NASA Technical Memorandum 104760

# JSC Director's Discretionary Fund 1992 Annual Report

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

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

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# Preface

Johnson Space Center's (JSC) capability to identify and initiate creative research supports an important aspect of the NASA's benefit to the nation. As an independent research medium, the Center Director's Discretionary Fund (CDDF) often initiates investigations of significant value to the agency, with eventual spinoff to commercial uses. The project selection criteria assures overall aid to the NASA mission, as well as providing development opportunities for JSC's science and engineering staff.

During FY92, the Office of the Inspector General conducted a routine audit of the CDDF. The audit did not identify any serious deficiencies. Their findings substantiated the belief that the CDDF is one of the most effective uses of resources in the NASA budget. The $1,694,000 funding for FY92 was distributed among 27 projects with participation across the Center directorates.

The following is a brief status report on selected projects that made outstanding progress and produced notable results.

- Several space-based medical research investigations reflect direct potential for Earth benefits. The use of stable isotopes of deuterium and oxygen to measure crew energy utilization was developed and demonstrated in bed-rest studies. Techniques for noninvasive administration of motion sickness medication showed promise. Partially hydrogenated, soybean oil microspheres assured bioavailability from the intranasal dose of promethazine.

- Research on the potential of recycling essentials for crew support on spaceflights was continued. The Regenerative Life Support Systems test bed, an integrated biological and physicochemical life support system, tested a unique, hydroponic, nutrient-delivery system by growing lettuce and wheat. The Hybrid Regenerative Water Recovery System demonstrated successful processing of waste water that was collected from shower, hand wash, laundry, and urinal sources. An 85 percent yield of potable water was achieved – demonstrating the efficiency and stability of the process.

- Investigation of two-phase fluid flow under simulated zero gravity and low-gravity conditions in KC-135 aircraft was continued. Excellent test results were obtained that will provide data and verified models to support design of two-phase systems. Preliminary results indicate the existence of a new flow regime for low-g conditions, presently named the stratified annular regime.

- Natural and man-made hypervelocity particles in low-Earth orbit constitute a substantial collision hazard to spacecraft. Hypervelocity particle tests on light-weight collisional bumpers in an open mesh pattern demonstrate a potential performance advantage over the conventional continuous-foil shields. A related investigation at White Sands Test Facility is evaluating the effects of hypervelocity particles on pressure vessels.

- The use of microcalorimetry for measuring the long-term compatibility of hydrazine with selected materials has shown a good correlation in the initial short-duration tests. Testing techniques have resulted in a patent disclosure.

- A patent application was also made on the design for a shape-memory-alloy release nut. Further, a NASA Tech Brief award was received for the concept, which will be less hazardous than conventional explosive-release devices.

- The Habitation Development Tool was demonstrated and put into use by JSC to provide realistic computer estimates of the requirements for crew accommodations for advanced missions and concepts. Spacecraft and surface habitat needs can be efficiently evaluated for different crew numbers and mission durations.

- Training is a major cost element in present and future NASA operations. Multi media, videography, music, image processing, artificial intelligence, computer graphics, databases, and data communication are being evaluated as supplements to current training techniques. Virtual environment technology may also provide alternatives to physical simulators. Laboratory evaluations are making excellent progress in this promising field.

- The Electronic Still Camera provides high resolution digital images for transmission to the ground. Through CDDF support, the time to record an image has been reduced to 3.7 seconds, with a goal of one second per image achievable.

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

William J. Huffstetler
Manager, New Initiatives Office

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# Figures

**TITLE OF INVESTIGATION:** Determination of Human Energy Utilization During Space Flight Using Doubly Labeled Water

**PROJECT MANAGERS:** Helen W. Lane, Ph. D./SD4/(713) 483-9147
Everett K. Gibson, Jr., Ph. D./SN/(713) 483-6224
Randall J. Gretebeck, Ph. D./SD4/(713) 483-9945

**PURPOSE OF INVESTIGATION:** Establish a self-supporting laboratory using water labeled with the stable isotopes deuterium and oxygen-18 to measure energy utilization in humans, and to develop this technology to measure the energy utilization of crew members during space flight.

**AUTHORIZED FUNDING FY92:** $60k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $20k | $40k | $0 | $40k | $40k |
| Contractor: | 30k | 10k | 60k | 10k | 10k |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 | 0 |
| **Total funds:** | **$50k** | **$50k** | **$60k** | **$50k** | **$50k** |

## OBJECTIVE AND APPROACH

Exposure to microgravity induces physiological and biochemical changes that may interfere with the health and normal functioning of humans in space. The availability of nutrients and the energy (caloric) requirements in microgravity may also differ from those on the ground. Traditional ground-based methods for determination of crew energy (calories) utilization have been difficult or impossible to perform in space. Therefore, the objective of this project is to establish a self-supporting laboratory using water labeled with the stable isotopes deuterium and oxygen-18 to measure energy utilization in humans, and to develop this technology to measure the energy utilization of crew members during space flight. The first objective was to build and test the analytical systems for purification of

hydrogen and oxygen from human physiological specimens. From this data, models will be developed for using doubly labeled water (DLW) in space.

## ACCOMPLISHMENTS

The hardware required to build the isotope purification system was obtained in FY90, and the system for oxygen analysis was completed and tested in FY90/91. Pilot studies were conducted to validate the precision and accuracy of the oxygen system by splitting samples and having our results compared with those of a well-established independent laboratory. Pilot studies to validate the precision and accuracy of the hydrogen purification system were completed in FY91 by using international water standards. The methodology employed in the oxygen analysis used a novel approach which is not well known in some scientific areas, so a preliminary methods study was reported at the International Conference on Geochronology, Geochemistry, and Isotopic Geochemistry in Canberra, Australia, in 1990. A manuscript based on this report has been published (ref. 1). Preliminary studies have also been conducted to measure the isotopic concentration of water used in the Orbiter. This water is produced as a by-product of the fuel cells and is used by the crew for drinking and food preparation. These studies have found that this water has a higher concentration of deuterium and oxygen-18 than the normal ground water used to fill the Orbiter potable water tanks prior to launch.

A ground-based, bed-rest study supported by the extended duration Orbiter (EDO) to measure energy utilization in adult men was completed in FY92 and preliminary results have been published in abstract form (ref. 2). A simulated Orbiter water study supported by Research and Technology Objectives and Plans Program funds to test the effects of drinking water with isotopic enrichments similar to those found on the Orbiter has been completed, and portions of this study have been presented at the 43rd Congress of the International Astronautical Federation. Another study utilizing the technology developed by this project to determine total body water by deuterium dilution was submitted to the Aerospace Medical Association for presentation at the 1993 annual meeting. A flight study supported by the EDO has been conducted on STS-45 and STS-47, which used DLW to measure energy utilization in crew members during spaceflight. Figure 1 shows the preflight, and

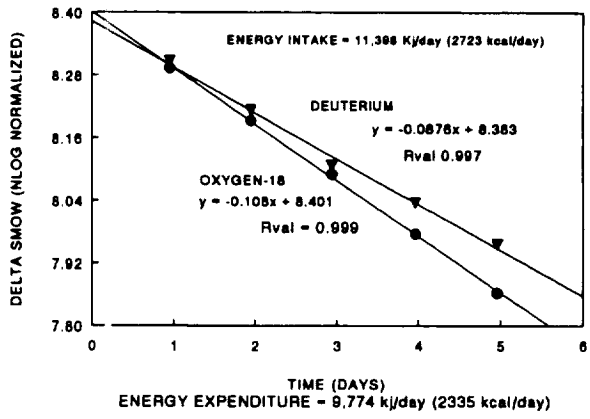



Figure 1.– Isotope elimination preflight - one subject (STS-45).

Figure 2, the inflight isotope elimination rates for one subject on STS-45.

In summary, we now have in place a "state-of-the-art" laboratory for using DLW to measure energy utilization. With this laboratory in place we have been able to obtain funding from EDO and RTOP to conduct ground-based as well as flight studies.

## PLANNED FUTURE WORK

Future efforts include developing models to determine optimum dosing, sample collection, and data analysis protocols for use during Shuttle flights, and determine the effects of recycled water on the accuracy of DLW for use on Space Station Freedom. Studies are in progress comparing the use of saliva versus urine samples on the accuracy of the DLW method to ease sample collection in space, and obtain data from female crew members. Modifications of the oxygen purification system are being planned to accommodate microliter sample sizes, which are necessary due to difficulties in collecting large amounts of physiological fluids during space flight. In addition, a methodology study for deuterium analysis will be conducted. The flight study which began with STS-45 and STS-47 has been manifested on STS-58 and STS-60, and will continue until 36 subjects have been tested.

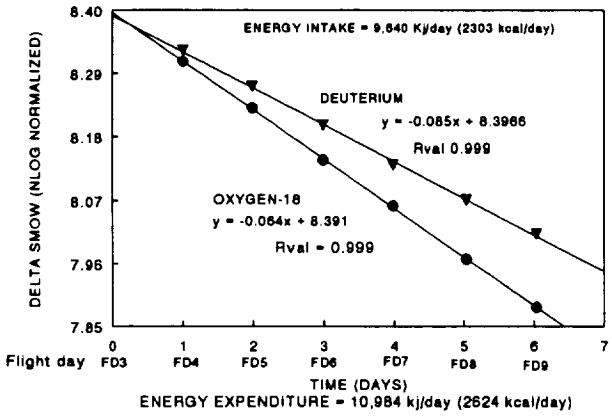



Figure 2.– Isotope elimination inflight - one subject (STS-45).

## REFERENCE DOCUMENTS


1. Socki, R.A.; Karlsson, H.R.; and Gibson, E.K. Jr.: Extraction technique for the determination of oxygen-18 in water using preevacuated glass vials. *Analytical Chemistry*, 64(7), 1992, pp. 829-831.

2. Gretebeck, R.J.; Davis-Street J.; Shoeller, D.; and Lane, H.W.: Energy regulation during ten days of simulated microgravity. FASEB J., vol. 6, 1992, A1117.

**TITLE OF INVESTIGATION:** **Search Coil System to Record Eye Movements For Studies of Eye, Head, and Hand Coordination**

**PROJECT MANAGER:** Jacob J. Bloomberg, Ph.D./SD5/(713) 483-0436

**IN-HOUSE TEAM MEMBER:** William P. Huebner, Ph.D.

**PURPOSE OF INVESTIGATION:** Determine how adaptive modification of visual-vestibular interaction affects eye, head, and hand coordination, enabling predictions to be made concerning crew responses in the space environment.

**AUTHORIZED FUNDING FY92:** $30k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | (Projected) | |
|---|---|---|---|---|
| | **FY91** | **FY92** | **FY93** | **FY 94** |
| In-house: | $50k | $30k | $15k | 0 |
| Contractors: | 50k | 0 | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 75k | 75k | 75k |
| **Total funds:** | **$100k** | **$105k** | **$90k** | **$75k** |

## OBJECTIVES AND APPROACH

The central nervous system integrates multisensory information to determine body spatial orientation relative to the environment. Exposure to microgravity during space flight induces alteration in this internal construct producing perceptual and sensory-motor disturbances during adaptation to zero g and readaptation to a one-g environment. With plans for extended duration missions (specifically, involving development of the proposed Space Station and future missions to Mars), these alterations in perceptual and sensory-motor constructs are of particular importance.

The ability to accurately coordinate eye, head, and hand movements is essential for safe Shuttle operation. Astronauts' vestibular responses are known to change both on achieving orbit and following return to Earth. Little is known, however,

about the role vestibular information plays in the coordination of eye, head, and hand movements. Therefore, the first objective of this study is to investigate the role vestibular information plays in the formulation of goal-directed eye and hand localization of targets.
The second objective of this study is to determine if adaptive alterations in eye-head coordination produce commensurate alterations in the ability to manually locate target positions; and conversely, if adaptive modification in eye-hand coordination transfers to the eye-head system. This investigation will help elucidate the basic mechanisms underlying the spatial programming of coordinated eye, head, and hand movements along with their adaptive properties.

Subjects are seated on a rotatable chair for presentation of whole-body, *passive* rotation. Following termination of a transient rotational displacement, in darkness, they are asked to point and generate eye movements toward the position of a previously seen, stationary, Earth-fixed target; the errors between the perceived and true target positions are recorded. These tests are repeated following exposure to stimuli which cause various combinations of visual, vestibular, and proprioceptive conflict. Post-adaptation test results will help determine the adaptive transfer characteristics between the eye-head and eye-hand systems based on observed errors in manual and ocular localization of the stationary target.

Developing a basic scientific understanding of the underlying mechanisms involved in the adaptation process will aid in the identification and testing of countermeasures that will reduce or eliminate the risk associated with these neural adaptive changes. A countermeasure which can readapt one system may actually help readapt all of these sensory-motor systems. Conversely, it may be that each system needs its own readaptation countermeasure.

**Measurement of Gaze, Head, and Arm Motion**

The angle of gaze (angular eye position with respect to space) and head rotation is obtained directly using a magnetic field/scleral search coil technique with a 6-$ft^3$ field coil system (CNC Engineering, Seattle, WA). This system basically works as follows. A rotating magnetic vector is established about the subject using *field coils* driven by an oscillator. The subject wears a contact lens (sylastic annulus) with a coil of very fine copper wire embedded in it. The alternating magnetic field induces a minute current within this *search coil*. The phase of the signal induced in the search coil is compared with the phase of the signal induced in a stationary *reference coil* using special phase-detector amplifiers. The resulting phase difference indicates the angle of the coil (and thus, the angle of the eye) in space. A similar coil may be attached to the head to measure angular head position.

A commercially available, active matrix, liquid-crystal-display computer projection system has been used to measure the ability to point toward targets following rotation. With this system real-time measurement of hand-pointing trajectories can be obtained using a small, hand-held laser.

## FY 92 ACCOMPLISHMENTS

- A unique, state-of-the-art, experimental setup designed to investigate eye, head, and hand coordination following vestibular input was established.
- A laser pointing system that derives and measures hand-pointing accuracy was developed and integrated into the program.
- The experimental program funded by the Research and Technology Objectives and Plans Program has been implemented; work continues.

## PLANNED FUTURE WORK

These experiments will provide the initial ground-based data required for a basic understanding of the possible interactions between various sensory-motor systems when one or more of these systems has been altered. In the future, we hope to perform similar experiments on upcoming Spacelab missions that will include SLS-4 (Neurolab) and the Shuttle-Mir Biomedical I Mission (SMB-1).

**TITLE OF INVESTIGATION:** **Impact Experiments into Multiple-Mesh Targets: Concept Development of a Light-Weight Collisional Shield**

**PROJECT MANAGER:** Friedrich Hörz, Ph. D./SN4/(713) 483-5042

**PURPOSE OF INVESTIGATION:** Develop light-weight collisional shields for protection of spacecraft.

**AUTHORIZED FUNDING FY92:** $45k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | FY91 | FY92 | (Projected) FY93 |
|---|---|---|---|
| In-house: | $0 | $0 | $0 |
| Contractor: | 35k | 45k | 50k |
| Grants: | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 |
| **Total funds:** | **$35k** | **$45k** | **$50k** |

## OBJECTIVE AND APPROACH

Natural and man-made hypervelocity particles in low-Earth orbit constitute a substantial collision hazard to spacecraft. Suitable protection can be provided by passive shields, mounted at some stand-off distance from the flight system, that intercept the projectile and cause it to fragment, melt and vaporize, decelerate, and disperse. Acceptable shields must decrease the specific energy particle (erg/cm$^2$) encountered by a flight system to some threshold value which can be tolerated by the system. Substantial efforts are under way to develop acceptable shields of minimum specific shield mass (g/cm$^2$) that will keep launch mass and associated costs low ( ref. 1).

The current feasibility study argues that shock physics does not demand a laterally contiguous shield, the traditional approach. Relatively transparent meshes should suffice, provided their mesh-opening (M) is smaller than the diameter of a prospective projectile ($D_p$), and as long as the mesh wires are thick (T)

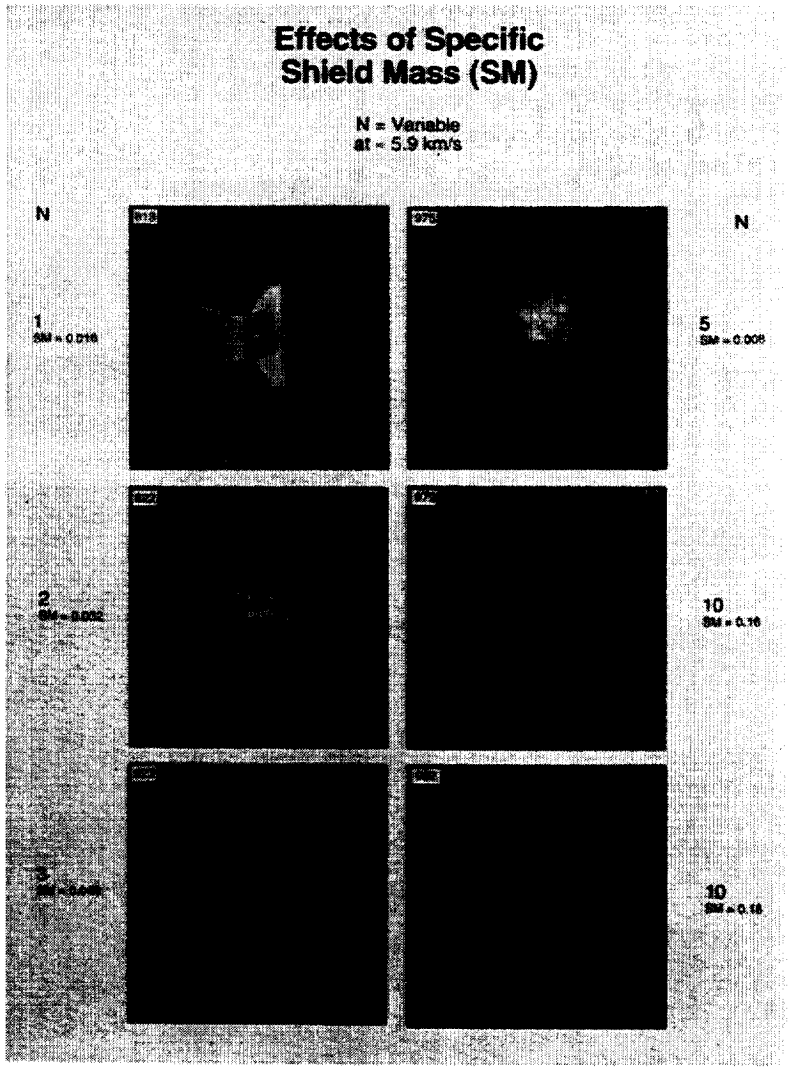
enough to disrupt the impactor. It was demonstrated via DDF funds in FY91 that T of single meshes (ref. 2) is equivalent to T of contiguous sheets (ref. 3) in controlling the degree of projectile fragmentation. The current effort explores the effects of multiple meshes and repetitive shock interactions as theorized in reference 4 and as experimentally demonstrated for contiguous shields by reference 5.

## FY92 ACCOMPLISHMENTS

The project utilized soda-lime glass projectiles of 3.175 mm diameter, at 1-6 km/s impact velocity, and target meshes constructed from aluminum that had wires 0.25-1.59 mm thick; mesh-openings were 3.175 and 1.59 mm, i.e., 0.5 and 1.0 $D_p$. Typical experiments employed 5 or 10 meshes and specific shield masses ranged from 0.08 to 1.71 g/cm$^2$. This compares to 0.467 g/cm$^2$ for the projectile and to 3 g/cm$^2$ for a single aluminum sheet at the ballistic limit (T=11 mm) at projectile speeds of 6 km/s. Thus, most tests employed light-weight shields indeed. A witness plate was placed behind each target to monitor the ensuing debris cloud and assess the damage suffered by a prospective flight system. The following variables were addressed: impact velocity(V); separation distance (S) of successive meshes; total, specific shield mass (SM), and mesh-size (M).

