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A Mars EMU/Education Outreach Project Plan to the Office of Exploration

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July 2007

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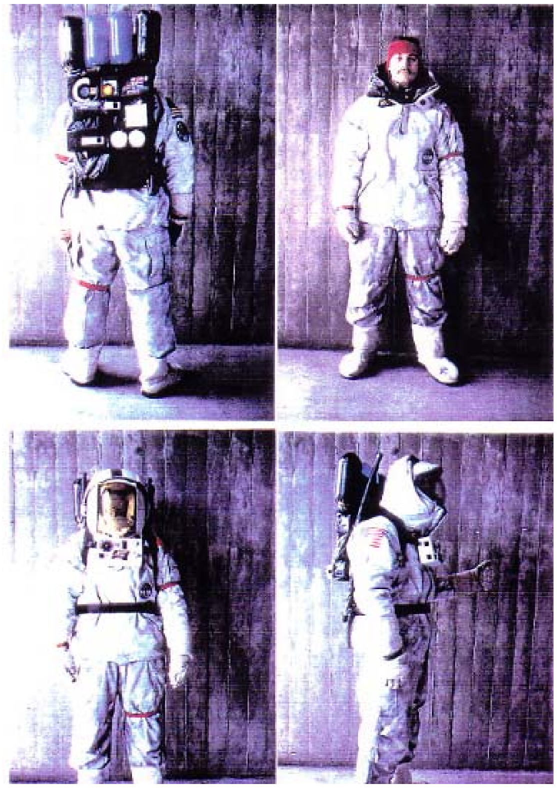
Acronyms

ACES	Advanced Crew Escape Suite
CASS	Center for Advanced Science Studies
CDR	Critical Design Review
CG	center of gravity
DMM	dense monolithic membrane
EMU	Extravehicular Mobility Unit
EVA	Extravehicular Activity
IDE	interactive design environment
ISS	International Space Station
JSC	Johnson Space Center
LCVG	liquid cooling and ventilation garment
NSBRI	National Space Biomedical Research Institute
OBPR	Office of Biological and Physical Research
PDR	Preliminary Design Review
PLSS	primary life support system
UCC	University Collaborative Center
USNA	United States Naval Academy
USRA	University Space Research Association

MarsSuit concept A, Carter Emmert, 1990



MarsSuit prototype, UC Berkeley, 1992

1.0 MARSSUIT PROJECT DESCRIPTION

The MarsSuit Project is an innovative research initiative that will engage multiple universities in a coordinated and synergistic effort to assist NASA in the formidable task of designing a lightweight, blue-collar Mars Extravehicular Mobility Unit (EMU) for human exploration of the Martian surface. It is a revolutionary and evolutionary project, using a collaborative design Web site (the University Collaborative Center, UCC) to link 16 university teams with NASA, industry, and other external institutions in a virtual organization mirroring an actual NASA Project Office. While several universities are already studying Mars space suits, they do so in a vacuum with little or no input to actual design. The MarsSuit Project will add to, focus, and galvanize these efforts into a nationwide program that will involve technology identification, assessment, and development; systems engineering; systems design; and education enhancing opportunities for participants. It will partner underrepresented minority institutions with established universities having a rich legacy of NASA research experiences such as: the United States Naval Academy (USNA)*, Massachusetts Institute of Technology*, University of Texas*, Johns Hopkins School of Medicine*, University of Maryland, University of California Berkeley*, Stanford University*, University of Washington*, Purdue University*, Dartmouth College, Penn State University, University of Michigan, University of Missouri, Rice University*, the Universities Space Research Association*, and others in a new research paradigm (asterisks denote institutions with support letters provided, all others have expressed verbal interest). To assure relevance to NASA's requirements there will be a strong NASA presence through a NASA MarsSuit Advisory Panel led by the EVA Program Office; Joseph J. Kosmo, Johnson Space Center's (JSC's) Senior Extravehicular Activity (EVA) Project Engineer; and Astronaut Dr. Michael Gernhardt. To assure reality in the design and its ability to be reproduced by industry, an Industry Advisory Panel will be established as well, with representation from Hamilton Sundstrand and ILC Dover, leaders in the design and development of NASA space suits.

