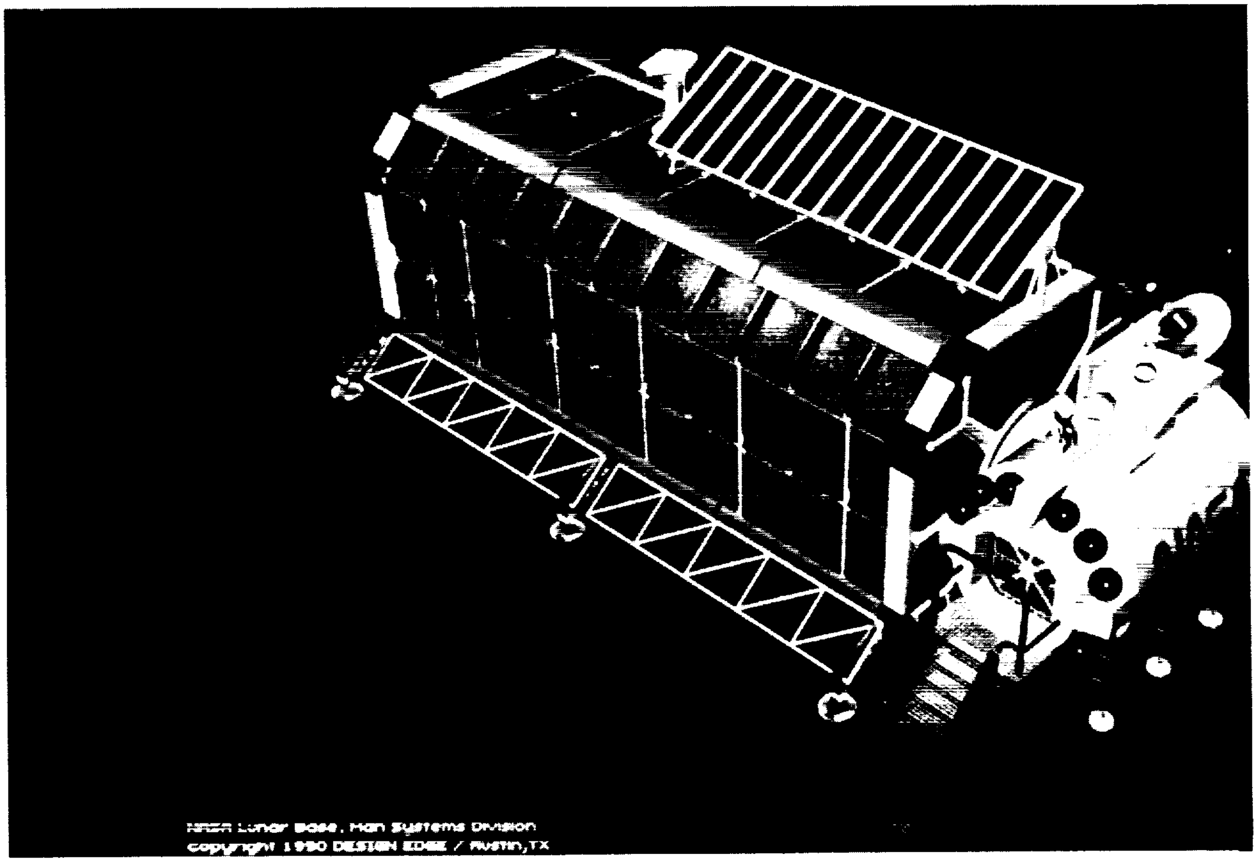


Figure 33. Exterior view showing airlock, radiation protection, and radiators.

ORIGINAL PAGE IS
OF POOR QUALITY

Figure 34. Interior view of topology.