Figures 3 and 4 represent typical experimental products and results. Figure 3 shows the damage sustained by each of 10 successive meshes. Note that mesh 9 and 10 were not damaged at all. Figure 4 portrays the damage suffered by the witness plates as the number of meshes increases from 1 to 10. It is obvious that increasing numbers of meshes increasingly comminute the impactors to generate progressively less damage on the witness plate. Note that experiment 982 (fig. 3 ) uses meshes of M=0.5 $D_p$, while all other experiments in Figure 4 employ meshes of M=1.0 $D_p$ (at essentially constant shield mass; SM). The effects of mesh size (M) are thus to afford more physical interactions and increased comminution, coupled with increased deceleration of the debris based on the shallow nature of witness-plate craters. The effects of separation distance (S) are pronounced as well, because the incipient debris cloud is permitted to increasingly disperse with increasing S. This results in a significantly different deposition of kinetic energy into successive meshes and in a decreased specific energy (=ergs/cm$^2$) for that debris which reaches the witness plate. The specific SM does control comminution and deceleration of the debris cloud, yet massive mesh shields are as undesirable as massive contiguous plates because the mass displaced from the shield itself will frequently exceed projectile mass, thus adding to the orbital debris problem. The effects of velocity (V) are modest. The multiple meshes result in qualitatively similar witness-plate damage over the entire velocity range investigated, 1-6 km/s. This is a most desirable shield property because single sheet penetrations are highly velocity-dependent.

Figure 4.– Witness plates monitoring the debris that exits targets composed of N meshes and that possess a cumulative specific shield mass of MS; V=5.9 km/s for all experiments; width of individual frames: 30 cm.





3. Hörz F. et al.: (1992b) Dimensionally Scaled Penetration Experiments. Article submitted to the *International Journal of Impact Engineering*.

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5. Cour-Palais, B.G. and Crews, J.J.: A Multi-Shock Concept for Space Craft Shielding, *International Journal of Impact Engineering.*, vol. 10, 1990, pp. 135-146.

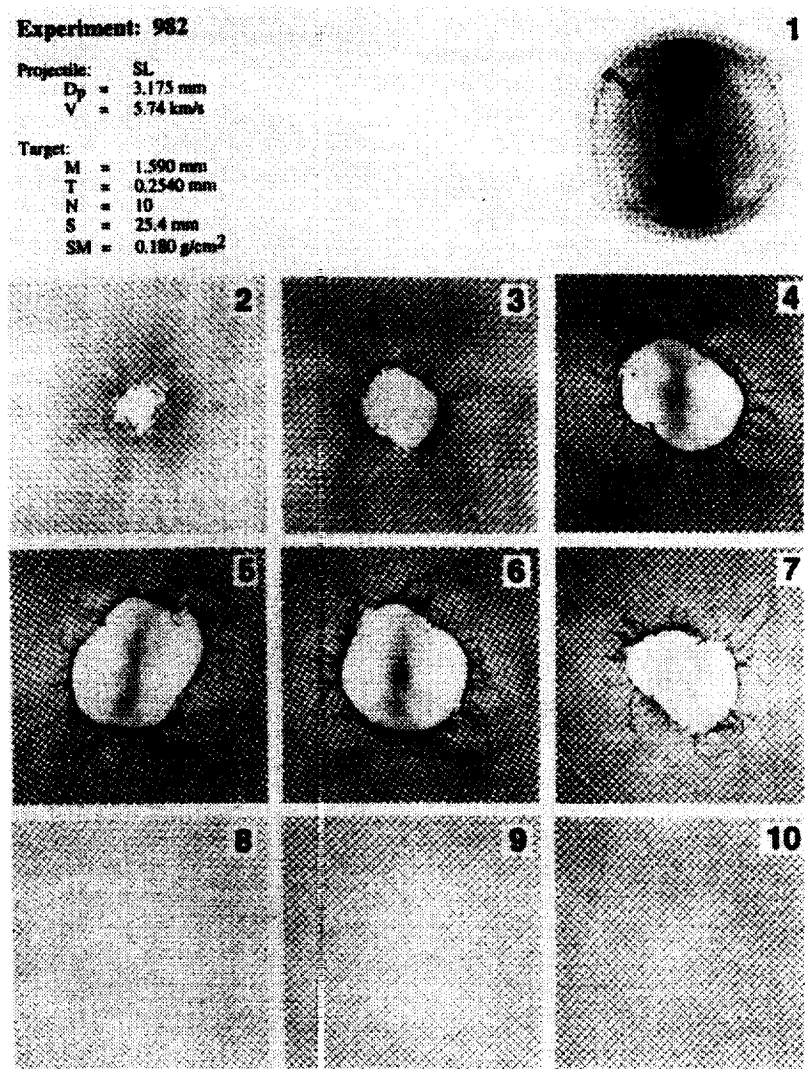



Figure 3.– Damage suffered by 10 successive meshes (1 through 10) impacted by a 3.17 mm diameter glass projectile at 5.7 km/s. Note, for internal scale, mesh opening M is 1.59 mm or 0.5 $D_p$.

## PLANNED FUTURE WORK

The present experimental conditions were designed to permit direct comparison with single-sheet penetrations that were sponsored from non-DDF sources (ref. 3). This limits direct comparison with other light-weight shield developments (e.g., ref. 1, ref. 5). Mesh experiments that constitute high-fidelity analogs to the light-weight shields of reference 5 are planned for FY93 to quantify such comparisons.

## REFERENCE DOCUMENTS


1. Christiansen, E.L.: Performance Equations for Advanced Orbital Debris Shields, AIAA 92-1462, 1992.

2. Hörz, F. et al.: (1992a) Comparisons of Continuous and Discontinuous Shields, NASA TM 104749, 1992.

**TITLE OF INVESTIGATION:** **B Cell Radiosensitivity and Protection by Cytokines**

**PROJECT MANAGER:** Peggy Whitson, Ph.D./SD4/(713) 483-7046

**IN-HOUSE TEAM MEMBER:** Clarence F. Sams, Ph.D./SD4/(713) 483-7160

**PURPOSE OF INVESTIGATION:** Determine if naturally produced hormones, termed cytokines, were capable of modifying the radiosensitivity of antibody-producing B cells.

**AUTHORIZED FUNDING FY92:** $25k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | FY90 | FY91 | FY92 |
|---|---|---|---|
| In-house: | $0 | $0k | $0k |
| Contractors: | 0 | 35k | 25k |
| Grants: | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 |
| **Total funds:** | **$0** | **$35k** | **$25k** |

## OBJECTIVE AND APPROACH

A number of naturally occurring hormones, termed cytokines, have been shown to be capable of protecting lymphocytes from ionizing radiation under both *in vivo* and *in vitro* conditions. This property is believed to be due to the ability of these agents to reduce the transition time from a radiosensitive quiescent ($G_0$) state to a less radiosensitive activated ($G_1$) state. Mature bone-marrow derived lymphocytes, or B cells, circulate throughout the vascular system in a quiescent state exhibiting a relatively high radiosensitivity to ionizing radiation. Because B cells are solely responsible for the production of antibodies, and, as such, are indispensable for human survival, their radiosensitivity (particularly during long-duration space flights) could lead to immune suppression which, in turn, could severely limit the mission goals or threaten crew members' lives. It was hypothesized that the well-characterized inhibitory effects of sublethal (low dose) radiation on B-cell activation by antigenic or mitogenic stimuli damaged

specific radiosensitive sites in the lymphocyte activation cascade. This inherent radiosensitivity of one or more activation events would then be responsible for precluding lymphocyte entry into the cell cycle and subsequent differentiation into antibody-producing cells. This project is now in the process of identifying the activation event(s) that are radiosensitive, and thus, most likely to be involved in the differential radiosensitivity between quiescent and activated B lymphocytes. It was further hypothesized that pretreatment of B lymphocytes with specific *permissive* cytokines abrogates or significantly reduces B cell radiosensitivity. To perform these studies, purified human peripheral B cells are gamma-irradiated at the University of Texas Medical Branch (UTMB) and analyzed at the Johnson Space Center using both tissue culture and molecular biology techniques and equipment.

## FY92 ACCOMPLISHMENTS

### B Lymphocyte Purification

Several B cell purification protocols were investigated for their abilities to eliminate T cells, monocytes, and NK cells from peripheral blood "buffy coats." When lymphocytes were eluted from a CD19-bead column, >99 percent of the unattached cells were CD $3^+$ (T cells). However, the attached cells were only 45 percent CD $20^+$ (B cells). In a second protocol, lymphocytes were incubated with monoclonal antibodies directed against T cells, monocytes, and NK cells. Following incubation, the final cell pellet contained no detectable monocytes, 10 percent T cells and 85 percent B cells. Therefore, this procedure was adopted for the studies described below.

### B Cell Activation by *S. aureus* Cowans I (SAC)

Formalin treated SAC can activate B cells via both protein kinase C and protein tyrosine kinase systems. Additionally, SAC activated cells are capable of proceeding through cell division and ultimately differentiating into antibody-producing cells. Prior to our radiosensitivity studies, we ran several experiments to determine the optimal concentration of SAC needed for B cell activation. The results of these studies indicated that a 1:3000 dilution of SAC stock solution resulted in a maximum increase in B cell metabolism.

### B Cell Radiosensitivity

Purified B cells were rested overnight in RPMI-1640 media containing 10 percent fetal calf serum, then removed from the incubator and subjected to either 0, 25 or 100 cGy of gamma irradiation ($^{137}Cs$ source; 79.7 cGy/min) then returned to the incubator for 2 hours. At this time appropriate samples were activated with SAC and returned to the incubator for an additional 70 hours. All samples were pulsed with bromodeoxyuridine (BrdU; 10 μM) for 2 hours and fixed in ice cold 70 percent ethanol. Following this procedure, the samples were permeabilized with Tween 20 and incubated for 30 minutes with a fluorescent conjugated antibody to BrdU, then washed and resuspended in propidium iodide. Then the samples were analyzed for fluorescence by flow cytometry using an EPICS

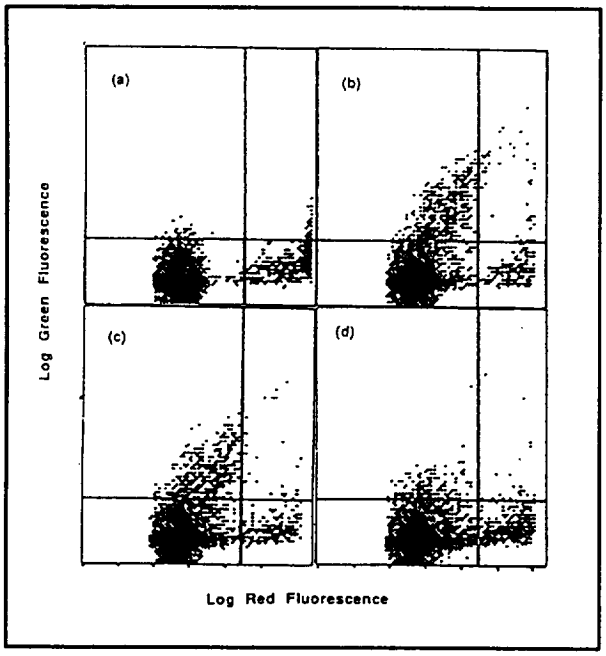



Figure 5.– Effect of low dose gamma irradiation on B cell activation.

V instrument. In figure 5, $G_0/G_1$ cells are identified in quadrant 3 (lower left); S phase cells are identified in quadrants 1 and 2 (top); and G2/M phase cells are in quadrant 4 (lower right).

Panel (a): Resting B cells were primarily in Go/G1 phase (90.5 percent) with few in S (1.2 percent) and G2/M (5.6 percent) phases.

Panel (b): Cells activated, but not irradiated, now show a significant increase in S phase (11.6 percent), similar G2/M (4.2 percent) and reduced $Go/G_1$ phase (84.1 percent).

Panel (c): Cells irradiated (25 cGy), then activated, exhibit a small reduction in activation; S phase is reduced to 9.8 percent, $G_o/G1$ is 85.2 percent, and G2/M is 5.0 percent.

Panel (d): Cells irradiated (100 cGy), then activated, exhibit a significant reduction in activation; S phase is down to 4.0 percent and more of the cells remain in $Go/G_1$ (87.4 percent).

These results suggest that low-dose gamma irradiation can significantly interfere with B cell activation events.

## PLANNED FUTURE WORK

A Research and Technology Objectives and Plans (RTOP) proposal was submitted to the Radiation Health RTOP. The proposal has not been reviewed due to a lack of new funding for this RTOP.

**TITLE OF INVESTIGATION:** **Loading, Electromyograph, and Motion During Exercise**

**PROJECT MANAGER:** Linda Taggart M. D./SD2/(713) 483-3610

**PURPOSE OF INVESTIGATION:** Describe muscle activation patterns, motion, and loads in relation to biomechanical segments of the musculosketetal system using exercise equipment designed for shuttle use.

**AUTHORIZED FUNDING FY92:** $57k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | (Projected) | |
|---|---|---|---|---|
| | FY91 | FY92 | FY93 | FY94 |
| In-house: | $0 | $8k | $0 | $0 |
| Contractors: | 0 | 49k | 40k | 0 |
| Grants: | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 11k | 0 | 0 |
| **Total funds:** | **$0** | **$68k** | **$40k** | **$0** |

## OBJECTIVE AND APPROACH

Astronauts experience decreased loads while living and working in space which results in decreased bone strain. The human skeleton responds to mechanical strain, a function of bone-loading conditions and bone strength, by remodeling in the lines of stress. Bone is deposited when strain increases and is reabsorbed when strain decreases. Bone strength is decreased exponentially when bone density decreases, as bone strength is proportional to density squared for trabecular bone. Remodeling may result in bone mass and architecture unsuited to a return to gravitational loading and place the astronaut at risk for stress fractures and traumatic fractures. Significant calcium loss from bone remodeling occurs in long-duration flights, with Skylab astronauts losing 4.5 percent and 7.9 percent from the Calcaneus during the 84-day mission.

Exercise countermeasures should be designed to simulate the loading pattern to which the astronauts' skeletons are modeled to decrease the resorption and be effective for skeletal

maintenance and calcium homeostasis. Measurement of the factors involved in mechanical loading of the skeleton can give an idea of the accuracy of the simulation and allow adjustment of exercise equipment and protocols prior to the development of long-term changes. This will speed the countermeasures development process, and decrease risk of acute and cumulative musculoskeletal injury to the astronauts. Muscle activity, body segment motion, and externally applied loads contribute to skeletal loading and remodeling. Description of these factors during exercise in one g creates a basis for comparison of the accuracy of exercise in reproducing these loading factors in weightlessness.

Loading factors of muscle activity, externally applied loads, and motion of the biomechanical segment can be measured with skin-mounted electromyograph (EMG) electrodes and accelerometers and with load cells and tensiometers on exercise equipment/body contact interface. Body kinematics can be determined through accelerometers and a video camera. Measurements can be made in the lab while the subject is exercising on the bicycle ergometer and on the treadmill.

The methodology to describe muscle activation patterns, motion, and loads in relation to biomechanical segments of the musculoskeletal system of volunteers, using exercise equipment designed for shuttle use, will be developed and proven. Descriptive analysis will be performed for EMG and external loads magnitudes, directions, and durations, and for concomitant body segment motion.

**Anticipated results**

The product will be an analysis of EMG activity, body part accelerations, externally applied loads, and relative body segment positions over time during exercise on shuttle equipment used on the ground. These same measurements can be performed during exercise in space using the developed methodology. The accuracy of exercise countermeasures in space in duplicating the musculoskeletal loading conditions of exercise in gravity can be determined and used to develop countermeasures that are effective for the maintenance of skeletal strength. In addition, data collected to assist in countermeasure development can be utilized for mathematical modeling of loads and expected bone remodeling. [The mathematical model assumes a steady state, requires the appropriate laboratory development of transfer functions for the EMG to load and for verification of methodology, and ignores time dependency until further basic research defines time function.

## FY92 ACCOMPLISHMENTS

- October 1991 - July 1992: Acquired hardware: Teac 28 channel

- August 1992: Tested EMG preamplifiers and utilized them to support exercise study

- September 1992: Received math processing software; interface software; and cables or computer. Requested computer memory upgrade and math coprocessor received tension and compression load

## PLANNED FUTURE WORK

- November 1992: Test equipment and software
- December 1992 - February 1993: Data acquisition
- December 1992 - May 1993: Data analysis
- June - August 1993: Write report and proposal to apply techniques to measurement in space and to compare them

**TITLE OF INVESTIGATION:** **Sustained Release Nasal Delivery System**

**PROJECT MANAGER:** Lakshmi Putcha, Ph.D./SD4/(713) 483-7760

**PURPOSE OF INVESTIGATION:** Develop a sustained-release-dosage delivery system for promethazine.

**AUTHORIZED FUNDING FY92:** $30k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | (Projected) | |
|---|---|---|---|
| | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $15k | $30k |
| Contractors: | 30k | 0 | 0 |
| Grants: | 0 | 30k | 15k |
| RTOP, Program or other: | 0 | 0 | 5k |
| **Total funds:** | **$30k** | **$45k** | **$50k** |

## OBJECTIVE AND APPROACH

The objective of the proposed project is to identify and develop a sustained-release-dosage form of promethazine that can be administered by a noninvasive route (intranasal) to crew members during spaceflight for the control of motion sickness symptoms.

Microencapsulation, coupled with controlled release technology, will be utilized to produce novel delivery systems. *In vitro* and *in vivo* experiments will be conducted to characterize the delivery kinetics and bioavailability, respectively.

Several polymeric systems [polymethylmethacrylate (Eudragit RL) and cellulosic based polymers] will be tested for their ability to provide sustained release of promethazine hydrochloride. Microspheres, 50-100$\mu$m in size, will be prepared by a rotating disc method. The micros-pheres contain 50 percent active drug by weight.

## ACCOMPLISHMENTS

Microsphere formulation of promethazine was successfully synthesized with six different microsphere carrier systems.

Release kinetics of these formulations were tested by *in vitro* drug release techniques (rotating basket method, USP XXII) and compared to neat drug dissolution in a pH 7.0 buffer at 37°C. The release kinetics resulting from combining neat drug with a potential carrier (monoglyceride cubic phase gel, which may be used to maintain the microspheres of the drug) was also tested. Finally, the ethylcellulose microsphere formulation was incorporated in a gel carrier (monoglyceride cubic phase gel) and tested for *in vitro* release characteristics. Results of these experiments are presented in Figure 6. The KLX (partially hydrogenated soybean oil) microspheres showed promising release characteristics at the 50 percent loading (fig. 6). This formulation was later modified to achieve complete release within 5 hours. This was required to assure maximal bioavailability from the intranasal dose, which has a limitation of short residence time.