The technical requirements of the MarsSuit Project include: conservation of resources; extension of the safety envelope; reduction of mass, volume, and subsystem complexity; reduction in EVA pre-breathe time; augmentation of EVA time; optimization of fit demographics (multi-size, multi-gender); optimization of human performance with respect to dexterity, mobility, and mechanical work effort; maximization of science return and incorporation of new sensor technologies which can: 1) assess human performance versus task (metabolic rate); 2) monitor consumable usage for science and traverse planning, and 3) monitor suit system safety (suit leakage rates, radiation, etc.). The expected outcome of the MarsSuit Project is the identification of new technologies and their integration into a conceptual and preliminary prototype of a Mars unique space suit. The long range aim is to make genuine contributions to a Mars EMU design before human missions to Mars go from the planning to the implementation stage.

While the MarsSuit Project seeks to identify, assess, and develop new technologies for a Mars unique space suit, an equally important objective is to promote science and technology education, affording a unique opportunity for undergraduate and graduate students to be part of a multi-organizational entity with a common and exciting goal. The project is based on a pilot program conducted at the University of California, Berkeley in conjunction with NASA-Ames and Stanford University.

2.0 OBJECTIVES

The primary objectives of the MarsSuit Project are to:

- Develop requirements for a Mars space suit with NASA and industry input.
- Identify and develop new technologies applicable to the design of a Mars space suit that may help satisfy the requirements.
- Evaluate promising technologies.
- Complete a conceptual design of a Mars space suit with supporting evidence of the anticipated performance.
- Inspire and motivate all who participate, infusing them with a stake-holder status that will energize the effort to address this barrier technology.
- Utilize a cross-disciplinary approach involving many disparate fields to attract and retain students in the science, math, and engineering fields, thereby increasing the nation's technology base and economic return and growth.

- Draw and engage traditional, non-traditional and underrepresented students, while providing them with a pipeline to careers in aerospace. University partnerships will be required, thereby ensuring relationships between experienced and non-experienced or minority-serving/minority-based institutions.
- Provide educators with a new paradigm in science and math instruction with the potential for broad dissemination nationally, while adhering to national standards.

3.0 PROGRAMMATIC NEEDS

The MarsSuit project addresses a critical NASA need, development of advanced space suit technologies necessary for the exploration of the Martian surface as defined in the NASA Bioastronautics Critical Path Roadmap, [Appendix 13]. BCPR risk 41 in the crosscutting area of Advanced Human Support Technology identifies the risk as

Provide Space Suits and Portable Life Support Systems.

This risk is rated color RED for Mars meaning "Considerable potential for improvement in efficiency in many areas or proposed missions may be infeasible without significant improvement.

The risk description is specified as:

Inability to provide a robust EVA system that provides the life support resources, mobility and ancillary support, including robotics interactions and airlock design, to perform defined mission EVA tasks.

The context of the risk factors is identified as:

Suit pressure, power consumption, CO_2 removal system consumption, thermal comfort consumables, increased carry weight, dust contamination, accommodation for waste including potential for emisses[sic].

Specific current countermeasure(s) or mitigation(s) identified are:

[All missions]: Regenerable CO_2 removal systems, longer life rechargeable batteries, limited maintenance, dedicated water. [Moon and Mars]: Apollo Era dust mitigation.

Specific projected countermeasure(s) or mitigation(s) identified are:

[All missions]: Regenerable closed loop CO_2 removal systems, longer shelf and service life batteries, increased on-orbit space suit service life, non-venting heat rejection system, cleaning and maintenance of soft goods (e.g., LCVG) [TRL TBD] [Moon and Mars]: Dust removal and dust prevention, reduced mass of suit and PLSS [TRL TBD]

In addition fourteen specific enabling questions are identified ranked in priority by a 1 for high and a 5 for low. These are:

41a. What EVA system design can be developed to reduce the pre-breath requirement? [ISS N/A, Moon 1, Mars 1]

41b. What suit and PLSS technology must be developed to meet mission requirements for EVA mobility? [ISS N/A, Moon 2, Mars 1]

41c. How do we protect against planetary surface dust through suit and airlock system design? [ISS N/A, Moon 1, Mars 1]

41d. How do we protect against toxic fluids and contaminants? [ISS 2, Moon 2, Mars 2]

41e. How do we design space suits to fit multiple crewmembers of various sizes and shapes? [ISS 1, Moon 1, Mars 1]

41f. How do we improve glove dexterity? [ISS 1, Moon 1, Mars 1]

41g. *What technologies can be developed to provide passive or active thermal insulation in various environments, including deep-space and lunar vacuum? [ISS N/A, Moon 1, Mars 1]*

41h. *What technologies must be developed to meet mission non-venting and non-contaminating requirements? [ISS N/A, Moon 2, Mars 2]*