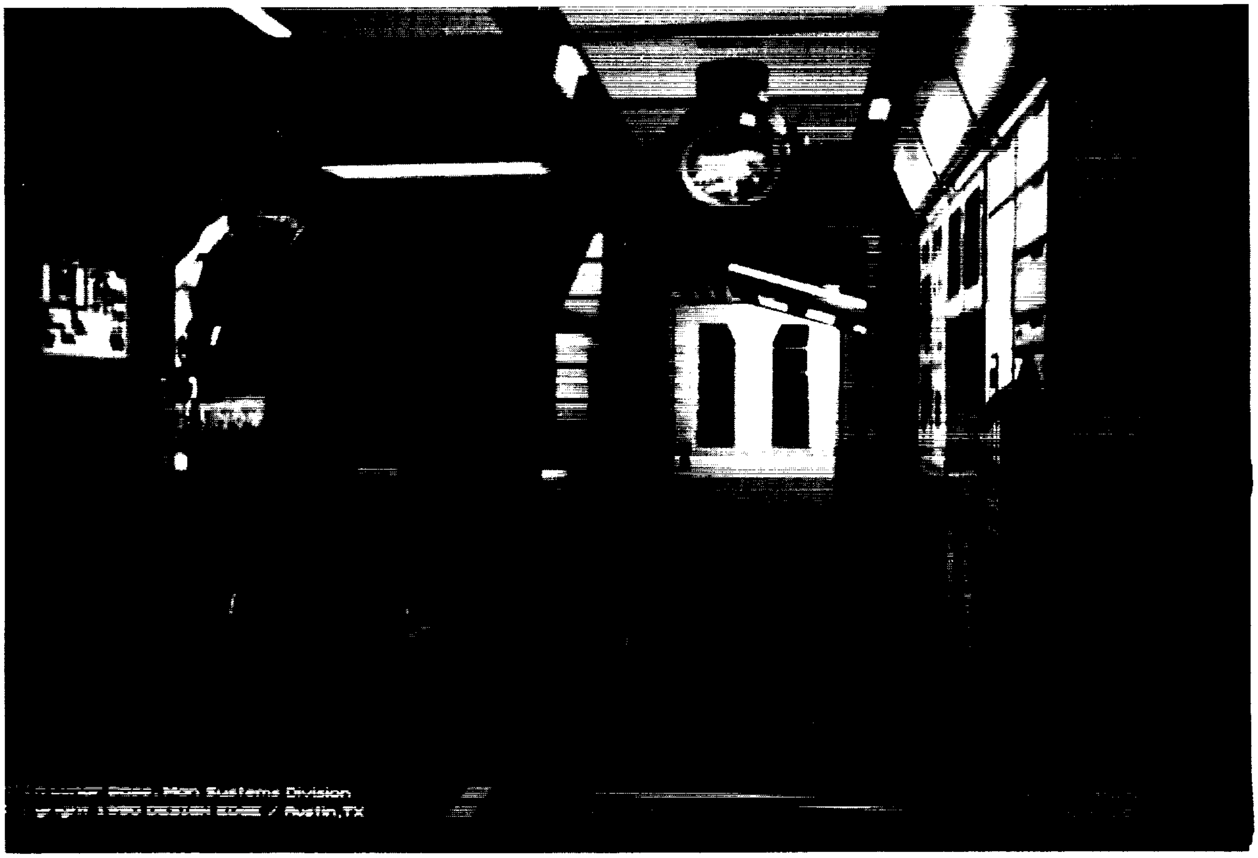


Figure 35. Interior view of wardroom galley area.

C.2

NASA
National Aeronautics and Space Administration

REPORT DOCUMENTATION PAGE

1. Report No. NASA TM 102177	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle JSC Director's Discretionary Fund Program		5. Report Date April 1991
		6. Performing Organization Code IA
7. Author(s) New Initiatives Office		8. Performing Organization Report No.
9. Performing Organization Name and Address New Initiatives Office NASA Lyndon B. Johnson Space Center Houston, Texas 77058		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The JSC Director's Discretionary Fund Program Annual Report provides a brief status of the projects undertaken during the 1990 fiscal year. For this year, three space exploration initiative related issues were focused on: regenerative life support, human spacecraft design, and lunar surface habitat. In this way, a viable program of life sciences, space sciences, and engineering research has been maintained. For additional information on any single project, the individual investigator should be contacted.

17. Key Words (Suggested by Author(s)) Space Exploration Initiative, regenerative life support, human spacecraft design, lunar surface habitat, artificial intelligence	18. Distribution Statement Unclassified - Unlimited Subject Category: 91

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	97	