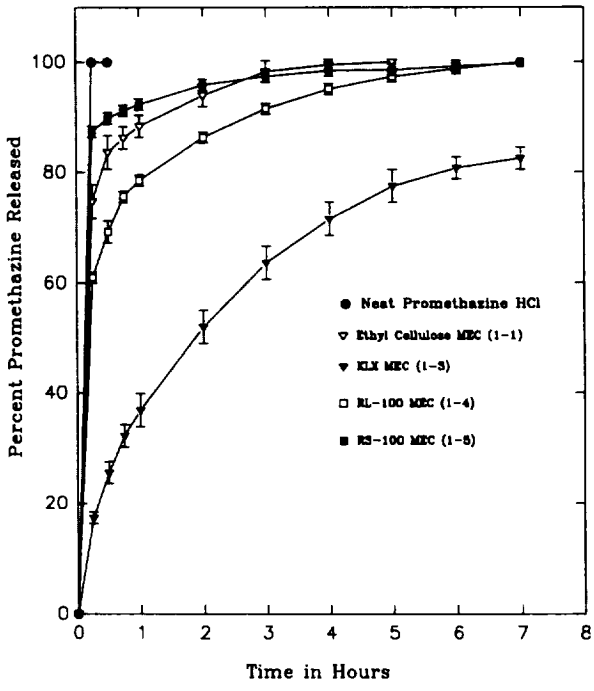



Figure 6.– Summary of the promethazine release profiles from microsphere formulations.

## PLANNED FUTURE WORK

Preliminary animal studies will be conducted in canines to determine the pharmacokinetics and bioavailability of the sustained-release formulation. Absolute bioavailability will be determined by comparing the intranasal dosage form to intravenous injection of promethazine hydrochloride.

A Research and Technology Objectives and Plans (RTOP) proposal will be prepared and submitted for funding to conduct clinical evaluation of the new formulation and for comparative efficacy studies.

## REFERENCE DOCUMENTS

1. Geary, R.S. and Lew, C.W.: Formulation development of a novel nasal delivery system for promethazine. Grant proposal, Southwest Research Institute, San Antonio, Texas, 1992.

2. Rakhnev, N.: "Development of tablets with prolonged action, containing promethazine hydrochloride. IV."Pharmacokinetic investigation of promethazine hydrochloride following oral administration in rabbits," *Probl. Farmacol. Farm.*, 1, 1987, pp. 18-26.

**TITLE OF INVESTIGATION:** **Electronic Still Camera Upgrades**

**PROJECT MANAGER:** Phyllis Grounds/SP43/(713) 483-7479

**IN-HOUSE TEAM MEMBER:** S. Douglas Holland

**PURPOSE OF INVESTIGATION:** Provide for improvements to the Electronic Still Camera (ESC) System, which will increase the camera's capabilities to record and transmit high resolution digital images to the ground from orbiting spacecraft.

**AUTHORIZED FUNDING FY92:** $60k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | FY90 | FY91 | FY92 | FY93 | FY94 |
| In-house: | $0 | $0 | $60k | $50k | $0 |
| Contractors: | 0 | 0 | 0 | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 | 0 |
| **Total funds:** | **$0** | **$0** | **$60k** | **$50k** | **$0** |

## OBJECTIVE AND APPROACH

The objective of this task is improving JSC's ESC to provide NASA with a high resolution digital camera system which can be utilized in lieu of film cameras on long-duration missions. The ESC has flown on four Shuttle missions as a Detailed Test Objective with great success, but has been limited to recording one image every 15 seconds. Also, the camera has only one fixed film speed (ASA or ISO equivalent). This limits the selection of exposures that can be used to photograph a given scene. The current task is to decrease the time to take and record an image to one second, and provide a minimum of three selectable ASA equivalents. This will be accomplished by incorporating an 80386SL microprocesser chip set to replace the obsolete 8088 processer currently being used, which will increase the system speed, incorporating a faster hard disk drive, reducing

the electromagnetic noise in the analog circuits, and boosting the gain on the read-out amplifiers selectively.

## FY92 ACCOMPLISHMENTS

The task got a late start in FY92, but much has been accomplished. The circuitry for the 80386SL has been designed and breadboarded. Testing of the breadboard with the camera is in progress. Testing of several new hard disks is also in progress. The record time has been reduced to 3.7 seconds per image without doing anything to optimize the system. A record time of one second per image should be easily achieved. Methods of reducing the electromagnetic noise in the analog circuits are currently being investigated. A good deal of work still remains to be done in this area.

## PLANNED FUTURE WORK

An effort to develop a laboratory prototype camera with a higher resolution imaging sensor is planned to be completed in FY93. This upgrade will incorporate a 2048 x 2048 charge-coupled device imaging sensor and the necessary circuit changes, along with the current upgrades, into a laboratory-prototype camera.

**TITLE OF INVESTIGATION:** **Two-Phase Flow Characterization for Fluid Components and Variable Gravity Conditions**

**PROJECT MANAGER:** Katy Miller/EC2/(713) 483-4546

**IN-HOUSE TEAM MEMBER:** John Dzenitis - Co-Project Manager

**PURPOSE OF INVESTIGATION:** Investigate gas-liquid flow regimes and pressure drops in tubing and components, and two-phase flows for variable gravity conditions applicable to the Space Station Freedom and Moon/Mars exploration.

**AUTHORIZED FUNDING FY92:** $55k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $5k | $50k | $0 | $0 |
| Contractors: | 0 | 0 | 0 | 0 | 0 |
| Grants: | 0 | 45k | 5k | 0 | 0 |
| RTOP, Program or other: | 0 | 120k | 108k | 0 | 0 |
| **Total funds:** | **$0** | **$170k** | **$163k** | **$0** | **$0** |

This program was planned as a 2-year effort. The program was terminated in FY92 when the test equipment was returned to the USAF Phillips Laboratory, at the completion of the 2-year loan period.

## OBJECTIVE AND APPROACH

This program was initiated in FY91 to investigate gas-liquid flow regimes and pressure drops in tubing and components and two-phase flows for variable gravity conditions.

The JSC Director's Discretionary Fund Program provided for the variable

gravity testing to support the development of thermal control systems for the Moon and Mars missions. In addition, both the Propulsion and Power Division and the Crew and Thermal Systems Division at (JSC) provided Space Station funding to investigate flow regimes and pressure drops expected in the Space Station Active Thermal Control System (ATCS) and Utility Distribution System.

The objectives of this program included

- A study of the two-phase flow phenomena in fluid components (e.g. smoothpipes, bellow lines, quick disconnect fittings) at zero-g conditions
- An expansion of the data base for two-phase flow for zero-g conditions
- Development of a data base for two-phase flow for low-g conditions (e.g. Moon-g, Mars-g)
- Validation of models for two-phase flow analysis
- Providing data and models to support the Space Station ATCS and future two-phase systems design

Zero-g and low-g data were gathered using the USAF Phillips Laboratory/ Foster-Miller experiment package, which was on loan to JSC for the duration of this program. Initially, test flights were conducted aboard the NASA KC-135 aircraft at Ellington Air Field to ensure that all instrumentation for the experiment package could operate adequately in the KC-135 test environment. Five test flight series were conducted and dedi-cated to collecting the two-phase flow data. Ground testing was conducted at Texas A&M University in conjunction with the flight series to provide a one-g data base. Since the final testing was completed in August 1992, extensive data reduction and analyses have been conducted.

## FY92 ACCOMPLISHMENTS

Flight series were conducted aboard the KC-135 aircraft in November and December 1991 and in January and July of 1992. Figure 7 shows the USAF Phillips Laboratory/Foster-Miller experiment package in its test configuration aboard the KC-135 aircraft. Ground testing was also conducted at Texas A&M University from March to August of 1992. Extensive data reduction and analysis have been ongoing throughout FY92.

A large flow-regime data base has been developed for smooth tubes in four gravity levels (i.e. zero-g, Moon-g, Mars-g, one-g). Preliminary results indicate the existence of a new flow regime for low-g conditions, presently named the stratified annular regime. This regime is similar to the annular regime seen in zero-g with the exception that the fluid film coating the tube is much thicker on the bottom due to the low-gravity effects.

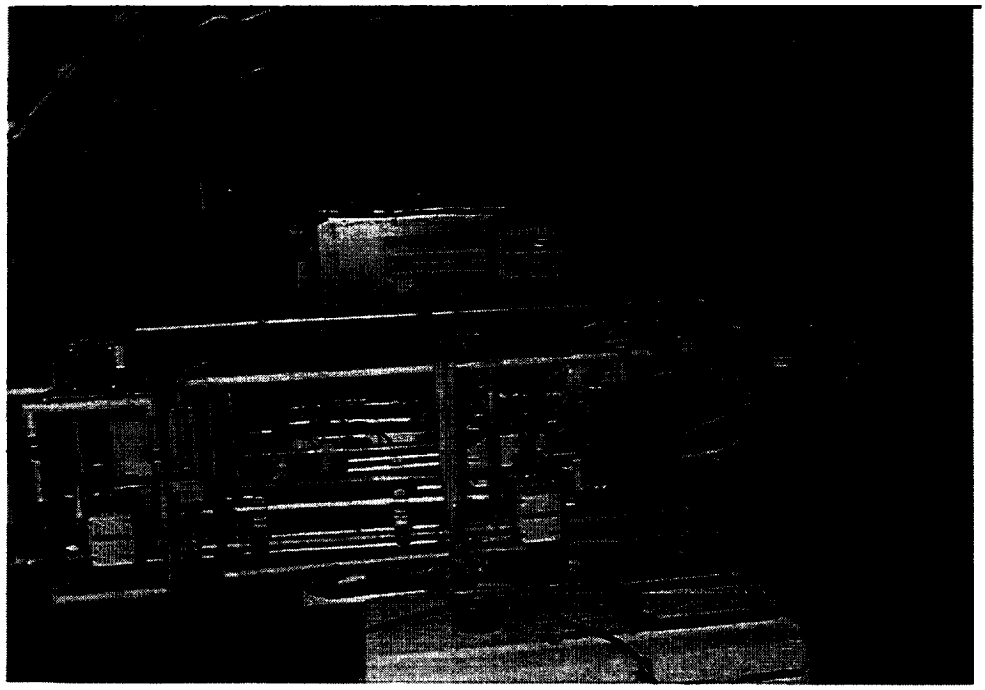


Figure 7.– USAF Phillips Laboratory/Foster-Miller Experiment Package aboard the KC-135 aircraft.

More limited pressure drop data was also obtained from the testing for the smooth tubes and component test sections for zero-g and low-g conditions. Analyses are continuing to finalize this data for the report.

Program results and applications to the Space Station and future programs will be documented in an internal JSC report, "JSC-32261 Two-Phase Flow Characterization for Fluid Components and Four Gravity Levels" scheduled to be published in early FY93.

## PLANNED FUTURE WORK

The JSC Crew and Thermal Systems Division plans to pursue a flight experiment related to two-phase flow research in support of future programs. In addition, future Research and Technology Objectives and Plans (RTOP) proposals may be initiated to develop two-phase thermal control systems for the Moon and Mars missions.

## REFERENCE DOCUMENTS

1. Best, Frederick, Miller, Kathryn M. and Reinarts, Thomas: Refrigerant 12 Zero-Gravity Flow Regime Data from KC-135 Flight Testing, Proceedings of the Fifth International Meeting on Nuclear Reactor Thermal Hydraulics, September 21-24, 1992.

2. Dzenitis, John M., and Miller, Kathryn M.: Two-Phase Flow Characterization for Fluid Components and Variable Gravity Conditions. Proceedings of the 9th Symposium on Space Nuclear Power Systems, January 12-16, 1992.

3. Georgevich, Vladimir; and Best, Frederick: Dynamic and Kinematic Waves Analyzed for Microgravity, Proceedings of the Fifth International Meeting on Nuclear Reactor Thermal Hydraulics, September 21-24, 1992.

**TITLE OF INVESTIGATION:** **Hybrid Regenerative Water Recovery System**

**PROJECT MANAGER:** Eugene H. Winkler, Branch Chief/EC3/(713) 483-9255

**IN-HOUSE TEAM MEMBERS:** Charles E. Verostko/EC3/(713) 483-9228
Marybeth Edeen/EC7/(713) 483-9122

**PURPOSE OF INVESTIGATION:** Demonstrate an integrated and regenerative biological and physicochemical system for the treatment of waste water to produce potable water for reuse.

**AUTHORIZED FUNDING FY92:** $50k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $0 | $75k | $0 |
| Contractors: | 0 | 50k | 50k | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 190k | 358k | 297k | 0 |
| **Total funds:** | **$0** | **$240k** | **$408k** | **$372k** | **$0** |

## OBJECTIVE AND APPROACH

The major objective of the Hybrid Regenerative Water Recovery System (HRWRS) is to demonstrate that waste water can be processed into potable quality water for reuse. The unique nature of this system resides in the integration of biological and physicochemical subsystems. The system collects and processes waste water from a four-person crew (approximately 120 liters per day). The waste water sources are the urinal, shower, hand wash, dish wash, and shower. Automated collection of the waste water and logging of production amounts is followed by transportation of the waste water to a central tank. Cooling of the waste water prohibits degradation of urea to ammonia and hence an elevated pH (undesirable

from the biological treatment viewpoint). The water is then sent to the first treatment subsystem – a 2-stage, aerobic, trickling-filter bioreactor. Here, total organic carbon levels of 400-600 mg/l (parts per million) are reduced by oxidation to less than 50 mg/l. Additionally, the nitrogen content of the waste water is converted from ammonia and organic nitrogen to nitrate. The second subsystem in the HRWRS is the reverse osmosis unit. Inorganic contaminants in the bioreactor effluent are reduced from approximately 2,000 mg/l to less than 50 mg/l. However, a concentrated brine (15 percent of the total influent volume) is produced which is currently not recovered. The reverse osmosis permeate is then treated by the third subsystem – a photocatalytic oxidation unit. Trace organic carbon is removed to less than 500 g/l (NASA's requirement for potable water use). Product water disinfection is also accomplished by this subsystem. Due to the batch nature of the current unit, only a fraction of the reverse osmosis permeate can be treated. A schematic of the system is shown in Figure 8.

## FY92 ACCOMPLISHMENTS

The treatment of waste water by the HRWRS was initiated in December 1991 with the inoculation of the bioreactors with effluent from a local waste water treatment plant. Since that time, over 56,000 ℓ of waste water have been treated. Bioreactor performance has been remarkable despite several off-nominal conditions. The reverse osmosis subsystem has operated for 170 hours at 5.7 ℓ/min permeate production. Limited success has

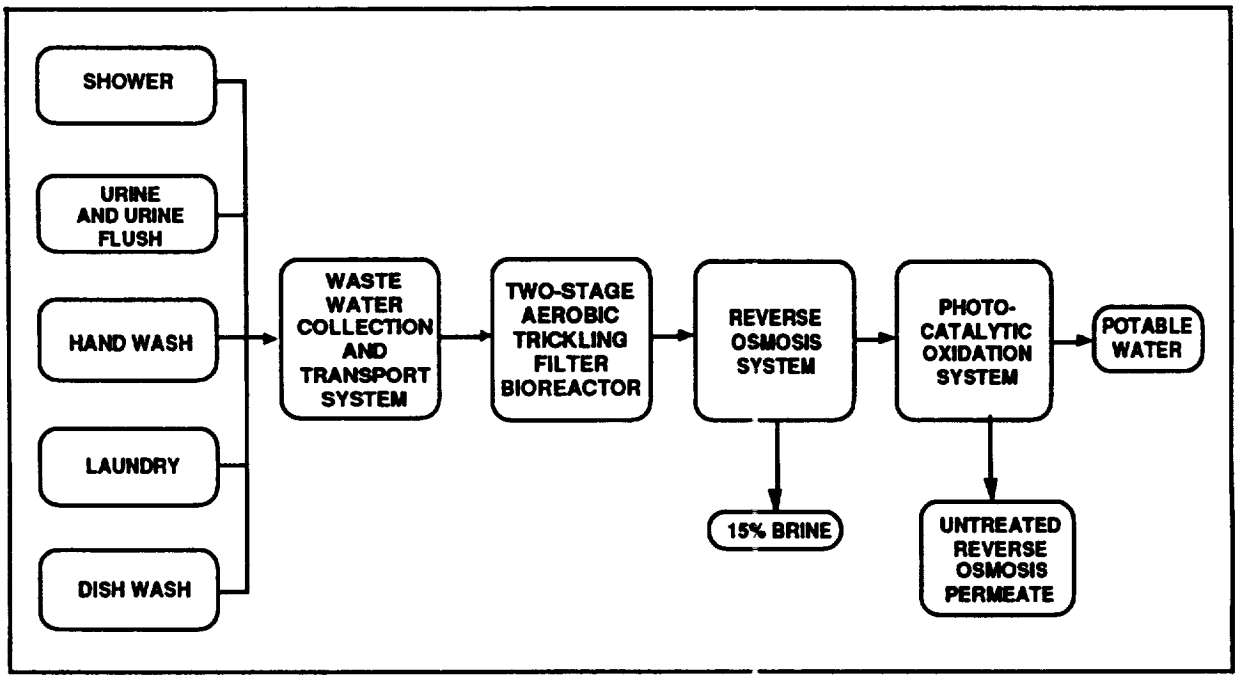



Figure 8.– Schematic of the HRWRS.

been achieved with the photocatalytic oxidation subsystem. However, water of potable quality has been produced. The automated waste water collection and transport system has functioned without fault for the entire duration of the test.

## PLANNED FUTURE WORK

Anticipated FY93 accomplishments will include continued testing of the HRWRS and parallel testing with an alternate design bioreactor (procured with other funding sources). Testing of several pretreatment and posttreatment technologies will be performed, including techniques for the recovery of reverse osmosis brine. Attempts will be made to initiate closure of the gas loop from the bioreactors. An immobilized enzyme reactor will be designed and fabricated in-house to be used for polishing of reverse osmosis permeate. Incorporation of solid waste (predominantly inedible plant biomass) treatment subsystems will be initiated. Evaluation of two, advanced, electrochemical-breadboard systems (a total-water recovery system and a post-treatment system) developed under Small Business Innovation Research (SBIR) Phase II contracts will be performed.

## REFERENCE DOCUMENTS

1. Verostko, C.E., Edeen, M.A. and Packham, N.J.C.: A Hybrid Regenerative Water Recovery System for Lunar/Mars Life Support Applications. Presented at the 22nd International Conference on Environmental Systems, Society of Automotive Engineers, Seattle, Washington, July, 1992.

**TITLE OF INVESTIGATION:** **Pershing Precision Planetary Landing Studies**

**PROJECT MANAGER:** Timothy E. Fisher/EE6/(713) 483-1456
Tracking Techniques Branch

**IN-HOUSE TEAM MEMBER:** EE6/Bill Culpepper

**PURPOSE OF INVESTIGATION:** Capture existing Department of Defense hardware and knowledge of precision terminal-guidance systems for application to precision landing on the Moon and Mars. Use this knowledge to improve the advanced planning of lunar and Mars programs.

**AUTHORIZED FUNDING FY92:** $50k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $0 | $50k | $50k |
| Contractors: | 0 | 0 | 50k | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 10k | 40k | 40k | 40k |
| **Total funds:** | **$0** | **$10k** | **$90k** | **$90k** | **$90k** |

## OBJECTIVE AND APPROACH

The objective of the task is the evaluation of Pershing missile terminal-guidance hardware to lunar and planetary missions. Available Pershing II flight hardware will be acquired for JSC laboratories through a contract with the original hardware manufacturer for installation, training, and technical support. In-house studies using the flight hardware and actual flight video recordings will estimate performance on *natural* terrains. This work will be extended to estimate performance on lunar and martian terrains.

## FY92 ACCOMPLISHMENTS

Loral Defense Systems, Akron, Ohio, maker of the Pershing II terminal-guidance system, was placed under contract. This contract provided for the delivery

and installation of the hardware in JSC laboratories, training on its theory and use as well as providing technical support to our evaluation at JSC. Due to delays in getting a contract in place, not all phases of the contract were completed in FY92. The Pershing hardware was delivered and installed in JSC's laboratories and training was given on how to run simulated missions with the Integrated Evaluation System. The Reference Scene Generation Facility could not be installed due to a missing critical component which is being replaced. The remaining tasks should be completed in early FY93 using the FY92 funding.