41i. *How do we provide and manage increased information to EVA crewmember, including suit parameters, systems status, caution and warning, video, sensor data, procedures and text and graphics? [ISS N/A, Moon 2, Mars 2]*

41j. *How do we achieve EVA and robotic interaction and cooperation? [ISS N/A, Moon 1, Mars 1]*

41k. *What biomedical sensors are needed to enhance safety and performance during EVAs? [ISS N/A, Moon 2, Mars 2]*

41l. *How can space suit design accommodate crewmember physical changes after long time in microgravity? [ISS N/A, Moon 1, Mars 1]*

41m. *What technology can be developed to monitor EVA crewmember thermal status and provide auto-thermal control? [ISS N/A, Moon 1, Mars 1]*

41n. *Can a practical EMU containment receptacle for emesis be developed? If a vomiting episode occurs, is there a way of refurbishing the suit during the mission? How can suit life support systems be designed to be more resistant to vomiting episode? [ISS 1, Moon 1, Mars 1]*

Note that 10 of the 14 enabling questions are ranked 1 (highest) for Mars with the other 4 ranked 2 on a scale of 1 high and 5 low. Furthermore, many of the benefits derived for the Mars environment will also be applicable to the lunar environment.

4.0 SIGNIFICANCE TO EDUCATION AND PUBLIC OUTREACH

Statement of the Problem:
"The dangerous decline in math and science education poses a greater threat to U.S. national security than any potential conventional war." -------Conference on National Security in the 21st Century

"We've arranged a global civilization in which the most critical elements profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology. This is a prescription for disaster." ------Carl Sagan

"America's pipeline in science and engineering is drying up at a time when the nation is desperate for innovation. The year-over increase in engineering grads in China is greater than the total number of engineers graduating from American universities. Aerospace now presents a negative image to potential employees because of years of cutbacks, consolidation and stagnation. At the same time, NASA's brains and hands are aging. Employees 60 or older outnumber those younger than 30 by 3 to 1." -----New York Times June 8, 2004

The significance of the MarsSuit Project lies in its potential to address the very serious issues described above. Precedent in this approach can be drawn from the Apollo Project era, which experienced a 120% increase in math and science enrollment from 1972-1982, largely attributed to the Lunar landing missions (Figure 1).

The MarsSuit Project will address the following key higher education goals and objectives as identified by NASA's Office of Education and Public Outreach:

- To create and disseminate innovative space life sciences educational materials for university faculty and students;
- To provide educational and training opportunities and courses for undergraduate college students;
- To nurture Project teams focused on interaction and collaboration through yearly workshops;
- To address the technology required to *enable* the next explorers to travel beyond where we have been;
- To address the need to assure human survival and productivity;
- To understand the effect and response of life to gravity and the space environment;
- To provide opportunities for professional development to university faculty, staff, and researchers;
- To identify new opportunities that research (basic and applied) brings to expand the understanding of the laws of nature and enrich life on Earth
- To increase university students' overall scientific literacy through the development and distribution of materials for reading and language arts; and
- To produce and disseminate space life sciences promotional resources for students, educators, families, and the public using a wide variety of printed and electronic media.

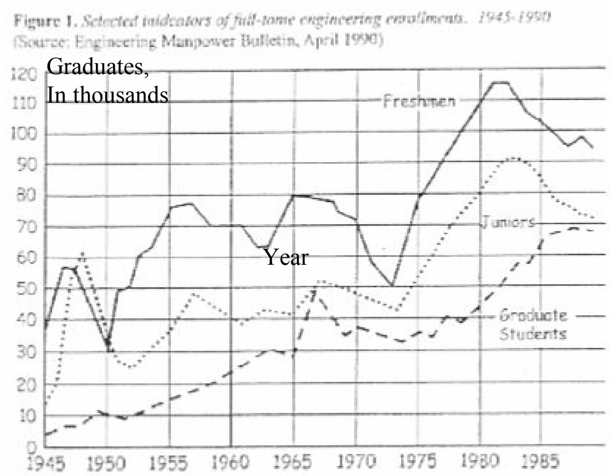


Figure 1. Math and Science graduation rates, 1945-1990. Source: Engineering Manpower Bulletin, 1990

For more information on the goals and critical questions identified by NASA's Office of Education and Public Outreach, please see the 2004 OBPR (Office of Physical and Biological Research) Project Plan in Appendix 7

5.0 TARGETED AUDIENCE AND SCOPE

The primary audience will be students with diverse major fields of interest, from non-traditional and underrepresented backgrounds to traditional ones as well. Participation will focus on the undergraduate university level with some selected high schools possible. Indirect audiences to be targeted include the public at large and external organizations that can contribute to the effort, such as the Universities Space Research Association (USRA), the Texas and National Space Grant consortium, the Mars Society Space Suit task force and the Planetary Society. Some facts on the MarsSuit Project are:

- Participation is expected to be ~1200 undergraduates per academic year for a team size of 12 (= 50 x 12 x 2), not including high school students or participation by external organizations such as The Mars Society. This estimate is based on experience with the pilot program, which had an enrollment that varied between 40 to 60 students per semester
- Participation is expected to grow incrementally as the project expands to additional universities. Growth to 16 university teams will be targeted in later phases, bringing the total number of participants to approximately 1600 undergraduates.
- The geographical reach of The MarsSuit Project will include but not be limited to the continental United States. Expansion internationally to institutions such as the University of Alberta, Canada or the International Space University is a possibility.
- Based on its success, The MarsSuit Project concept can grow into a larger "Synergy Project" (see Appendix 8 and http://mars2012.berkeley.edu). In this expanded phase, The MarsSuit Project would be a subset of the 12 or more elements constituting a human Mars Design Reference Mission, thus multiplying the scope and participation to a potential size of 20,000 students or more.

- Encapsulating external interest groups, the public-at-large and use of this paradigm to similar technical/science venues could extend the reach of this project to a vast audience well beyond initial projections.

6.0 TECHNICAL APPROACH

As annunciated in the Critical Path Roadmap (http://criticalpath.jsc.nasa.gov), a space suit for Mars exploration (MarsSuit) is one of the barrier technologies needed by our next generation explorers to go beyond Earth orbit to the Moon and Mars. The development of a space suit for Mars based on advanced concepts and technologies is crucial because existing space suits will not work on Mars. The current space suit design:

- Is mass intensive with a load of 400 lbs on Earth, equivalent to 152 lbs on Mars
- Uses sublimation for thermal control when Martian atmospheric pressures preclude it
- Will not provide thermal radiation protection, as the multilayer insulation requires a hard vacuum
- Has a severely impaired useful work ability due to a poorly placed center of gravity
- Has non-existent lower mobility because the lower torso is not designed for walking
- Is resource wasteful, leaking up to 50 liters O_2/EVA on a planet where O_2 is rare and expensive
- Is not designed for repeated use in dusty, surface conditions where maintenance is critical
- Has excessive pre-breathe times, resulting in fatigue and reduced surface operation time
- Has severe safety limitations
  - There is no buddy system (EMUs cannot be shared between crewpersons)
  - Useful consciousness is limited to ~11 seconds following a serious puncture

While scrutiny of the above problems by university teams may seem idealistic, several university programs are already doing this on their own with intriguing results, including the University of California Berkeley, Massachusetts Institute of Technology, Stanford University, USNA, University of Maryland, Dartmouth College, University of Alberta, and others. Focused industrial input will enhance this overall capability. The wide scope of creative potential solutions from the university community is best appreciated by examining the partial list below that has already been generated.

6.1 Helmet – Torso Independence

Separating pressurization of the helmet from the torso permits the helmet to be pressurized with O_2 and the torso to be pressurized by the Martian atmosphere. The separation can be achieved by a neck dam or face mask. As a result, the 100% O_2 pressurization of the helmet can be achieved through a design similar to a fireman's re-breather unit. The pressurization of the torso can be achieved by using the atmosphere on Mars (95% CO_2) via a blow-through, suit-worn compressor or pre-loaded CO_2 canisters. For safety, the helmet pressure would be maintained slightly greater than the torso pressure to preclude leakage of CO_2 into the helmet.

Advantages include:

Safety: If puncture of the suit occurs, useful consciousness in current suits is on the order of 11 seconds due to contiguity between helmet and torso. This can be extended to minutes, enabling EVA crewman to take corrective action.

Resources: O_2 is a precious resource on Mars. Current suits leak up to 50 liters O_2 per EVA through soft joints. This suit will primarily leak Mars atmosphere back to its source, saving O_2.

Mass: The torso design can be open loop, using compressed Martian atmosphere in CO_2 canisters to eliminate components that increase the complexity and mass of the current primary life support system (PLSS).