## PLANNED FUTURE WORK

The activities initiated in FY92 will be completed in FY93. At this point, NASA will be able to estimate the performance of the radar area guidance (RADAG) system using actual radar data and correlator hardware. These estimates will be based on the White Sands Missile Range, the most lunar/martian-like terrain for which we have actual data. These tests will be conducted with in-house civil service personnel.

Future work will entail an additional contract with Loral Defense Systems to take advantage of their unique expertise in building radar return predictions from various types of terrain data (optical, Synthetic Aperture Radar (SAR), etc.) and the ensuing RADAG correlator performance estimates. Loral will be provided with the best knowledge available of the lunar and martian surfaces and will predict the radar returns from those surfaces. From these predictions, actual correlator performance, and hence total guidance performance, can be predicted.

An additional task for Loral will be to develop a software simulation capability for this system. It will simulate the current state of the hardware (correlator and reference scene generation algorithms) as well as the enhanced work that Loral has already undertaken under separate studies. This simulation capability would be modular to allow different a) correlation algorithms and parameters, b) surface data inputs, and c) surface sensor models (radar, SAR, ladar, etc.) This modular construct will allow NASA to further expand the system to study alternate sensors and correlation techniques. The result will be a simulation capability that will allow NASA to design a terminal-guidance sensor appropriate for our often changing requirements.

The existing Pershing RADAG system provides altitude and ground-relative positions only. With the capabilities developed on this program, NASA should have enough in-house expertise and tools to develop not only a terminal-guidance navigation sensor, but also include a ground-track velocity and a hazard-avoidance sensor system all in a single, efficient package with a single sensor (e.g. without additional hardware). This work can be conducted in-house until appropriate Research and Technology Objectives and Plans funding can be obtained.

**TITLE OF INVESTIGATION:** **Shape Memory Alloy Actuators and Release Techniques**

**PROJECT MANAGER:** Darin N. McKinnis/EP52/(713) 483-9052

**PURPOSE OF INVESTIGATION:** Evaluate and test promising actuators and devices based on Shape Memory Alloys.

**AUTHORIZED FUNDING FY92:** $36k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $36k | $0 | $0 |
| Contractors: | 0 | 0 | 0 | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 | 0 |
| **Total funds:** | **$0** | **$0** | **$36k** | **$0** | **$0** |

**OBJECTIVE AND APPROACH**

Shape Memory Alloy (SMA) devices are finding applications in the computer, robotics, automotive, aerospace, construction, and medical industries replacing or supporting mechanical, electromechanical, and pyrotechnic devices. SMAs are not usually considered in subsystem trade studies due to their cross-discipline applications and recent growth in viable devices. Efforts are being focused on devices which can be most readily applied to current or near-term programs and vehicles. Promising actuators and release mechanisms will be taken into environment testing of appropriate programs, e.g. Shuttle/Inertial Upper Stage (IUS), Assured Crew Return Vehicle, and Common Lunar Lander. Knowledge and data gained will allow SMA actuators and devices to be considered in future subsystem trade studies as a viable and understood alternative. Recent aerospace applications of SMAs indicate that they are a viable alternative to other actuator types.

- The U.S.S.R. used SMA fasteners to make an addition to Mir in 1991.

- An SMA release device was baselined by TRW for the Total Ozone Mapping Spectrometer with qualification underway.

- The Naval Research Laboratory is funding development of several SMA actuators for Navy satellites. Test flights will start in 1993.

This investigation started with three SMA actuators for evaluation and testing: a release bolt, a rotary actuator, and a JSC-designed release nut. Midway through the year another device was added to the study, a linear SMA release system, the Nitinol Fuzing Element Separation System (NFESS). Under contract, Boeing Defense and Space Group completed fabrication and initial testing of the NFESS. Larger potential cost benefits and greater demonstrated maturity of the NFESS indicated that it should receive priority in evaluation and testing. Because of its late entry into the study, existing fabrication and testing capabilities of Boeing were utilized to accelerate the design and test schedule beyond in-house capabilities. Requirements and deliverables were determined to stay within the study budget and 1-year schedule. A full description of the NFESS design and testing can be found in reference 1.

Nitinol Fuzing Element Separation System requirements were to

- Design an SMA fuzing element that could support a 5000 lb tensile load and release on command at high speed. This load was selected to scale with requirements for the Shuttle/IUS release system, Super*Zip.

- Design a sequentially operated, electrical control circuit to fuze the SMA element.

- Fabricate the SMA fuzing element, the test fixture, and control circuit.

- Install and perform tests of assembled mechanism, recording maximum loading, time to release, and power required for release.

The results and conclusions of testing

- Showed that 3200 lbs caused premature shearing of the mounting holes. The decision was made to perform the release test with the system loaded to a maximum of 2000 lbs.

- Showed that a successful release of a 2000 lb load was recorded in a total release time of 838 milliseconds. The power required for release of each subset of elements was 6 kW (6v at 1000 amps), supplied by a 12v marine battery.

All objectives of the experiment were achieved. Future work will achieve the original requirement of a 5000 lb load with better selection of SMA material and greater provision for mounting-structure stress. No additional power or release time will be required by the change. The research team feels that the experiment verified the SMA fuzing element technology, and has potential in large-load restraint and release applications.

## FY92 ACCOMPLISHMENTS

- Completed design study and submitted patent application for SMA release nut
- Procured materials for SMA release nut
- Conducted initial testing of Frangibolt, an SMA release bolt
- Designed, fabricated, and tested the Nitinol Fuzing Element Separation System
- Initiated initial design concepts for SMA Laser Firing Controller
- Received NASA Tech Briefs Award for SMA release nut

## PLANNED FUTURE WORK

- No follow-on funding is requested from the JSC Director's Discretionary Fund
- Extend initial testing of devices tested to date: Frangibolt and the Nitinol Fuzing Element Separation System
- Conduct initial testing of the SMA rotary actuator
- Fabricate and test the JSC-designed SMA Segmented Release Nut
- Support laser initiation of pyrotechnic devices. Development and testing in FY93 and FY94 of the Shape Memory Metal Precision Actuator (SMMPA), a laser pointing and aligning device developed by Boeing. Designed for accurately pointing or aligning telescopes and optical sensors, the SMMPA would be used for firing control of a laser-firing system for pyrotechnic devices. Acting as a laser distributor and Safe and Arm, the device would permit use of a single-laser firing unit to initiate all the pyrotechnic functions on a spacecraft.
- Evaluation and testing of SMA actuators and release techniques will continue to stay abreast of industry developments and defense research activities, and to meet in-house actuator requirements. Lockheed, Boeing, GE-Astro, Raychem, TiNi Alloy, Swenson Technologies, Hi-shear, Memry Metals, and others are developing SMA devices and techniques. Collaboration with the Naval Research Laboratory will prevent duplication of effort.

## REFERENCE DOCUMENTS

1. Julien, G.J.; Nitinol Fuzing Element Separation System (Research Experiment Test Report) 9-5541-MR92-134 Reference: Purchase Order T-4137S, Boeing Defense and Space Group, Seattle, Washington.

**TITLE OF INVESTIGATION:** **Performance Analysis via Taguchi Methods**

**PROJECT MANAGER:** Ivan Johnson, ETS/(713) 483-8097

**IN-HOUSE TEAM MEMBERS:** Ivan Johnson and Mike Tigges

**PURPOSE OF INVESTIGATION:** Reduce the number of simulations required in vehicle design.

**AUTHORIZED FUNDING FY92:** $45k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | (Projected) | |
|---|---|---|---|
| | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $0 |
| Contractors: | 0 | 0 | 0 |
| Grants: | 45k | 0 | 0 |
| RTOP, Program or other: | 0 | 60k | 0 |
| **Total funds:** | **$45k** | **$60k** | **$0** |

## OBJECTIVE AND APPROACH

Using the NASA LifeSat vehicle design as an example, the goals of this task were to demonstrate that using the Robust Design Technique (Taguchi's Method), the set of design parameters could be found which maximizes the quality of vehicle design, uses fewer numbers of simulations, and achieves a level of confidence rivaling that obtained by using the Monte Carlo Analysis Technique.

## FY92 ACCOMPLISHMENTS

The University of Houston was issued a University Research Grant to investigate ways of achieving our task objectives with a team A and team B approach. Team A concentrated on experimental design using Taguchi's Method orthogonal arrays (OAs) and other areas in Robust Design. Team B concentrated on taking an analytical approach, approximating outliers for the target's footprint

dispersions, and a method of efficiently measuring reliability. The results of team A showed that for OAs:

- Conclusions derived from the experiments were valid over the entire experimental region spanned by the control factors and their settings.
- There is a large savings of experimental effort and therefore a reduction of computational time for simulations.
- Data analysis can be done easily.
- Orthogonal arrays and their experiments are designed deterministically and not randomly.

A Monte Carlo simulation with 1000 samples and a simulation based on OAs with 27 samples were used to obtain two footprints of the landing range.

Statistical parameters (mean and standard deviation) of the landing range were compared for both methods, and differences were found to be small.

The method of Analysis of Variance (ANOVA) was applied to evaluate the contribution of noise factors on the performance of the LifeSat vehicle, based on the results of the simulation prescribed by the OAs. The performance was determined by the landing position and the performance parameters.

In conclusion, team A proved that the use of OAs for simulation is a valuable and time-saving method which provides accurate results comparable to the Monte Carlo simulation. The performance of a design can be evaluated within a short period of time and can be improved by using design models. The analysis of results can be done easily with ANOVA. Further work, however, is recommended to develop the proposed method into one that can be routinely used by NASA with confidence.

Based on a simplified LifeSat model, a FORTRAN program was developed by team B for the equations of motion in the spherical coordinate system.

The dependence of the LifeSat footprint on atmospheric density at sea level, on vehicle drag coefficient, and on wind speed was plotted and observed to be nearly linear. It was calculated that in the dispersion ranges of interest, the errors caused by linear approximation were less than 8 percent.

Using such a linear approximation, the footprint function in terms of three parameters was determined by six simulations. The landing reliability was calculated for selected normal dispersions of the parameters and various peak G-loads.

It was noted that for each G-load associated with a given set of nominal values of the parameter, six simulations were needed to determine the footprint function. However, no additional simulations were required to compute the reliabilities for different dispersions of the parameters under the given nominal values.

Both teams presented their results in a division-wide presentation, delivered prototypical software, and delivered final reports.

## PLANNED FUTURE WORK

- Apply to more highly nonlinear systems.
- Use higher level of OAs.
- Implement several tools together for a total design.
- Study additional cases to validate method.
- Completion date would be September 30, 1993.

## REFERENCE DOCUMENTS


1. Mistree, F.; Lautenschlager, O.; and Erikstad, S.: "Simulation Reduction Using Taguchi Method." DDF Final Report, 1992.

2. Rao, J. R. J.; and Chen, Y. C.: "An Analytic Model for Footprint Dispersions and its Application to Mission Design." DDF Final Report, 1992.

**TITLE OF INVESTIGATION:** **Artemis Strategic Defense Initiative Engine Feasibility Demonstration**

**PROJECT MANAGER:** Joe Riccio/EP4/(713) 483-0405

**IN-HOUSE TEAM MEMBER:** Landon Moore/EP4

**PURPOSE OF INVESTIGATION:** Determine the feasibility of using high thrust-to-weight ratio, advanced materials engines developed under Strategic Defense Initiative (SDI) programs for applications such as the Artemis main propulsion system.

**AUTHORIZED FUNDING FY92:** $100k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $0 | $0 | $0 |
| Contractors: | 0 | 0 | 100k | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 120k | 0 | TBD |
| **Total funds:** | **$0** | **$0** | **$220k** | **$0** | **TBD** |

## OBJECTIVE AND APPROACH

The Artemis project has defined weight reduction of subsystems as a high-priority task. In recent years, high thrust-to-weight ratio, advanced materials engines have been developed and tested under many SDI programs which can offer significant weight savings and packaging advantages to a program such as Artemis. The life required of these engines in the SDI missions is approximately 10 to 12 seconds, whereas for an Artemis-type mission the life requirement is approximately 800 to 1000 seconds. Some of the SDI engines have been tested to approximately 250 seconds with excellent results. However, none of these engines have been tested to durations approaching that of the Artemis mission. The objective of this effort is to assess the ultimate life capability of these engines to determine their applicability to the Artemis mission. The approach to meet this objective is to first, purchase an SDI 100 lbf engine, and second, test it at the JSC to determine its

ultimate life capability. Next, channel this experience base and test data into an Artemis Advanced Development Engine which demonstrates all the capabilities required for the Artemis mission. Finally, move into the qualification and flight engine program.

## FY92 ACCOMPLISHMENTS

FY92 Center Director's Discretionary Funds were received in May 1992. The procurement cycle was then started to purchase a 100 lbf SDI engine from Rocketdyne on a sole-source basis. The contract was negotiated and the authority to proceed given in September. In addition, preliminary planning for the required test facility modifications and upgrades occurred in FY92.

## PLANNED FUTURE WORK

The Rocketdyne SDI engine is scheduled to be delivered February 1, 1993. Life testing should take place immediately thereafter, concluding in February. The test data and final report are planned to be published in early April. Based on knowledge gained through this test program, the procurement cycle for the Advanced Development Artemis Engine could begin in late FY93.

**TITLE OF INVESTIGATION:** **Common Lunar Lander (Artemis) Mockup**

**PROJECT MANAGER:** William Schnieder, Ph.D./ES6, (713)483-8939.

**IN-HOUSE TEAM MEMBERS:** Jimmy D. Bradley/ES63 (713) 483-8812,
Ted W. Tsai/ES64 (713) 483-8953,
Timothy E. Pelischek/ES22 (713) 483-8843

**PURPOSE OF INVESTIGATION:** Fabrication of a full-scale mockup of the Common Lunar Lander, including the installation and mounting of the representative subsystem models. System development test for landing gear energy attenuation. Concept evaluation and development test for off-loading a lunar-rover-type vehicle to the lunar surface.

**AUTHORIZED FUNDING FY92:** $50k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | (Projected) | |
|---|---|---|---|---|
| | **FY91** | **FY92** | **FY93** | **FY94** |
| In-House: | $0 | $50k | $0 | $0 |
| Contractors: | 0 | 0 | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 |
| **Total funds:** | **$0** | **$50k** | **$0** | **$0** |

## OBJECTIVE AND APPROACH

Recognizing that a full-scale mockup was valuable in supporting the phase A study of the Artemis Common Lunar Lander design, a decision was made to proceed with the design and fabrication of a full-scale, high-fidelity mockup to use as an engineering tool for subsystem location and installation, and structural concept evaluation. The model's design would resemble the intended flight vehicle configuration, but would use available in-house materials and manufacturing techniques.

## ACCOMPLISHMENTS

Approximately 75 drawings were produced and provided to the JSC Technical Services Division for fabrication of parts and final assembly. Figure 9 is a Computer-Assisted-Design isometric of the mockup.

A list of components used to assemble the completed structure include:

- Round, tubular struts (100 primary, 105 secondary - 205 total)
- I-beams (4 upper, 4 lower - 8 total)
- Node joints (33 primary, 72 secondary - 105 total)
- End fittings for struts (200 primary, 210 secondary - 410 total)
- Avionics attach panels (2 outer, 2 inner - 4 total)
- Attach brackets for engines (4 primary, 6 RCS - 10 total)
- Attach brackets for external avionics (antennas, radar, etc)
- Adapter attach ring

The assembled mockup is pictured in figures 10 and 11. In-house testing

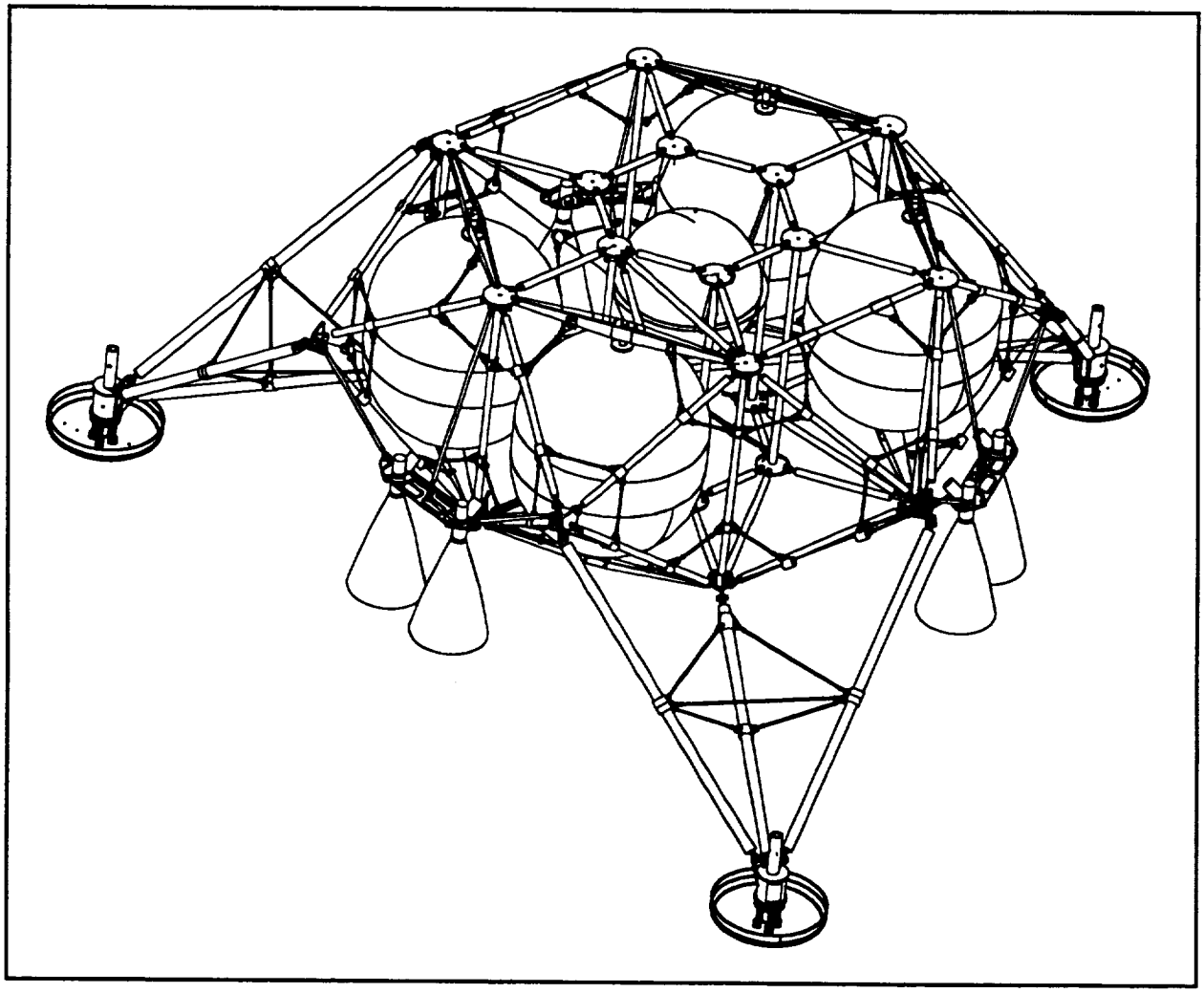
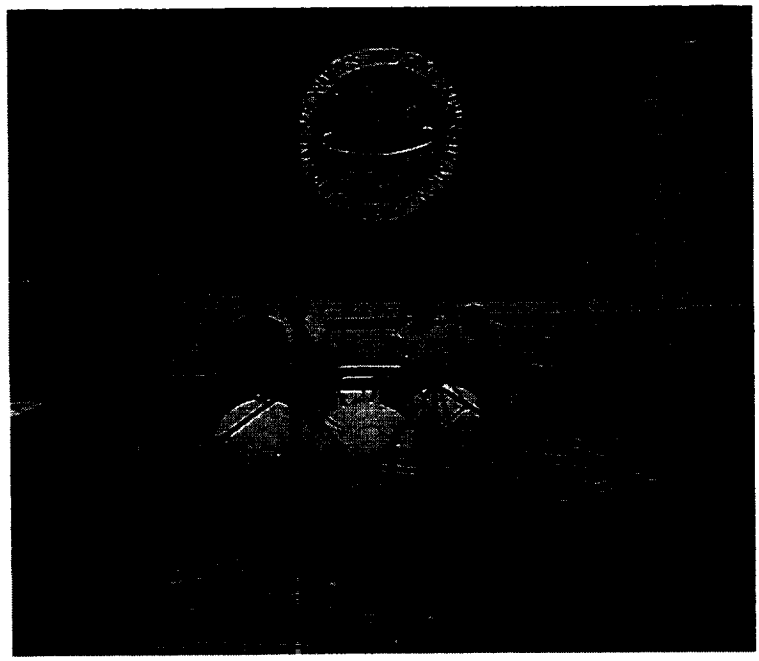


Figure 9.– Isometric view of the Artemis Vehicle without payload.