6.2 Layered Space Suit

Adoption of a space suit with removable layers, instead of the current multi-layered insulation, can result in significant potential savings in mass and comfort. Using thermoregulatory models of the human body, combined with models of the Mars environment and potential suit layup (layers of lamina) combinations, it has been shown that it is possible to design a Mars space suit like an arctic suit, with layers instead of thermos-like multilayer insulation. (The latter is problematic on Mars, in any event, due to the presence of a pressure environment; see reference--NRC Senior Fellowship Final Report, NASA-ARC, 1990]. Studies have shown that jacket layers can be added when the crew is doing light work like riding a rover, and removed when heavier work tasks are undertaken. The outer layers can be designed specific to the location on the surface of Mars (poles, equator, etc.), much as they are on Earth. Current computer thermoregulatory models can be instrumental is aiding the design of apparel for astronauts based on the environment and metabolic rate, [Pisacane et al, submitted for publication 2004a].

Advantages include:

- *Mass*: By using a layered design the suit can be less massive, as it does not have to have a universal hot/cold capable system as in the vacuum of space.
- *Comfort*: By donning only layers that are comfortable, the Mars space suit will weigh less and better satisfy the thermal needs of the astronaut.
- *Resources*: Since the layers would be interchangeable from one Mars space suit to another, this would provide redundancy and reduce the total mass needed to be transported.

6.3 Variable Pressurization

Variable pressurization of the Mars space suit using O_2 for the helmet and the native Mars atmosphere for the lower torso has significant advantages besides safety and O_2 conservation. Starting in the airlock at the habitat pressure, then slowly reducing it to 4.2 psi on the surface will greatly reduce long pre-breathe times (currently on the order of an hour or more on shuttle or ISS). This would permit quick transitions from the habitat to the surface to increase productivity and allow rapid donning of the MarsSuit in emergencies. A ramp down in pressure on the surface instead of in the airlock will substantially increase productive endeavors as well. The loss of dexterity during the ramp-down phase at the higher suit pressures is a small price to pay for the ability to egress the habitat rapidly and the potential increase in productive EVA time.

Advantages include:

- *Safety*: Minimal prebreathe time to transition into the Martian environment
- *Productivity*: Increased productivity as initial period on exiting the habitat could be used to transition to the work site during which reduced dexterity may not be an issue
- *Psychosocial*: Knowing that the Mars space suit can be used without a prebreathe delay provides emotionally reassurance in case of emergencies

6.4 Direct Blood Cooling

Heat impairs performance, decreases cognitive ability and reduces endurance. While thermal control is essential to athletes, firefighters and industrial workers, it is also important to astronauts. Overheating in a space suit is of concern due to constrained evaporative cooling of sweat. Current suits utilize the liquid cooling and ventilation garment (LCVG) to transport water through a network of tubing for thermal control. The LCVG requires a cooling liquid, heat exchanger, and regulation/ pumping system and is extremely limited in efficiency. This is especially true in shuttle applications when the cabin temperature is elevated [Pisacane et al, submitted 2004a]. An alternative, developed at Stanford University, is direct blood cooling by heat exchange with the extensive capillary network in the hands and feet. This device has been shown to markedly facilitate heat transfer in the presence of a reduced pressure with respect to the torso. Incorporated into a boot or glove it could provide a more robust, lighter, and simpler means of thermal regulation.

Advantages include:

- *Mass:* Reduced mass due to smaller components and increased heat transfer efficiency
- *Safety*: Reduced risk of hyper/hypothermia; reduced heatstroke potential; increased resistance to cognitive motor task error and increased thermal comfort
- *Productivity:* Permits astronauts to work at higher metabolic rates for longer periods of time than otherwise possible
- *Psychosocial*: Provides a more comfortable working environment

6.5 Anthropomorphics, Human Performance and Countermeasures

The current EMU design does not fit small individuals and makes work difficult for those not optimized to its anthropomorphics. The suit also cannot be effectively used for walking since the lower torso is not designed to traverse a planetary surface. Furthermore, the current design weighs over 400 lbs (with accessories) and places its most mass intensive component, the primary life support system (PLSS), directly over the shoulders. This design would result in a 100 lb PLSS sitting over a 60 lb suit worn by a 60 lb individual on Mars (all Mars weights for a 160 lb person on Earth). The result would dwarf the inefficient “hopping” motion observed on the Apollo missions, assuming the astronauts would be able to move in the first place. The new MarsSuit design will redistribute the PLSS components more uniformly over the torso to bring the center of gravity (CG) lower to the ground; optimize the anthropomorphics for a spectrum of users, and reduce the mass through methods described below.