Figure 10.– Overall view of the Artemis Mockup.



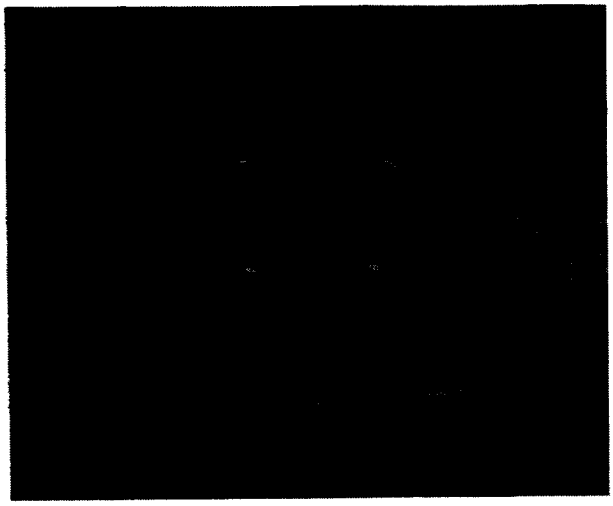


Figure 11.– Closeup view of construction details of the Artemis Mockup.

characterizes the performance of the load-limiting landing pad concept proposed for the Common Lunar Lander. The results will refine the engineering needed to proceed with this landing leg design in the next project phase.

Rover off-loading ramps have been investigated. One concept has been fabricated for in-house testing. This will be used for display with the mockup, as well as technical evaluation of the concept of inflatable ramps.

## PLANNED FUTURE WORK

Future activity is dependent on decisions for continuation of the Artemis Program. The mockup will be a key element in implementation of a vehicle for continuing exploration of the Moon.

**TITLE OF INVESTIGATION:** **Adaptive Neural Net Controller for a 7-Degree-of-Freedom Robot Arm.**

**PROJECT MANAGER:** Timothy F. Cleghorn, Ph.D. /PT41/(713) 483-8090

**PURPOSE OF INVESTIGATION:** Develop an adaptive Neural Net Controller for a 7-Degree-of-Freedom (DOF) Robot Arm.

**AUTHORIZED FUNDING FY92:** $60k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | FY90 | FY91 | FY92 |
|---|---|---|---|
| In-house: | $0 | $15k | $0 |
| Contractors: | 50k | 0 | 0 |
| Grants: | 0 | 45k | 60k |
| RTOP, Program or other: | 0 | 0 | 40k |
| **Total funds:** | **$50k** | **$60k** | **$100k** |

## OBJECTIVE AND APPROACH

The objective of this project is to develop for NASA the technologies needed to perform autonomous space robotics. The approach was to develop a simulation of an adaptive robot arm controller to run on the Silicon Graphics computer. This controller is a neural net, which uses simulated stereo vision for input. The initial task in FY90 developed the graphics model of the Robotics Research Corporation's 7-DOF arm and the neural net which allowed the end effector to learn to capture a stationary sphere in the robot's workspace. The FY91 task was to expand this neural net to allow the robot to grasp the center of a stationary cylinder as well as the sphere. The FY92 task was to expand the network further to allow the system to track and capture moving targets, including the cylinder and sphere. Additional plans called for the inclusion of tactile, force and torque sensing, which would permit obstacle avoidance. In addition, it was planned to port the entire software simulation to a hardware robot arm.

## FY92 ACCOMPLISHMENTS

Deliveries of all code, including source code, together with a short video of the

simulation, and the final report have been received. Evaluation of the code will be provided in the future.

## PLANNED FUTURE WORK

No activity planned at this time.

## REFERENCES


1. Michael Kuperstein, Ph. D., Developing an Adaptive Neural Net Controller for a 7-DOF Robot Arm: Final Task Report, FY90, FY91, FY92.

2. Kuperstein, M.; and Rubenstein, J.: Implementation of an Adaptive Neural Controller for Sensory-Motor Coordination. *IEEE Control Systems Magazine*, Volume 9: Number 3, April 1989, pp. 25-30.

**TITLE OF INVESTIGATION:** **Multimedia Applications**

**PROJECT MANAGER:** Lui Wang
PT/Software Technology Branch
(713) 483-8080

**PURPOSE OF INVESTIGATION:** Explore the potential of multimedia and define system configuration requirements for potential application to simulators and trainers.

**AUTHORIZED FUNDING FY92:** $66k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $0 | $50k | $50k |
| Contractors: | 0 | 0 | 66k | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 | 0 |
| **Total funds:** | **$0** | **$0** | **$66k** | **$50k** | **$50k** |

## OBJECTIVE AND APPROACH

Multimedia embraces many technologies and disciplines including videography, music, signal, and image processing, artificial intelligence, computer graphics, data bases, and data communication. It is the fastest growing segment in the computer industry today. With the incorporation of animation, audio, video, and interactive navigational links, digital multimedia technology is changing the way computers are applied (figure 12).

For instance, computers are emerging as successful supplements to formal classroom instruction and as viable alternatives to expensive hands-on simulators and trainers. In education and aerospace training environments, it has also become necessary to maximize resources. Whether these resources are in the form of instructors, materials, or time, all must be prudently allocated in a cost-effective manner. Computerized instruction utilizing existing tools and developing technologies is being substantiated with a

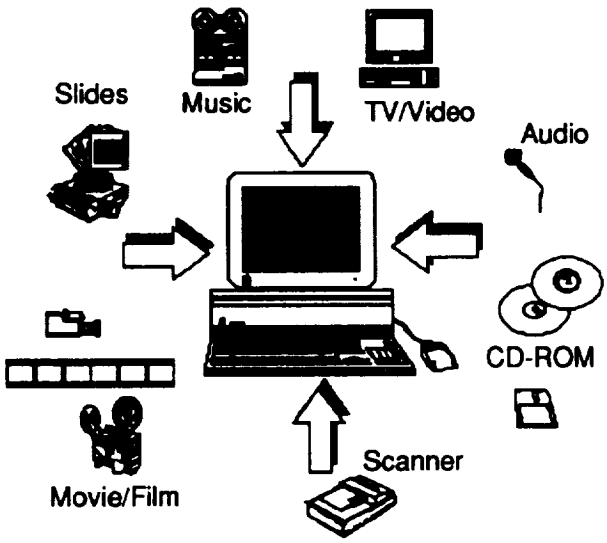



Figure 12.– A multimedia computing environment.

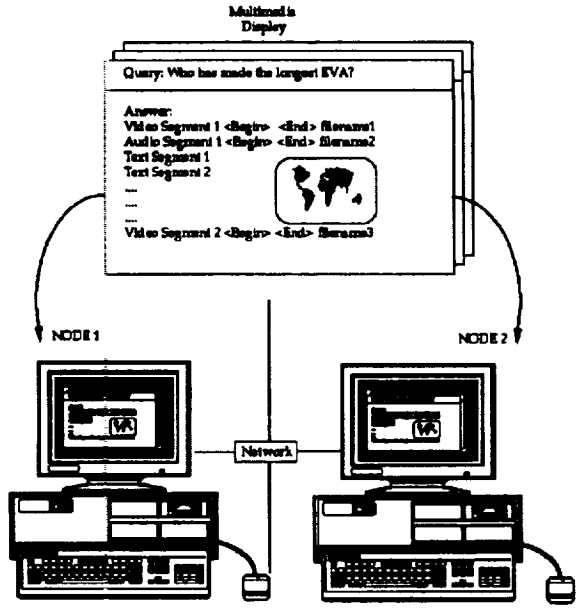



Figure 13.– A conceptual drawing of the networked multimedia scrapbook.

growing list of applications and increasing return on investment. Such applications can better stimulate human senses and help the transfer of information better than traditional, computer-based systems.

Using the knowledge gained from FY92 activities, multimedia technologies were incorporated in the Software Technology Branch's existing applications. They included Hyperman, the intelligent, electronic-documentation system, and several Intelligent Computer-Aided Training systems. The state-of-the-art, commercially available, multimedia components were evaluated for the PC, UNIX, and MAC environments. The FY93 activities will be focused in the area of networked multimedia for information retrieval and display. A networked multimedia scrapbook (figure 13) with audio and video indexing, annotation, and remote display capabilities will be developed on UNIX-based workstations.

## FY92 ACCOMPLISHMENTS

- Center Director's Discretionary Funds were used to procure the following equipment

  - One Macintosh Quadra 900 with a digital video compression board, a color scanner, and CD-ROM

  - One UNIX-based Parallax digital video subsystem with compression and decompression capabilities for the SUN Sparc station

  - One PC-based Super Video Windows digital video subsystem with compression and decompression capabilities for the PC

- Multimedia software development tools, PC X-Window server, and networking software

- One SONY Laserdisk player and an audio/video computer control interface

- Delivered the Automated Information Center to the Information Systems Directorate Product Center

- Explored cross-platform animation and digital video capabilities between Macintosh, PC, and UNIX environments

- Provided technical consultations to NASA and other governmental organizations (e.g. JSC's Public Affairs Office, Space Station Training, and Safety Reliability and Quality Assurance)

- Developed interactive multimedia presentations

**PLANNED FUTURE WORK**

- Procure Silicon Graphics Indigo UNIX Workstations

- Develop intelligent multimedia retrieval software on a distributed Transfer Communication Protocol/ Internet Protocol network as shown in figure 13.

- Continue studies of cross-platform development issues

- Develop a test bed to support the evaluation of the procured hardware

- Conduct a comprehensive evaluation and document the results

**TITLE OF INVESTIGATION:** **Virtual Environments for Training**

**PROJECT MANAGERS:** Robert T. Savely/PA/(713) 483-8105
Frank E. Hughes/DT/(713) 283-5623

**IN-HOUSE TEAM MEMBERS:** Beth Holewinski/DT/(713) 283-8131
Lui Wang/PT4/(713) 483-8080

**PURPOSE OF INVESTIGATION:** Explore the potential of virtual environment technology for use in NASA astronaut training tasks.

**AUTHORIZED FUNDING FY92:** $61k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $74k | $61k | $50k | $0 |
| Contractors: | 0 | 0 | 0 | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 | 0 |
| **Total funds:** | **$0** | **$74k** | **$61k** | **$50k** | **$0** |

**OBJECTIVE AND APPROACH**

Training is a major cost element for existing and future NASA operations. Virtual environment technology may provide alternatives to physical simulators (especially for part-task training) and avoid their high construction and maintenance costs. The integration of the JSC's Intelligent Computer-Aided Training (ICAT) technology with virtual environment technology will permit ICAT systems to address a larger variety of training tasks with the potential for unprecedented real-ism for the visual, auditory, and tactile senses. In addition to the integration of ICAT technology with virtual environment technology, this project will compare a virtual environment approach to Space Station cupola training with projection dome and pancake window

approaches. Ultimately, the project team intends to produce an ICAT application for a suitable Space Shuttle or Space Station training task. Finally, this project will explore the long-distance networking of virtual environment systems for data visualization and engineering design applications.

As an ancillary to the project, technology requirements to drive virtual environment research and development will be determined.

This investigation is a joint project between the Space Station Training Office (DT) and the Software Technology Branch (PT4).

## FY92 ACCOMPLISHMENTS

- JSC Director's Discretionary Funds were used to procure a VPL Research, Inc., High Resolution EyePhone System and a stand-alone DataGlove System.
- Hardware was delivered to the Software Technology Laboratory October 9, 1992.
- Implementation of an enhanced Space Station cupola environment (originally developed in FY91) is underway (figure 14).
- A graphical model of the Hubble Space Telescope (HST) has been integrated with a library of digitized photographs of the HST to investigate the use of virtual environments for training in on-orbit maintenance and repair missions.
- A payload interaction environment has been created to study the efficacy of virtual environments for training in support of missions similar to STS-49 (figure 15).
- Design and assembly of a Virtual Environment Development Suite has been initiated. This suite of software tools will provide for rapid development and low-cost maintenance of virtual environments.
- The Shared Virtual Environments Project (with the Marshall Space Flight Center and U.S. Army Human Engineering Lab) continues to explore the issues related to sharing, through networks, virtual environments over long distances.
- An educational spinoff – a Virtual Physics Laboratory – has been created to demonstrate the potential of the technology for educational applications.

## PLANNED FUTURE WORK

- Procure tactile and force feedback systems for evaluation (11/1/92 - 2/1/93).
- Develop a test bed to support the evaluation of the procured hardware (11/1/92 - 12/31/92).
- Conduct a comprehensive evaluation and prepare a report detailing the results (1/1/93 - 6/1/93).
- Integrate selected systems with existing virtual environments (e.g.,

Figure 14.– Space Station cupola model.

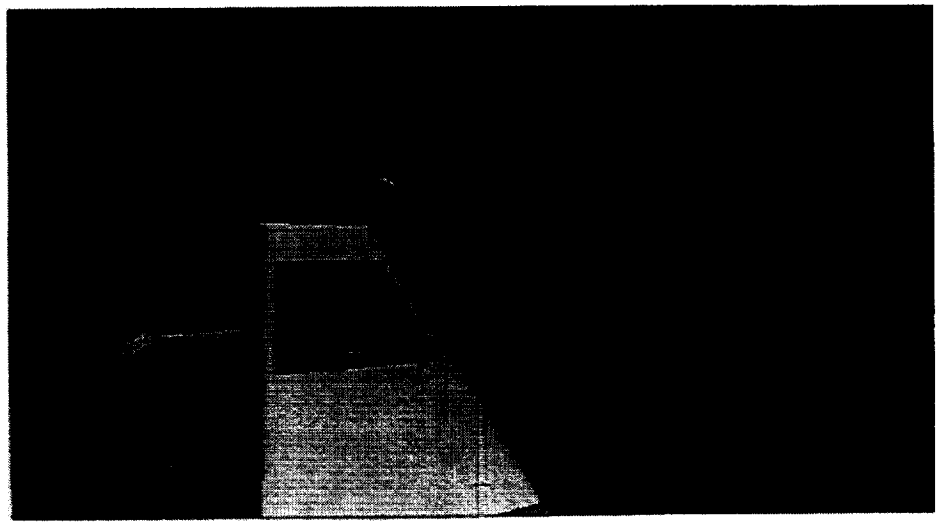
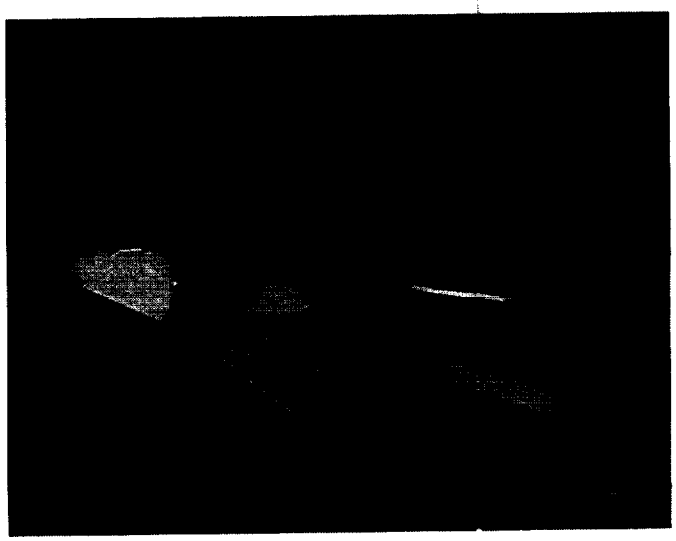


Figure 15.– Space Shuttle and IntelliSat.



Payload Interaction, Space Station Freedom, and HST. This will serve to demonstrate and test the effectiveness of adding this additional *dimension* to a virtual environment for training (3/1/93 - 9/30/93).

- Identify technology needs to enhance the ability of virtual environment technology to support future training requirements (ongoing).

**TITLE OF INVESTIGATION:** **Onboard Training Hardware Evaluation**

**PROJECT MANAGER:** Ven C. Feng/DT22/(713) 283-5897

**IN-HOUSE TEAM MEMBER:** Sean M. Kelly/DT33/(713) 283-5603

**PURPOSE OF INVESTIGATION:** Evaluate hardware and software for use as an onboard training platform on extended-duration orbiter flights for Space Station Freedom and future missions.

**AUTHORIZED FUNDING FY92:** $50k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | FY90 | FY91 | FY92 | FY93 | (Projected) FY94 |
|---|---|---|---|---|---|
| In-house: | $0 | $0 | $50k | $0 | $0 |
| Contractor: | 0 | 0 | 0 | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 | 100k |
| **Total funds:** | **$0** | **$0** | **$50k** | **$0** | **$100k** |

## OBJECTIVE AND APPROACH

An onboard training platform could provide crewmembers with on-orbit proficiency training to ensure crew safety and mission success. Specifically, an onboard trainer should refresh crew members in cognitive and psychomotor skills and knowledge, allow instructors to obtain and evaluate data to verify training effectiveness and improve future training. Implementation of the project has applications of lessons learned to lunar/Mars missions.

Two factors which negatively influence on-orbit task performance are the length of time between training and execution of tasks, and differences between one-g and μ-g training. Reports on the magnitude of performance decrement have thus far been largely subjective. Since the Skylab missions, the longest U.S. space mission has been 16 days. Therefore, additional empirical data is required to substantiate the need for onboard training. Gathering this information while utilizing existing hardware and software allows a cost-effective means to obtain that data.

The Onboard Training Project has procured a Silicon Graphics Indigo workstation to host a near-real time, kinematic simulation of Space Station Freedom (SSF) robotics systems. The robotics domain was chosen as the evaluation domain, since it incorporates both psychomotor and cognitive skills. The SSF robotics domain also has a direct analog in the Shuttle Remote Manipulator System, therefore data obtained via SSF robotics may be applied directly to shuttle tasking. After integration of the platform, volunteers will operate the simulation while selected cognitive and psychomotor parameters are collected. After analysis of the preliminary findings, the results and prototype trainer will be submitted to the Astronaut Office and Training Division for evaluation. With approval, a flight unit will be constructed and flown as a Detailed Test Objective (DTO). Multiple flights of varying (long) duration are required for the on-orbit task efficiency data base to reach statistically significant conclusions.

## FY92 ACCOMPLISHMENTS

In FY92, the Onboard Training Project

- Obtained Silicon Graphics Personal Iris workstation
- Received estimates for rotational and translational hand controllers from NASA Technical Services and the Automation and Robotics Division
- Procured Silicon Graphics Indigo workstation (W-4D310VGX Graphics Supercomputing Workstation): Appropriation 802/30105, PWC: 307-51-07-6A, PWC: 569-226-DM-00-6F
- Began related efforts to manifest a Spacehab onboard training flight experiment (DTO 1210) as part of the Crew Personal Support Computer project. This project will test the efficiency of "just in time" onboard training.

## PLANNED FUTURE WORK

- Continue coordination with Space Station Training Division Robotics Group for integration (and upgrades) of Magik software on indigo workstation
- Procure rotational and translational hand controllers (FY94)
- Submit platform for crew and instructor evaluation and validation
- Gather ground-based cognitive and psychomotor data
- Build and manifest the flight experiment

**TITLE OF INVESTIGATION:** **Pressurized Vessels Subject to Hypervelocity Particle Impact**

**PROJECT MANAGER:** Michelle A. Rucker/RF/(505) 524-5730

**IN-HOUSE TEAM MEMBERS:** Rob Poe, Arnold Zamora, LESC

**PURPOSE OF INVESTIGATION:** Study the failure modes of pressurized vessels following hypervelocity particle impact.

**AUTHORIZED FUNDING FY92:** $50k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | FY90 | FY91 | FY92 | (Projected) FY93 |
|---|---|---|---|---|
| In-house: | $0 | $0 | $0 | $0 |
| Contractors: | 0 | 15k | 50k | 60k |
| Grants: | 0 | 0 | 0 | 0 |
| RTOP, Program or others: | 0 | 0 | 15k | 15k |
| **Total funds:** | **$0** | **$15k** | **$65k** | **$75k** |

## OBJECTIVE AND APPROACH

Testing is being performed with a 4.3 mm (.17-caliber) two-stage light-gas gun. Projectiles up to 3.1 mm (.12-inch diameter) are accelerated to 7 km/sec (22,966 ft/sec) to impact selected test vessels in simulation of orbital debris and micrometeoroid impacts. Vessel failure is monitored using an array of instrumentation.

## FY92 ACCOMPLISHMENTS

During FY92 we received a shipment of 1.3 l (80 $in^3$) aluminum pressure vessels, free of charge, from Structural Composites Industries (SCI). A series of tests was conducted on these vessels. Variables included vessel pressure, pressurized media (nitrogen, water, and a combination of nitrogen and water), projectile size, and vessel-mounting hardware.

Preliminary results indicate that mounting technique may have an effect on the severity of pressure-vessel failure following impact. These results are expected to have far-reaching implications regarding mounting techniques for pressure vessels on spacecraft.

Additionally, there appear to be great variations in vessel failure modes depending on whether a projectile impacts into a liquid-filled or gas-filled vessel; similar variations are seen in vessels that are impacted either above or below the liquid level when filled with liquid or gas mixtures. Although additional work is needed, these results are expected to affect shielding requirements for space-based pressure vessels. In particular, results indicate that only portions of a pressure vessel, rather than the entire vessel, may need to be shielded from orbital debris and micrometeoroids. This will significantly change operational requirements and may reduce shielding costs.

A paper detailing these results will be presented at the First European Conference on Space Debris in April, 1993. Results will also be presented to the JSC Meteoroid and Debris Protection Working Group.

## PLANNED FUTURE WORK

Additional testing on composite-overwrapped pressure vessels, also provided by SCI, is planned for FY93. A Research and Technology Objectives and Plans (RTOP) proposal to investigate the implications of this work to space-based pressure vessels will be submitted later this year.

## REFERENCE DOCUMENTS

1. Rucker, M. A.; and Garcia, B.: Evaluation of Pressure Vessels Subject to Hypervelocity Projectile Impact. National Aeronautics and Space Administration, White Sands Test Facility, test plan no. TP-WSTF-668.

**TITLE OF INVESTIGATION:** **Long-Term Material/Fuel Interactions Predicted by Microcalorimetry**

**PROJECT MANAGER:** Radel L. Bunker/RF/(505) 524-5733

**IN-HOUSE TEAM MEMBERS:** Dennis D. Davis, Steve D. Hornung, LESC

**PURPOSE OF INVESTIGATION:** Determine if microcalorimetry can be used to predict the long-term effects of materials on hypergolic fuels such as hydrazine.

**AUTHORIZED FUNDING FY92:** $50k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | FY90 | FY91 | FY92 | (Projected) FY93 |
|---|---|---|---|---|
| In-house: | $0 | $0 | $0 | $0 |
| Contractors: | 0 | 30k | 50k | 50k |
| Grants: | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 15k | 10k |
| **Total funds:** | **$0** | **$30k** | **$65k** | **$60k** |

## OBJECTIVE AND APPROACH

Many materials catalyze the decomposition of hydrazine to nitrogen and ammonia with the liberation of heat.

$$N_2H_4\,(l) \rightarrow 1/3\,N_2\,(g) + 4/3\,NH_3\,(g)$$

$$\Delta H = -123\ kJ$$

The decomposition reaction of hydrazine can be followed by several techniques including measurement of pressure generated by the product gases, quantification of products by chemical analysis, or calorimetric measurements of the heat generated.

The objective of this project is to determine if microcalorimetric data can be used to make reliable long-term estimates of hydrazine-material compatibility.

To meet this objective, the project was divided into three phases: small-scale, long-term exposure studies (approximately 2 years); microcalorimetric studies; and data correlation between the two studies.

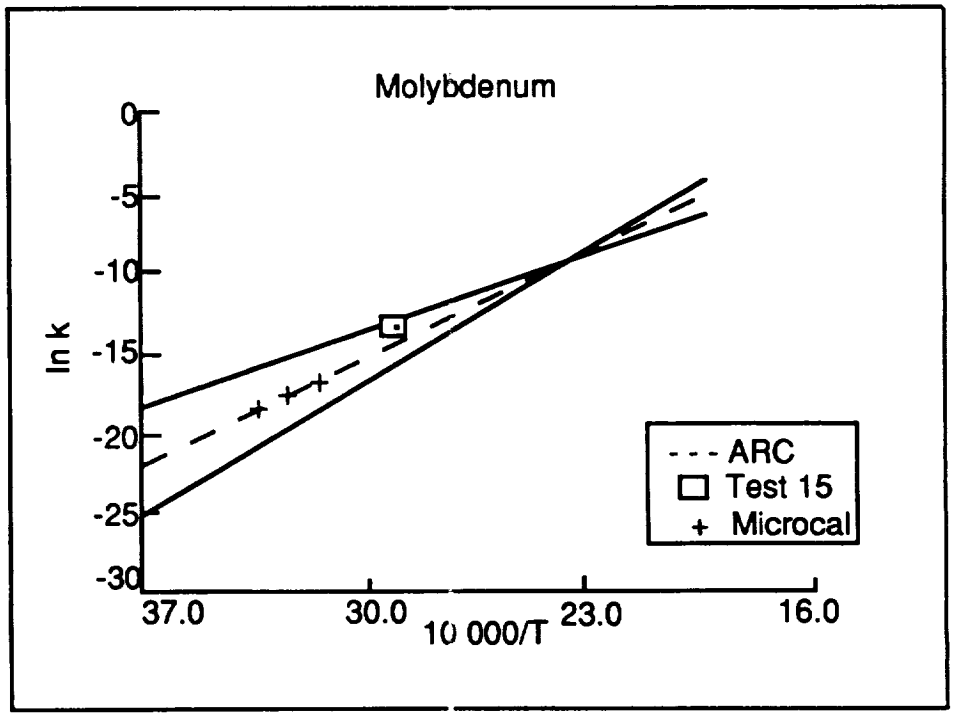
## FY92 ACCOMPLISHMENTS

Progress on the long-term exposure studies continues this fiscal year. These studies are performed with three materials (Stainless Steel 304L, Inconel, and Hastelloy C) of varying reactivity immersed in hydrazine. The hydrazine and the metal were loaded into a 15 ml ampule, which was then sealed and placed into a temperature-controlled water bath. At selected time intervals, ampules were removed from the water bath and placed into an opening fixture designed and constructed at the White Sands Test Facility for this project (a patent disclosure has been submitted). Four sets of data have been collected over the last 250 days.

A Hart microcalorimeter was purchased this fiscal year and is currently being evaluated using various pure metals and some alloys immersed in hydrazine at temperatures ranging from 25° to 50° C. Approximately 50 tests have been performed. Experimental, safety, data collection, and computerized data collection procedures have been developed. These procedures will be used during Phase 2 of this project.

The data analysis program developed for this project, called "HYKIN," is used to study hydrazine decomposition kinetics. The program is designed to correlate microcalorimetric, Test 15, long-term exposure, configurational, and ARC data in terms of the common denominator of chemical reactivity, mole/(sec $m^2$), and plot the data on a master plot. An example of a master plot is shown in figure 16 for molybdenum. The ordinate is the log of the rate of the molybdenum catalyzed decomposition of hydrazine. The abscissa is inverse absolute temperature in Kelvins. The dotted line is extrapolated ARC data. The solid lines represent *error* limits for the ARC extrapolation. As shown in figure 16, the

Figure 16.– Master plot from HYKIN for molybdenum.



microcalorimetry data is in excellent agreement with the ARC extrapolated data. Long-term data will be added when it becomes available.

## PLANNED FUTURE WORK

During FY93, the long-term exposure studies and the microcalorimetry studies will be completed and the data will be correlated to determine if microcalorimetry can predict long-term exposure effects. Particular attention will be paid to incorporating surface passivation and activation features (i.e., decreasing and increasing reactivity) into the predictive method for long-term material and fuel interactions.

During FY93, the master plot concept will be extended to include the long-term exposure materials as well as a variety of other materials for which ARC, Test 15, and literature results are available.

At the end of FY93, a final report which summarizes the findings of this project will be prepared and published. Results from these studies will also be presented at the Joint Army–Navy–NASA–Air-Force (JANNAF) Propellant Development and Characterization Subcommittee Meeting (ref. 1), and at the JANNAF Safety and Environmental Subcommittee Meeting (ref. 2).

## REFERENCE DOCUMENTS


1. Hornung, S. D.; Davis, D. D.; Bunker, R. L.: "Evaluation of Microcalorimetry for Determining Material Reactivity with Hydrazine". Unpublished JANNAF paper, Lawrence Livermore National Laboratories, Livermore CA, April 1993.

2. Davis, D. D.; Hornung, S. D.; Bunker, R. L.: "Correlation of Long-term and Microcalorimetric Results for Hydrazine/Materials Interactions". Unpublished JANNAF paper, NASA White Sands Test Facility, Las Cruces, NM, August 1993.

**TITLE OF INVESTIGATION:** **Real-Time Multipurpose Monitor for Assessing the Integrity of Confined Atmospheres**

**PROJECT MANAGER:** Harold D. Beeson/RF/(505) 524-5542

**IN-HOUSE TEAM MEMBERS:** T. Roth, T. Shelley, D. Emery, LESC

**PURPOSE OF INVESTIGATION:** Develop and demonstrate a prototype system capable of real-time monitoring of confined atmospheres with artificial intelligence feedback.

**AUTHORIZED FUNDING FY92:** $50k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | FY91 | FY92 | (Projected) FY93 |
|---|---|---|---|
| In-house: | $40k | $0 | $25k |
| Contractors: | 0 | 50k | 0 |
| Grants: | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 |
| **Total funds:** | **$40k** | **$50k** | **$25k** |

## OBJECTIVES AND APPROACH

The objective of this study is to develop and demonstrate a prototype system capable of real-time monitoring of confined atmospheres with artificial intelligence (AI)-generated feedback.

The project is divided into three phases that correspond to the 3 years of requested funding. In Phase 1 (FY91), existing detector technology was reviewed, and appropriate gas and vapor data were identified and collected. The fabrication of a bench-scale test and monitoring system began using existing hardware. The end result of Phase 1 was a demonstration of the feasibility of Phase 2.

In Phase 2 (FY92), the fabrication of a bench-scale test and monitoring system was completed. The design of a configurational test system was completed and software to enable file conversion and transfer was written. Guidelines and

methodologies were developed to aid in the construction of an "event" data base which forms the foundation of the AI system. The AI interface was developed and is currently undergoing verification.

In Phase 3 (FY93), the development of the *event* data base will be completed along with final verification of the AI interface. The monitoring system (hardware and software) will be evaluated using the configurational test system as a mockup environment.

## FY92 ACCOMPLISHMENTS

In FY92, a bench-scale test chamber (see ref. 1) was fabricated. An atmospheric interface for the mass spectrometer was identified and tested using the bench-scale test chamber, which aided in the acquisition of spectral data pertaining to overheated wires possessing Kapton-based wire insulation. The procedures required to construct the required *event* data base from off-gas data present at the White Sands Test Facility were established. The AI interface process was begun and is progressing. A translation software routine was written to convert data gathered by the test instrumentation and transfer this data to high-speed processors for analysis. This data was then read into a sophisticated software package (PV-Wave) where auto and cross-correlation processes are performed (figure 17). This process forms the foundation of the AI interface. Therefore, the conclusion was made that it would be feasible to develop unsupervised pattern recognition algorithms.

## PLANNED FUTURE WORK

Phase 3 (FY93) is targeted for completion of the *event* database and the refinement of the AI interface with the establishment of a supervised learning system for characterizing unknown classifications of *events*. The configurational test system will undergo checkout and the entire monitoring system (hardware and software) will be evaluated in the mockup environment. Based on accomplishments, additional Research and Technology Objectives and Plans funding will be sought. We will coordinate this effect with the Space and Life Sciences directorate.

## REFERENCE DOCUMENTS

1. Beeson, H. D.; "Real-Time Multi purpose Monitor for Assessing the Integrity of Confined At mospheres," in *JSC Director's Discretionary Fund Program 1991 Annual Report*, NASA TM 104 745, November 1991, p. 75.

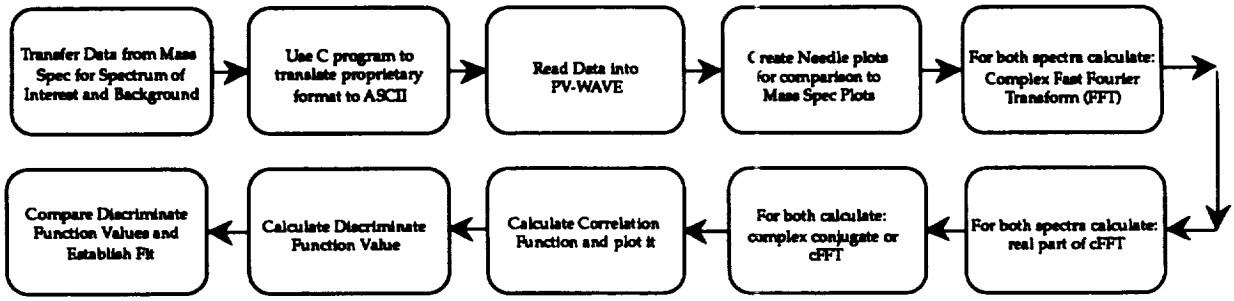



Figure 17.– Flow diagram of front-end of AI interface.

**TITLE OF INVESTIGATION:** **Vehicle Monitoring Devices and Techniques to Determine the Health of the Orbital Maneuvering System and Reaction Control System**

**PROJECT MANAGER:** Bob Kowalski/RD/(505) 524-5516

**IN HOUSE TEAM MEMBERS:** Ralph Tapphorn, Bill Smith, Randy Burton, Joe Kurtz, Tim Roth, LESC.

**PURPOSE OF INVESTIGATION:** Develop and demonstrate vehicle monitoring devices and techniques to determine the health of the shuttle Orbital Maneuvering System (OMS) and Reaction Control System (RCS) systems.

**AUTHORIZED FUNDING FY92:** $50k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $0 | $50k | $50k |
| Contractors: | 0 | 0 | 50k | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 15k | 125k | 150k | 150k |
| **Total funds:** | **$0** | **$15k** | **$175k** | **$200k** | **$200k** |

## OBJECTIVES AND APPROACH

Application of vehicle health monitoring (VHM) techniques is expected to benefit the shuttle program directly by providing a means to reduce the cost of operations during shuttle Orbiter checkouts at the Kennedy Space Center (KSC). Long-term benefits for the Space Station Freedom and the Space Exploration Initiatives programs are anticipated; in particular, the flexibility of including VHM concepts during initial design phases of these programs will reduce their costs of implementation. Industrial spin-offs of many of the VHM devices and techniques should be enhanced by assisting the National Laboratories with the technology transfer process.

The main objective is to develop the technology to perform VHM on OMS and RCS systems. This will be accomplished by investigating the application of sensors, microelectronics, and nondestructive evaluation (NDE) technology to the shuttle OMS and RCS systems on a component level and by demonstrating proven techniques applicable to flight VHM devices or ground support operation using the White Sands Test Facility (WSTF) propulsion test beds.

## FY92 ACCOMPLISHMENTS

During FY92, all of the planned activities for the year were accomplished.

A literature search and technology survey was initiated and is still ongoing. Shuttle OMS/RCS hardware failure modes documented at KSC, WSTF and JSC were evaluated. Results of this evaluation allowed the program to focus on three areas: 1) monitoring performance of primary reaction control system thruster valves, 2) monitoring internal and external propellant leaks and 3) uniquely adapting existing sensors and procedures for VHM.

Chemical sensor technology was evaluated for use in propellant leak detection, both internal and external to the system. Four state-of-the-art technologies were identified: spectroscopic, polymer, Pd diode, and ion mobility. Component test fixtures were developed to allow bench top evaluation of the sensors. The near-infrared absorption spectrum for mono-methyl hydrazine was measured with a peak absorption at 15 micrometers. The concentration-pathlength product was also determined. A test chamber for point-chemical sensors was fabricated for use in a wide range of pressures.

Much attention was given to investigating technologies for valve-motion sensors. Three nonintrusive sensors were procured to monitor primary RCS pilot-operated valve movement. The sensors concepts that were chosen were magnetic field perturbation (Hall) sensors, acoustic emission sensors, and current sensors. A bench top, gas-flow system was developed to test the technologies. These sensors were able to detect the operation of both the pilot and main stages of the valve. Valve response as a function of pressure was also determined.

Existing fleet leader instrumentation was evaluated for VHM application with respect to helium-regulator and check-valve performance during an OMS fleet lead firing. At the present time, data analysis is continuing and no conclusions can be drawn.

Two papers will be presented at the Fourth Annual Space System Health Management Technology Conference at the University of Cincinnati in November. They are entitled: "Application of a Hall Effect Sensor to Monitor Pilot-and Main-Stage Movement in a Pilot-Operated Valve," to be presented by Tim Roth, Lockheed Engineering & Sciences Company (LESC); and "Application of Acoustic Emission to Vehicle Health Monitoring," to be presented by Bill Smith, LESC.

## PLANNED FUTURE WORK

Phase II work planned for FY93 includes development of a VHM demonstration for the primary thruster pilot-operated valve located on the Fleet Lead test article, acquisition and fabrication of other sensor devices and equipment, testing of OMS/RCS components with known failures, and establishing a trend data base for measured signatures.

Phase III work planned for FY94 calls for the completion of demonstration testing and the evaluation of concepts for automated checkouts and artificial intelligence as employed in the aircraft industries. Final results of proven VHM techniques will be evaluated for applicability in the reduction of shuttle turnaround costs. A final report will be completed and recommendations made to the project office.

## REFERENCE DOCUMENTS

1. Sensor Technology Sourcebook: Guide to Worldwide Research & Development. Technical Insights, Inc., Fort Lee, New Jersey, 1992.