Another issue involves the lack of a suitable load on the body during the in-flight transit. The muscles, which can normally handle a 50 lb backpack on Earth, will be asked to suddenly don a suit upon landing that will triple the load they might experience on Earth after 6 months in microgravity. The solution may be a suit mass simulator, a piston-like or spring-like device the crewman steps under that simulates the equivalent suit mass on Mars. This countermeasure, used during the transit, would be used to “train” the crew muscles for the expected load of the suit during donning and egress.

Advantages include:

- *Safety*: Reduce the potential of musculoskeletal atrophy or damage
- *Productivity:* Permit astronauts to work at higher metabolic rates for longer periods of time than other wise possible, allow faster egress after landing
- *Psychosocial*: Provide a more comfortable working environment

6.6 Advanced Materials

The design of the MarsSuit would be enhanced if an outer removable and disposable layer were able to protect it against dust and the toxic reactive materials that may be in the Martian soil and air. This “exo-layer” could be made of selective membranes, clean-room type materials, etc. Several candidates are available:

DMMs: Dense monolithic membranes work by an active transport mechanism that allows water to selectively pass through at substantial pressure gradients. Such a DMM might allow astronauts to “sweat” through their pressure bladder to remove body heat by evaporation, as on Earth, while providing toxicity protection and eliminating the need for closed loop thermal control systems that contribute to mass buildup

DEMRON POLYMER: The University of Alberta, Canada, has recently published a peer reviewed article in the Journal of Materials that identifies a radiation shielding polymer that could be used in a Mars EMU. Radiation, both galactic cosmic rays and solar particle events, is problematic on Mars since it lacks a global magnetic field and appreciable atmosphere. Consequently, radiation countermeasures must be considered in the layup (layer of lamina) design.

Advantages include:

- *Safety*: Reduce the potential of habitat contamination and resulting illness and better protection against radiation
- *Mass*: Prolong the life of the space suit while reducing overall mass

Several other overriding issues to be addressed include:

6.7 Planetary Protection

Forward and back contamination whereby Earth biological contaminants are released into the Martian atmosphere or prospective Mars biological contaminants are inadvertently returned to Earth must be guarded against. A NASA committee for planetary protection oversees this increasingly worrisome problem and EMU designs must accommodate this concern. One possibility is to install viral/bacterial filters within the EMU ventilation air stream. Mass, disposability/sterility, delta P issues, and safety must all be considered in the design of this system.

6.8 Radiation Protection

Without a global magnetic field, astronauts face significant risk on Mars, and similarly on the Moon, due to galactic cosmic rays and solar particle events. The potential for incorporating a real-time microdosimeter into a space suit is a reality. The USNA is developing low mass, low power, solid-state, and robust microdosimeters for space applications that may be configured for space suit applications, [Pisacane et al, 2004 b].

6.9 Smart Technologies

Several of the technologies extant in the Apollo and Skylab EMUs have been compromised or lost. These include:

- Real time management of metabolic rates during all lunar surface and Skylab EVAs
- Real time management of EMU consumables during lunar surface and Skylab EVAs
- Real time management of astronaut thermal comfort and safety during lunar surface and Skylab EVAs
- Real time management of science and traverse objectives during lunar surface EVAs
- Pre mission predictions/post-mission correlations to verify and improve predictive capabilities and increase mission efficiency

6.10 Mass Breakdown and Analysis

Apollo suits weighed 220 lb on Earth, but only 37 lbs on the Moon. That same suit would weigh 84 lbs on Mars. Current suits weigh nearly twice as much as an Apollo suit making their use prohibitive. In addition, the current suit uses a thermal control system based on sublimation of water. The pressure of Mars (7-10 mb) precludes sublimation, rendering this approach useless. Consequently, a detailed mass analysis of current suits must be performed and a new design created to limit equivalent mass to a maximum of 50 lbs on Mars or 132 lbs or Earth. This requires an extreme reduction of nearly 2/3.

One approach is to use an open loop compressor to simply blow the cold, dry mars atmosphere through the lower torso, as described earlier. This simple approach could shed mass and complexity by the elimination of closed loop hardware from the current system (pumps, fans, heat exchangers, etc.). The compressor would work in conjunction with a relief valve set to the desired pressure (e.g., 4.3 psi) and could either be part of the PLSS if safety, size, power and mass permit, or used externally to pressurize canisters of Mars CO_2 that would then plug into the PLSS for blow-through pressurization. The thermal limits of evaporative cooling in such a design may not be enough to handle peak metabolic loads so a supplementary LCVG using direct blood cooling may be required for those EVAs where high workloads are anticipated.

A MarsSuit design incorporating the above is shown below. Additional details on the above concepts and others are shown in Appendix 10.

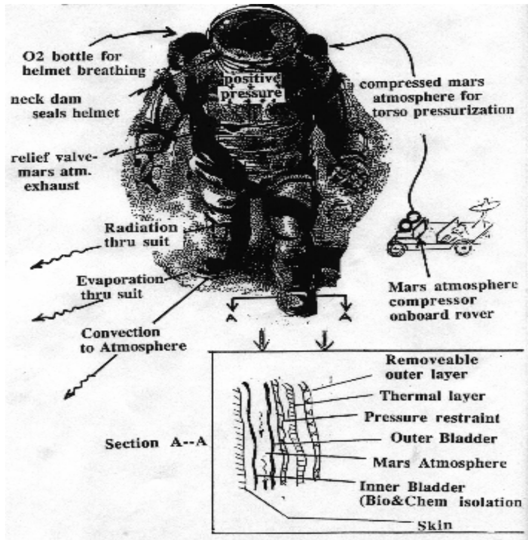


Figure 2. Mars atmosphere open loop pressure suit.

7.0 PROJECT MANAGEMENT

The MarsSuit Project management will be based on the following approach:

- Project Structure: Government/University/Industry Synergy
- Basis: Project partitioned into twelve (12) fundamental technical elements (Figure 3) and six (6) work packages (Figure 4), with teams organized around the work packages
- Organization: Multi-university/Industry teams in a "Virtual NASA" mirroring an actual project office with a strong systems engineering capability to assure an integrated result
- Communication: Interactive Design Environment (IDE) within University Collaborative Center (UCC)
- Establishment of a NASA Advisory Panel to assure relevance to NASA needs
- Establishment of an Industrial Advisory Panel to assure easy turn-over to industry

The MarsSuit Project divides the MarsSuit into 6 major work packages, grouped around the technical elements. These are shown in Figure 4 and consist of the following:

- Pressurization, thermal, environmental control and life-support
- Helmet, torso and PLSS design, anthropomorphics, sizing and mass reduction
- Life sciences: countermeasures, forward/back contamination, radiation, etc.
- Smart systems, materials, sensors and displays, precursor mission drivers, Web IDE design
- Surface Ops--Mars science, mission/traverse planning, robotics, in-situ resource use
- Power and subsystem tradeoffs; systems integration

The administration, organization and dissemination of information are structured around these work packages as shown in Figure 5. In this concept, 12 groups of university/industry teams are initially assigned responsibility to the elements based on prior experience, skill level and interest, with potential growth to 16. The specific participants will be chosen from a workshop co-hosted by NASA's EVA Program Office and the USRA. Invited teams will consist of universities having significant NASA research experience partnered with non-traditional underrepresented or minority institutions. Teams in the former category with a rich legacy of NASA participation include: the USNA, Massachusetts Institute of Technology, University of Texas, Johns Hopkins School of Medicine, University of Maryland, University of California Berkeley, Stanford University, University of Washington, Purdue University, Dartmouth University, Penn State University, University of Michigan, University of Missouri, Rice University and others. Letters of support and willingness to participate are provided in Appendix 1. In addition, letters of support are also included from Hamilton-Sundstrand and ILC Dover (providers space suit components and LCVGs to NASA); Dr. M. Gernhardt, lead astronaut for exploration suit development; Joseph J. Kosmo, NASA's Senior EVA Project Engineer at JSC's Crew and Thermal Systems Division; and Steve Doering and Glen Lutz of the EVA Program Office at JSC.