**TITLE OF INVESTIGATION:** **Assured Vision for Space Operations**

**PROJECT MANAGER:** Kumar Krishen, Ph.D./IA4/(713) 283-5875

**IN-HOUSE TEAM MEMBER:** Marie Collin/IA4/(713) 283-5752

**PURPOSE OF INVESTIGATION:** Define a means to comprehend objects and surface properties needed for robotic planetary operations.

**AUTHORIZED FUNDING FY92:** $19k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | FY90 | FY91 | FY92 | FY93 | FY94 |
| In-house: | $0 | $0 | $0 | $0 | $0 |
| Contractors: | 0 | 0 | 19k | 31k | 0 |
| Grants: | 0 | 4k | 8k | 0 | 0 |
| RTOP, Program or other: | 0 | 36k | 100k | 100k | 0 |
| **Total funds:** | **$0** | **$40k** | **$127k** | **$131k** | **$0** |

The project funding has been shared by several organizations: NATO ($12k), ITMI: Industry and Technology of Machine Intelligence, Grenoble, France ($236k), and NASA/Johnson Space Center ($50k).

## OBJECTIVE AND APPROACH

A vision system should be able to perceive a planetary environment for any location and any time on the surface and to describe the scene in terms of surface roughness, material characteristics, and surface orientation. To achieve this autonomous scene analysis, multifrequency and multimode sensing devices are used. The capabilities of sensors ranging from visible to infrared, and microwaves are exploited because of complementary capabilities in different environmental conditions (dust, specular reflections, night, short range, long range...) and different sensitivities to the needed surface characteristics (roughness, dielectric constant and orientation). The assured vision system is based on the

physical analysis of the mechanisms underlying the sensor perception.

An adaptive, multisensing approach will be developed according to the illumination conditions (figure 18). To this end, a *sensor selection module* will automatically select the best set of sensors and their sensing modes, according to the mission requirements and the environmental conditions to assure the scene perception. Then the perceived data will be processed by a *sensor fusion module* that will interpret the perceived scene. The scene perception and interpretation capabilities will be based on the physical models underlying the reflection and emission phenomena. These physical models take into account the relation between the environmental illumination (which can be active in case of radar sensors, or passive in case of thermal or visible sensors), the surface characteristics, and the perceived data. Then these physical models will be used with fuzzy-logic techniques to perform the fusion of the multisensor data and to interpret the physical and geometrical properties of the sensed surfaces.

## FY92 ACCOMPLISHMENTS

During FY 1992, the perception problems related to the space environmental conditions have been identified, the approach for overcoming these problems has been analyzed and selected, the theoretical basis for the implementation of the approach has been settled, the surface characteristics and their relative influence on the sensor returns have been identified and modeled for each sensor, and the sensing strategies for the perception of surface characteristics have been identified.

The results of this preliminary analysis have been reported in three technical reports (ref. 1, 2 and 3). These results as well as the newly developed approach have also been presented to a National Conference (ref. 4) and three International Symposiums (ref. 5, 6 and 7).

## PLANNED FUTURE WORK

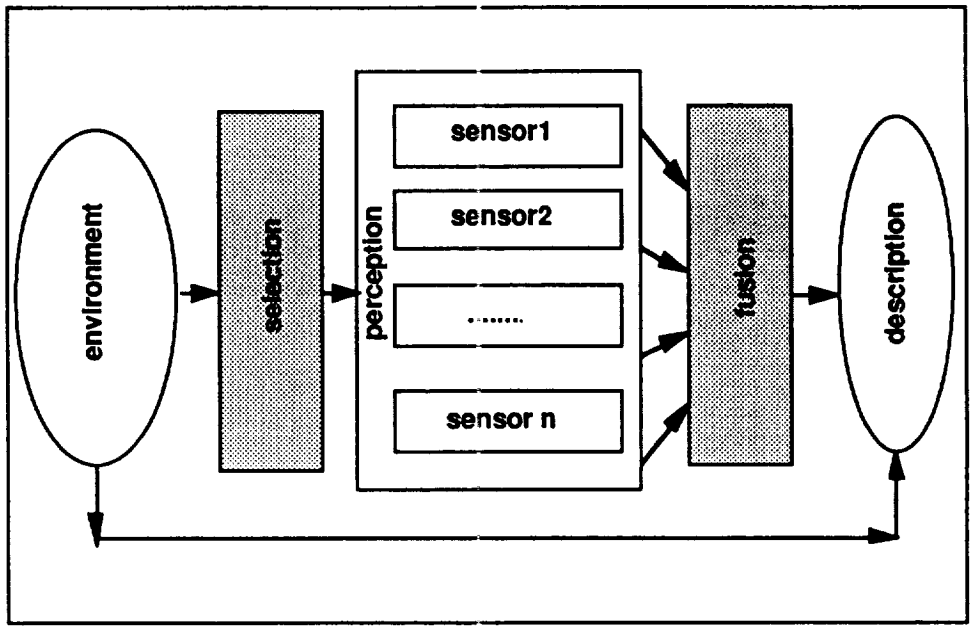
The next steps for the assured vision system development include implementation and testing of the sensor selection rules and implementation of the sensor fusion method for recovering the surface characteristics. This part represents the application stage of the theoretical analysis conducted during FY92.

A simulated environment is being designed to develop and test the selection and fusion modules of the vision system. This simulated environment will be realized using a graphical interface and simulated sensor data. The development steps of the simulation with their completion dates are:

October 1992 – Simulation of the lunar environment (lunar surface and man made objects) and illumination conditions (over a lunar day and for any given location on the surface).

November 1992 – Simulation of the sensor data for visible, infrared, and microwave data.

Figure 18.– Perception system architecture.




December 1992 – Simulation of the sensor selection module: autonomous selection of the sensors and sensing modes to perceive the scene.

February 1993 – Simulation of the data fusion module: recovering of the surface properties (roughness, orientation, dielectric constant, temperature, emissivity, reflectivity) to allow for further interpretation and operation control. Presentation of the results.

March-July 1993 – Demonstration of the assured vision system (ref. 8).

Several teams are involved in this development: ITMI for the scientific support, Robotic Applications Division (ER421/IGOAL) for the graphical interface of the simulation, and the Software Technology Branch (PT4) for consulting on the data fusion module.

## REFERENCE DOCUMENTS

1. Collin, M. F.: Perception for Space Robotics. Unpublished technical report nº 3/18, NASA Johnson Space Center, Houston, Texas, October 1991.

2. Collin, M. F.: Perception for Space Robotics. Unpublished technical report nº 6/18, NASA Johnson Space Center, Houston, Texas, January 1992.

3. Collin, M. F.: Perception for Space Robotics. Unpublished technical report nº 9 and 12/18, NASA Johnson Space Center, Houston, Texas, July 1992.

4. Collin, M. F.; and Krishen,K.: Assured Vision for Assured Vision in Space Applications, Space Operations Application and Research Workshop, Houston, August 1992.

5. Krishen, K.; and Collin, M. F.: Space robotics vision techniques, International Union of Radio Science, Houston, May 1992.

6. Collin, M. F.; and Krishen, K.: Sensor Fusion for Assured Vision in Space Applications, International Union of Radio Science, Houston, May 1992.

7. Collin, M. F.; Krishen, K.; and Pampagnin, L. H.: Adaptive multisensor fusion for planetary exploration rovers, International Symposium on Artificial Intelligence, Robotics and Automation for Space Robotics, Toulouse, France, September 1992.

8. Collin, M. F.; Krishen, K.; and Pesty, R.: Multisensor data integration for space operations, submitted to International SPIE Symposium on Sensor Fusion for Aerospace Applications, Orlando, Florida, April 1993.

**TITLE OF INVESTIGATION:** **Regenerative Life Support System Test Bed Project**

**PROJECT MANAGER:** Donald Henninger, Ph.D./EC3/(713) 483-5034

**IN-HOUSE TEAM MEMBERS:** Mike Hoy/EC3/(713) 483-0268
Daniel Barta, Ph.D./EC3/(713) 483-0268
Marybeth Edeen/EC7/(713) 483-9122

**PURPOSE OF INVESTIGATION:** Evaluate Regenerative Life Support System (RLSS) approaches in which plants are grown in a closed, controlled environment in conjunction with physicochemical subsystems.

**AUTHORIZED FUNDING FY92:** $300k

**FUNDING EXPENDITURE AND PROJECTIONS:**

| | FY90 | FY91 | FY92 | (Projected) FY93 |
|---|---|---|---|---|
| In-house: | $0 | $0 | $0 | $0 |
| Contractors: | 300k | 300k | 300k | 185k |
| Grants: | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 |
| **Total funds:** | **$300k** | **$300k** | **$300k** | **$185k** |

## OBJECTIVE AND APPROACH

The objective of the RLSS Test Bed Project is to use higher plants grown in a closed, controlled environment in conjunction with physicochemical-based life support systems to provide an integrated biological/physicochemical life support system test bed for evaluation of various RLSS approaches. The biological component of the test bed will be fully automated to grow candidate crops from seed to harvest without the need for human intervention. Additionally, one of the test bed's two growth chambers (figure 19) will be operable at both ambient and reduced atmospheric pressures to more closely duplicate candidate lunar and Mars habitat environments. The test bed will be complemented by incorporation of a human metabolic simulator which will supply variable metabolic loads to

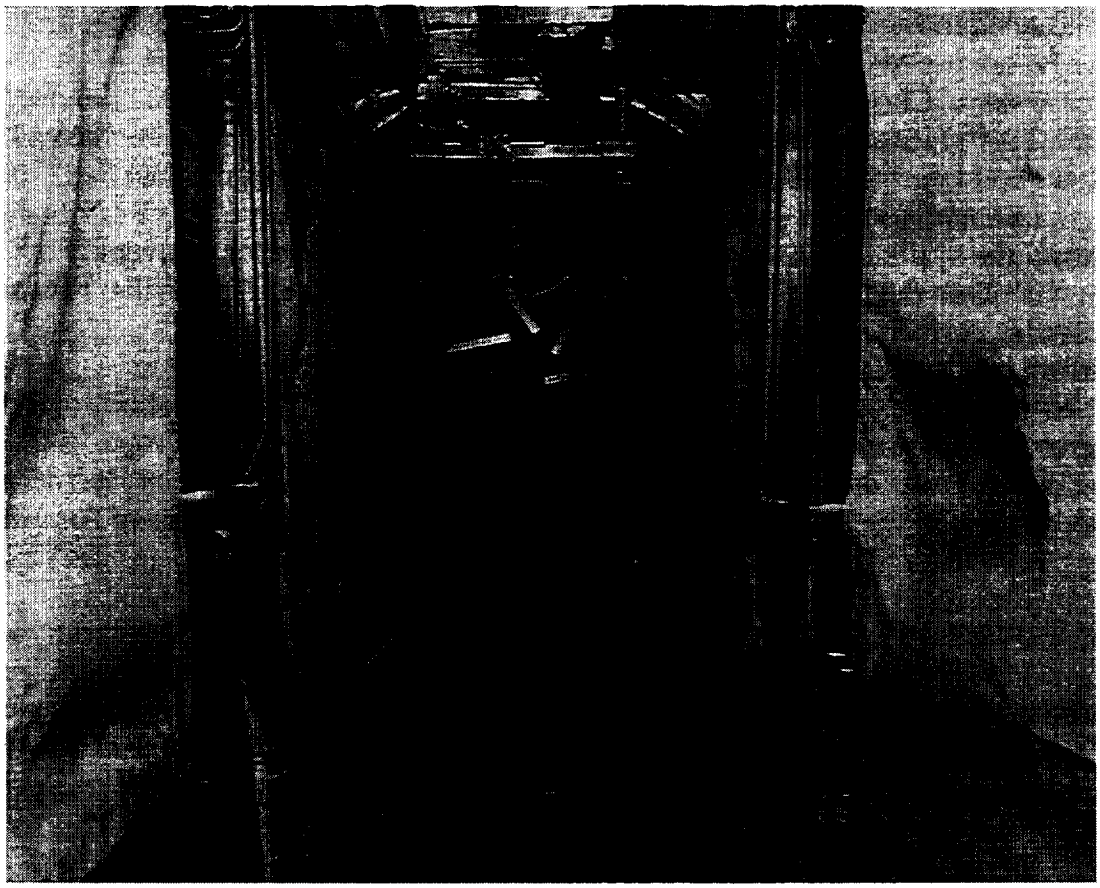


Figure 19.– Lettuce crop growing in the variable pressure growth chamber (VPGC).

the system to simulate the presence of a crew. 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 investigation of integrated control system approaches for providing variable life support capabilities on demand. Data from the RLSS Test Bed Project will be used to define requirements for the planned Human-Rated Test Facility (HRTF) being developed at JSC.

## FY 92 ACCOMPLISHMENTS

The RLSS Test Bed Project achieved several key accomplishments during FY92, including completion of buildup of the Ambient Pressure Growth Chamber (APGC), and a successful 90-day dwarf wheat crop growth test in the Variable Pressure Growth Chamber (VPGC). The wheat crop provided valuable insight on systems interactions which is being incorporated in the VPGC systems modeling activity. The build up of the APGC included the implementation of numerous system upgrades which had been identified as a result of the testing that

was conducted in the VPGC, and the design of a unique hydroponic nutrient delivery system. Checkout of a physico-chemical $CO_2$ removal system (known as SAWD II - Solid Amine Water Desorption) was initiated with the purpose of integrating the system with the plant growth chambers during FY93. Other key activities performed in FY92 include supporting off-line plant growth experiments, biomass production analyses, and plant growth hardware (i.e. hydroponic tray design and nutrient wicking material) evaluations in the RLSS Laboratory.

## PLANNED FUTURE WORK

No additional effort is planned for this JSC Director's Discretionary Fund (DDF) project. A new DDF proposal has been submitted and received preliminary approval for modification of the VPGC to perform detailed plant growth testing and analysis at reduced pressures.

## REFERENCE DOCUMENTS


1. Henninger, D. L., et al.: "Johnson Space Center's Regenerative Life Support Systems Test Bed," *International Conference on Life Support and Biospherics*, University of Alabama in Huntsville, February, 1992.

2. Barta, D. J.: "Troubleshooting Problems With Leafy Crops," *12th Annual Conference on Hydroponics*, Hydroponic Society of America, April, 1992.

3. Barta, D. J., et al.: "Regenerative Life Support Systems Test Bed Performance: Lettuce Crop Characterization," *22nd International Conference on Environmental Systems*, Society of Automotive Engineers, 1992.

**TITLE OF INVESTIGATION:** **Lunar Surface Systems**

**PROJECT MANAGER:** Jeri W. Brown/SP/(713) 483-6036

**IN-HOUSE TEAM MEMBERS:** Nathan Moore, Laurie Weaver, David Ray

**PURPOSE OF INVESTIGATION:** Use computer simulations, mockups, and partial gravity simulator to develop and evaluate requirements for crew operations on the surface of the Moon and Mars.

**AUTHORIZED FUNDING FY92:** $75k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $0 | $70k | $0 |
| Contractors: | 0 | 0 | 75k | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 | 0 |
| **Total funds:** | **$0** | **$0** | **$75k** | **$0** | **$0** |

**OBJECTIVE AND APPROACH**

Develop mockups and computer simulations of the systems and facilities needed for crew operations on the Moon and Mars. These representations will convey conceptual designs, aid in requirements definition, and help evaluate alternative approaches. Projections of technology needs and integrated man-in-loop test capabilities for surface systems will be products of the activity. The FY92 activity is concentrated in four subtask areas:

- Hyperbaric Airlock – Identify top-level and secondary guidelines and rationale for a lunar airlock that can accommodate hyperbaric treatment for the crew; define a conceptual design based on an "inside-out" approach, and document design with hypermedia 3-D computer models; employ a multidisciplinary team.
- Initial Mars Habitat – Explore requirements for a 6-person, 500-day surface stay-time initial Mars habitat,

focusing on habitation systems to support routine human operations, basic habitation needs, and surface science and exploration.

- Habitation Development Tool – Develop a habitat parametric model (i.e., computer-based tool) to facilitate the definition of habitat concepts and configurations, to facilitate estimation of habitat mass and volume, and to provide the user with a range of options for crew size, mission length, and system configuration.

- Partial Gravity Simulator – Salvage and upgrade the Apollo partial-gravity-simulator hardware to support research, technology, and evaluations for exploration missions. Test the hardware and make changes to increase the simulator's response and performance. Construct a new support structure to allow increased vertical and horizontal translation for human subjects.

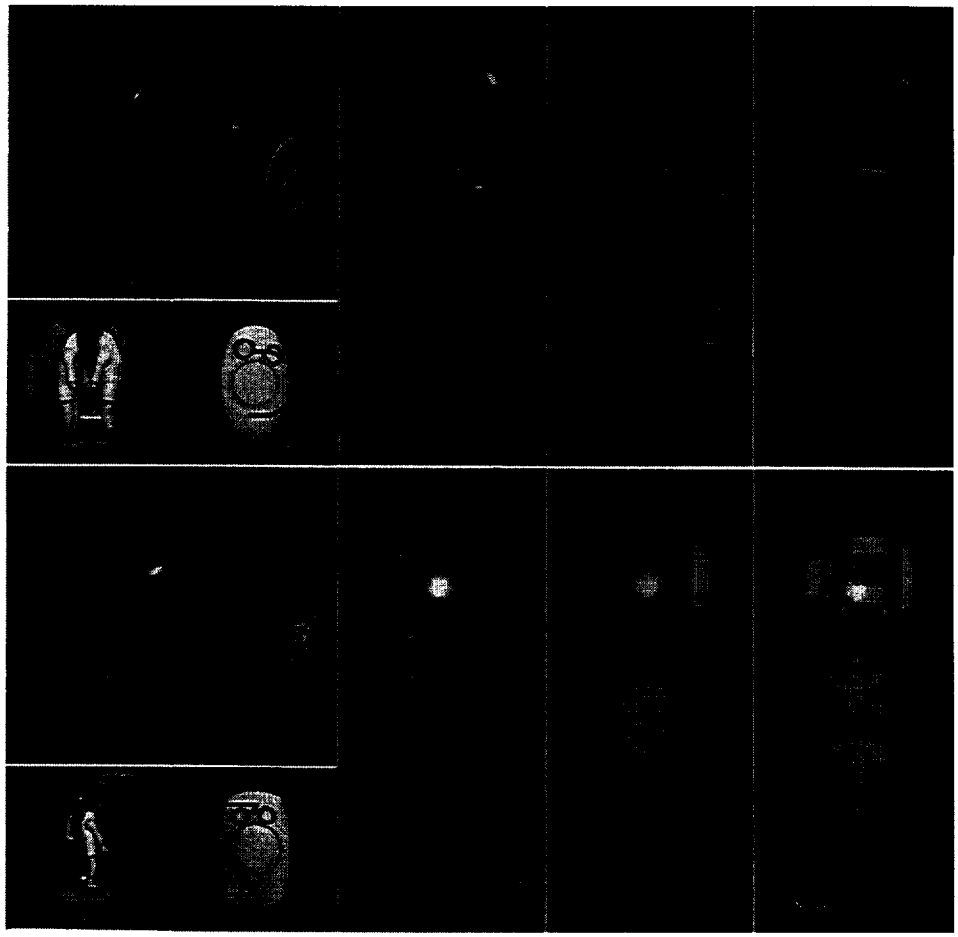
## FY92 ACCOMPLISHMENTS

- Hyperbaric Lunar Airlock – Top-level functions as summarized from the guidelines document (Lunar Airlock Mission and Functional Guidelines, JSC-25921, May 1992) were identified. Using the functions as a checklist, available airlock designs (e.g., Shuttle, Space Station) were assessed for applicability. Unique requirements for partial-g operations (e.g., EMU and equipment logistics transfer, hyperbaric treatment, dust control, airlock control, and conservation of consumables) were defined, including dimensional and volumetric constraints. The two- and three-person concepts are shown in figure 20.

- Initial Mars Habitat – A mission profile was defined to identify crew size, stay time, crew-tended capabilities, logistics issues, and assumed transportation shroud constraint. Mission objectives were synthesized resulting in a two-level, vertical-cylinder-configuration with required living and working areas (figure 21). The concept supports three basic functions (crew sustenance; habitation systems operations; and science). The concept was documented in a stand-alone, interactive, hypermedia computer program.

- Habitation Development Tool – User changes were incorporated into the Phase I tool. A radiation shield mass estimation model based on existing reference materials was developed. Apollo and Skylab crew accommodations data bases were expanded. The tool provided rapid estimates of habitable mass and volume when applied by a person knowledgeable about human support requirements and previous spaceflight programs. The tool was also applied to

Figure 20.– Hyperbaric lunar airlock concept.



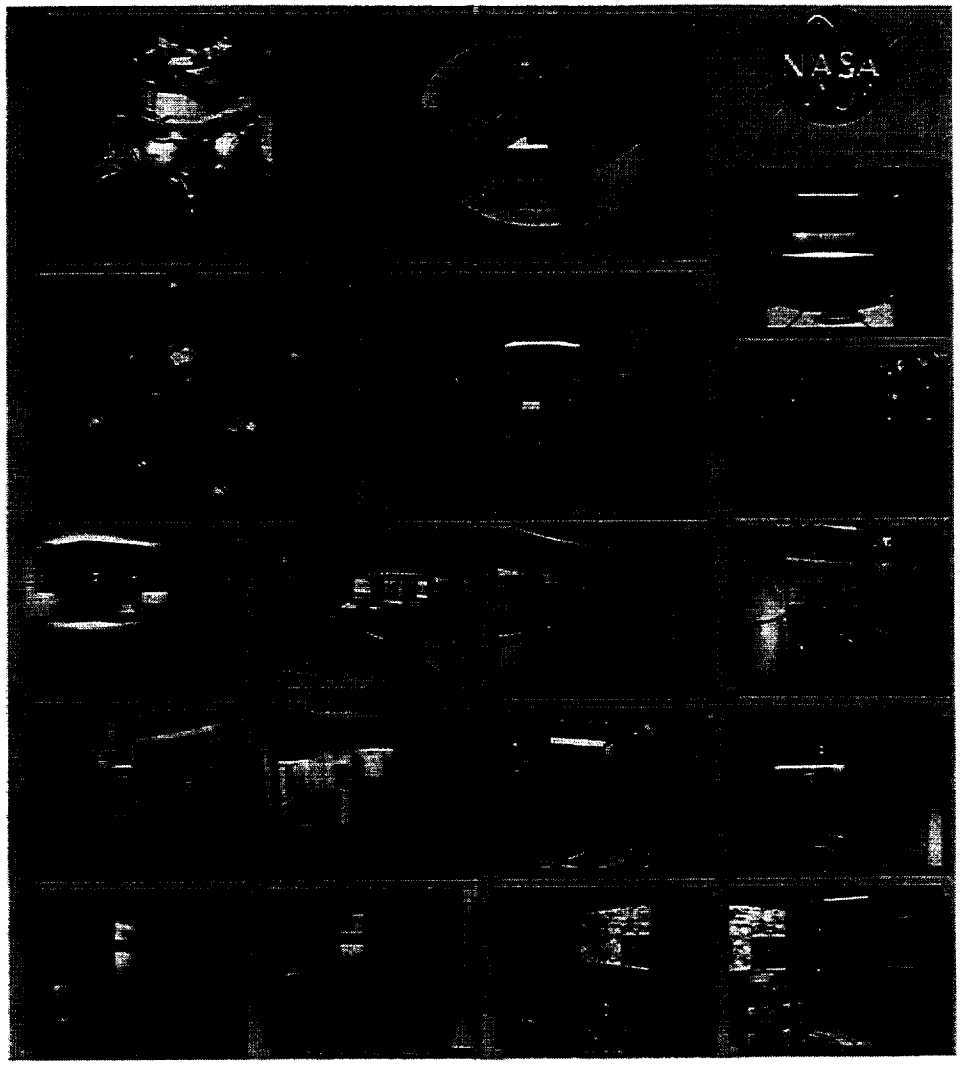
parametric study of the effects of mission parameters on habitable element sizing.

- Partial Gravity Simulator – Initial simultaneous tests of vertical- and horizontal-drive servosystems were successfully completed. Safety features were added to the system. Analyses and tests were conducted to obtain appropriate pressure-vessel rating. Proof load tests of gimbal and vertical servo were completed. A failure modes and effects analysis was prepared and a Test Readiness Review completed for approval to conduct tests and evaluations with human subjects.

## PLANNED FUTURE WORK

Habitation Development Tool – Incorporate radiation shield model; further develop subsystem data base and expand Apollo/Skylab data. Expand subsystem selection options.

Figure 21.– Initial Mars habitat concept.



**TITLE OF INVESTIGATION:** **In Situ Resource Utilization**

**PROJECT MANAGER:** David S. McKay, Ph.D./SN/(713) 483-5048

**IN-HOUSE TEAM MEMBERS:** Thomas A. Sullivan, Ph.D./SN4/(713) 483-0681
Carlton C. Allen, Ph.D./LESC C-23/(713) 483-2630

**PURPOSE OF INVESTIGATION:** Develop the technology necessary for the utilization of *In Situ Resources* as part of the developing Space Exploration Initiative program. Establish laboratory projects, develop skills and experience, and acquire necessary equipment and instruments. Subcontract engineering design studies and work on the procurement, testing, and storage of lunar simulant material.

**AUTHORIZED FUNDING FY92:** $150k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
| In-house: | $0 | $0 | $0 | $0 | $0 |
| Contractors: | 0 | 150k | 150k | 150k | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program, or other: | 0 | 0 | 85k | 0 | 0 |
| **Total funds:** | **$0** | **$150k** | **$235k** | **$150k** | **$0** |

## OBJECTIVE AND APPROACH

Three separate studies have been conducted under this project. The production of oxygen from lunar regolith material is the goal of two different chemical techniques, hydrogen reduction of basalt and glass and the sulfate process. The third project focuses on the production of ceramics by sintering, the bonding of solid material by melting at the edges. "Bricks" formed from sintered regolith could be used for construction material and radiation shielding at a lunar outpost.

### Hydrogen Reduction of Basalt and Glass

Direct reduction of the iron in lunar basalt and glass by hydrogen is being investigated as a method of liberating oxygen. The objectives of this program are to define the conditions under which reduction occurs and use this information to support the production of oxygen at a lunar base.

### Sulfate Process

This project explores modifications to a terrestrial commercial process in order to release oxygen from ilmenite. The reactions are carried out in solution. The three major process steps have been studied to explore their kinetics and yields. Concept development based on this and other data suggests that an efficient process is likely and points the way to future lab studies which will be done in the coming year.

### Ceramics

The purpose of this study is to investigate the sintering behavior of the lunar regolith. Experiments are designed to determine the range of conditions under which sintering takes place and the best methods for heating the material. The project has also responded to the needs of other investigators for large amounts of lunar soil simulant.

## FY92 ACCOMPLISHMENTS

### Hydrogen Reduction of Basalt and Glass

Laboratory experiments and analysis during FY92 led to determinations of the mechanism, kinetics and yields of oxygen from a range of lunar glass compositions (ref. 1). Reduction experiments on basalt and glass were carried out in both fixed and fluidized beds to compare their efficiencies. A method of improving process speed and yield by preoxidizing the feedstock was developed. Project personnel provided all analytical support for the first set of oxygen production experiments to utilize actual lunar samples (ref. 2). This study led to the development of a remote-sensing predictor for oxygen yield from lunar soil, based on parameters which can be determined from lunar orbit. An extensive survey was conducted to assess current technologies for separating water from hydrogen gas at high temperatures. The project sponsored a design study by Eagle Engineering for oxygen-producing flight experiments on the Artemis lander and at the First Lunar Outpost. This work led to the concept design of a full-scale test bed which will be used in FY93 to study oxygen production, material handling, and instrument control.

### Sulfate Process

Laboratory work in FY92 covered the three major process steps: acid digestion, recovery of sulfur from the reactants, and electrolysis of the acid solution to produce oxygen. Experiments determined the parameters for digestion of lunar simulant basalt and its constituent minerals (ref. 3). A series of tests in a furnace equipped with a sensitive microbalance established the kinetics of sulfur recovery by pyrolysis. Recovery was shown to be significantly enhanced when pyrolysis was carried out in a flowing hydrogen atmosphere. An electrolytic cell was

constructed and experiments to determine oxygen yield were initiated. In addition, a patent application covering the entire process was updated and resubmitted (ref. 4).

### Ceramics

Full-scale "bricks" with the compressive strength of concrete were produced by sintering lunar simulant basalt (ref. 5). A long series of tests determined the optimum heating, cooling, and insulation parameters for brick production. Test samples of basalt were sintered for the first time by a combination of microwave and radiant heating. An experimental program determined the optimum conditions for vibratory compaction of lunar soil simulants. This technique could be used as an alternative to pressure compaction in preparing material for sintering. The project placed subcontracts to the University of Texas at Dallas and Texas A&M University to procure, characterize, store, and distribute 20 metric tons of lunar soil simulant for spacesuit testing and other large-volume uses.

## PLANNED FUTURE WORK

### Hydrogen Reduction of Basalt and Glass

The major goal for FY93 is to fabricate and use our test bed to scale up oxygen output to that of a lunar pilot plant. In the process, feedstock and product handling methods, as well as instrument control procedures, will be developed. In addition, we will pursue the promising technique of preoxidation to increase oxygen yield. Further analytical work will be carried out on reduced lunar basalt and tests will be conducted on lunar pyroclastic glass.

### Sulfate Process

A key FY93 goal is to optimize the electrolysis procedure, which produces oxygen from lunar minerals digested in sulfuric acid. Sulfur recovery by improved pyrolysis techniques will be tested. The effects of varying acid concentrations of mineral digestion will be demonstrated. Competing designs will be evaluated, with the aim of maximizing yield while simplifying the overall sulfate process. A patent application for this process has been filed and is in negotiation.

### Ceramics

Innovative changes to the brick-making process will be investigated, with the goal of dramatically improving the products. The radiation protection potential of bricks will be compared to that of loose regolith. Large quantities of lunar soil simulant will be tested for engineering properties and distributed to a variety of investigators.

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1. Allen, C.C.; McKay, D.S.; and Morris, R.V.: "Lunar Oxygen – The Reduction of Glass by Hydrogen," *Engineering, Construction, and Operations in Space III,* Am. Soc. Civil Eng., 1992, pp. 629-640.

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**TITLE OF INVESTIGATION:** **Threshold Low-Cost Intermediate Technology Experiment (T-LITE) Mass Measurement Device**

**PROJECT MANAGERS:** Edgar Castro/ES221/(713) 483-8841 and Kelley Cyr/XP/(713) 283-5466

**IN-HOUSE TEAM MEMBERS:** Tony Dao, Kevin Hames, Leah Pate, Henry Wyndon, Ed Strong, Keith Speckman, Jerry Valle, Heath Hendrickson, Ann Arnett, Mike Jenson, Scott Merkle.

**PURPOSE OF INVESTIGATION:** Design a mass measurement flight experiment.

**AUTHORIZED FUNDING FY92:** $20k

**FUNDING EXPENDITURES AND PROJECTIONS:**

| | | | | (Projected) | |
|---|---|---|---|---|---|
| | **FY90** | **FY91** | **FY92** | **FY93** | **FY94** |
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| Contractors: | 0 | 0 | 0 | 0 | 0 |
| Grants: | 0 | 0 | 0 | 0 | 0 |
| RTOP, Program or other: | 0 | 0 | 0 | 0 | 0 |
| **Total funds:** | **$1k** | **$10k** | **$20k** | **$39k** | **$0** |

## OBJECTIVE AND APPROACH

The T-LITE is an activity sponsored by the Threshold Group to provide NASA employees with the opportunity to build teamwork and leadership skills by working on a Shuttle flight experiment. The T-LITE concept calls for the extensive use of in-house resources and off-the-shelf components to keep the cost down. The experiment selected for the initial T-LITE project was the Mass Measurement Device (MMD) proposed by Tim Pelischek. The MMD uses the principle of linear acceleration to determine the mass of a crew member in a microgravity environment.

The purpose of this device is to provide the crew with a convenient method of weighing themselves while in space on long-duration missions. The target

accuracy of the device is repeatability within ± 1 percent. Since the crew will use the device primarily to monitor weight trends, the absolute accuracy of the device is not as critical as consistent results. The team will design the device to fit inside a standard Shuttle middeck locker with a goal of fitting inside a half-size locker. The MMD will fly as a development test objective or detailed supplementary objective and will meet the design requirements associated with those payloads.

The MMD uses Newton's second law of motion: the acceleration of an object is directly proportional to the force acting on it and inversely proportional to the mass of the object. The mass of an object can be determined by applying a known force to it and measuring the resulting acceleration. In the MMD, an elastomer tube applies a force to a three-sided device resembling a scissor-jack. The force transfers through a triangulation of load cells to a plate on which the crew member may stand or kneel.

## FY92 ACCOMPLISHMENTS

The activity for FY92 focused on preparations for a zero-gravity test flight on the KC-135. An engineering test bed was set up on the air-bearing floor (ABF) facility in Building 13. The prototype testing aimed at refining the mechanical and electronic systems and the data analysis software. An electromagnetic release system was added to the MMD design. Extensive testing of both static and dynamic behaviors was conducted on the ABF. A major goal of the testing was to improve the absolute accuracy and consistency of the device. The objective was achieved in July when a series of 50 tests was conducted using 5 different masses ranging from 98 to 319 pounds. The difference between the actual mass and the mass estimated by the MMD was less than 2 percent. Also, the mass estimates for a given weight varied by about 2 percent.

In addition to developing the F=*ma* method, an alternative method, based on the principle of harmonic motion of a spring-mass system, was developed. The displacement of the mass is a function of the initial displacement and the cosine of the elapsed time, multiplied by the square root of the spring constant, divided by the mass. For the MMD, the initial displacement and the spring constant are fixed, therefore the mass can be estimated if the displacement and time are known. Two switches are positioned along the deployment path of the MMD such that one switch is opened when the device begins to deploy and the second switch is closed when the device nears the end of deployment. The switches are positioned so that the displacement of the device between the switches is constant. The time interval between the two switches is then a function of the mass. The time-based model offers some advantages over the F=*ma* method since it does not require sensitive load cells and accelerometers, and the computations are simpler. Preliminary testing indicates that the time-based model results are comparable to the F=*ma* model, however, additional testing is required to determine which method will work best in actual practice.

It was previously thought that, for testing conducted on the KC-135 zero-g aircraft, the MMD would have to be "free-flying" to eliminate noise from the natural vibration of the aircraft. The free-flying mode of testing posed great difficulties because of the need to use a very heavy countermass. To determine the best test mode, a system for monitoring the acceleration environment on board the KC-135 was developed. A system of three accelerometers, set up to measure acceleration in the three linear motion axis', and a chart recorder, was flown on the KC-135. The results were used to determine that the best method of testing was to attach the device to the floor. A *noise-canceling* accelerometer would also be added to the base of the MMD.

## PLANNED FUTURE WORK

Prototype testing will proceed with both dead-weights and human subjects on the precision AFB in Building 9. The prototype will be improved with a new hinge system, improved switch attachment, and a shock-absorbing mech-anism.

Once the objectives of the prototype test phase are reached, the testing on the KC-135 will begin. The KC-135 testing will consist of two series of two flights each. The first flight series is scheduled for the first quarter of 1993. The follow-on flight test is scheduled for the second quarter of 1993. If the KC-135 testing is successful, then the plan is to conduct an Orbiter test flight in late 1993.

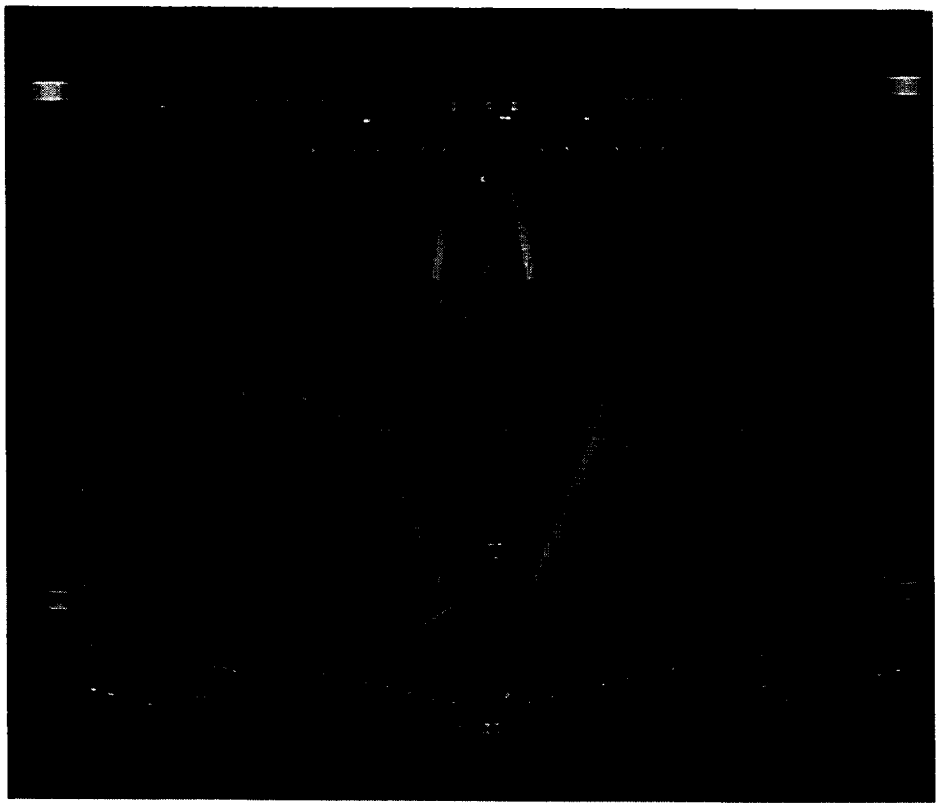

Figure 22.– Composite photo of the prototype MMD in the compressed and deployed positions.

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13. ABSTRACT *(Maximum 200 words)*

Annual report of the Johnson Space Center Director's Discretionary Fund documenting effective use of resources. The $1,694,000 funding for FY92 was distributed among 27 projects. The projects are an overall aid to the NASA mission, as well as providing development opportunities for the science and engineering staff with eventual spinoff to commercial uses. Projects described include space-based medical research such as the use of stable isotopes of deuterium and oxygen to measure crew energy use and techniques for noninvasive motion sickness medication. Recycling essentials for space crew support is conducted in the Regenerative Life Support and the Hybrid Regenerative Water Recovery test beds. Two-phase fluid flow simulated under low-gravity conditions, hypervelocity particle impact on open mesh bumpers, and microcalorimetry to measure the long-term hydrazine/material compatibility were investigated. A patent application was made on a shape-memory-alloy release nut. Computer estimate of crew accommodations for advanced concepts was demonstrated. Training techniques were evaluated using multimedia and virtual environment. Upgrades of an electronic still camera provide high resolution images from orbit. For additional information on the projects, contact the individual investigators or Lyle Jenkins at (713) 283-5405.

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