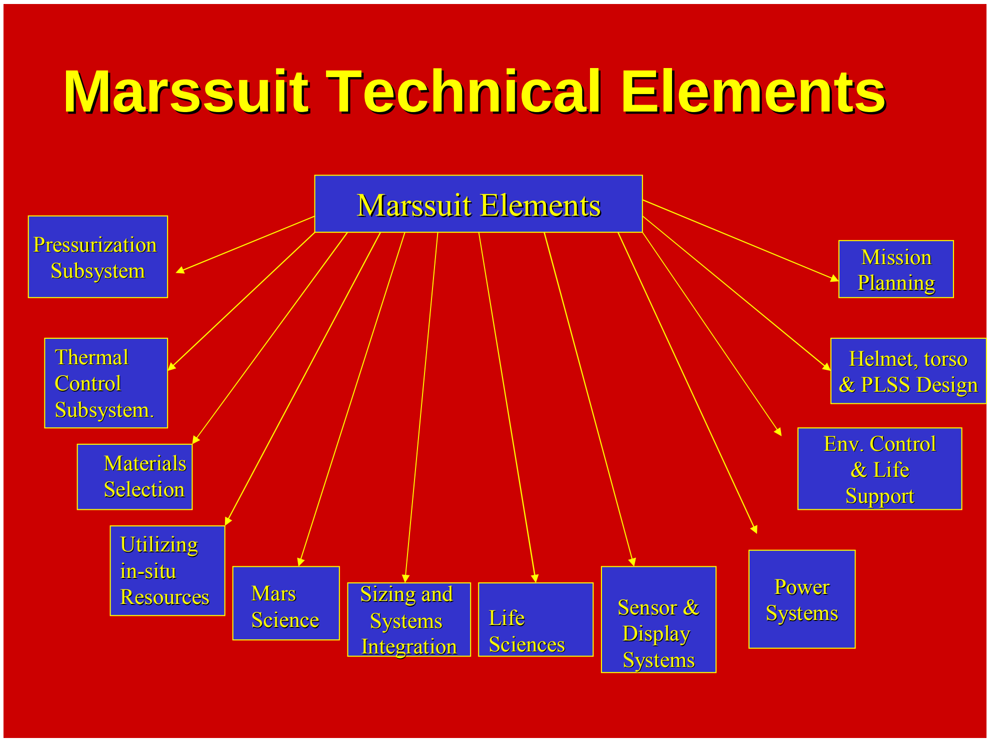
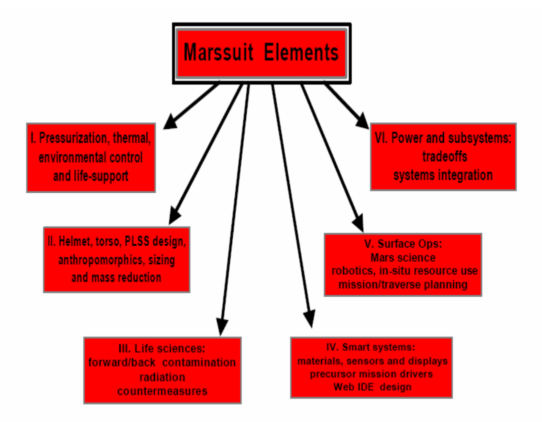


Figure 3. MarsSuit technical elements.



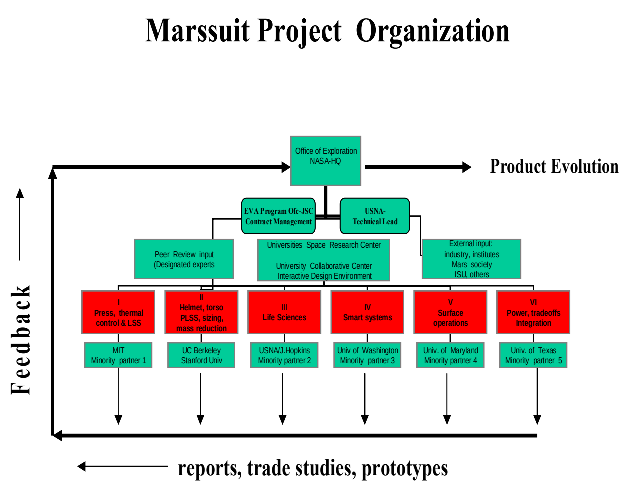


Figure 4. Work Breakdown Packages. **Figure 5. Project organization (Teams in Green).**

(See Appendix 11 for expanded view)

8.0 UCC – THE PROJECT COMMUNICATION AND INTERFACE TOOL

The MarsSuit Program will implement the University Collaborative Center (UCC) as the nexus between the project management and the university/industry teams. The UCC will be stewarded by the USRA Center for Advanced Science Studies in Houston, Texas (CASS). Principal features and functions of the UCC are:

- A location in which the university/industry teams can collaborate on the project
- Serves as a combination of centralized and distributed computing capabilities where universities and industries "link in" via standard client software, using standardized procedures
- Provides collaboration tools to allow teams of universities/industry to work together as a virtual project office.
- Provides an organized repository for all project data so that project continuity in maintained over the life of the project
- Allows teams to pool their resources to support the project
- Provides the university/industry community access to NASA's tools and technology to bring to bear on project
- Provides training to universities on collaborative methods and technologies
- Supports project development among the university/industry community

The Interactive Design Environment (IDE) is the web-based project tool that provides the virtual links between Project Leads and all university/industry teams. It acts like a ship's navigation wheel, with spokes between the Project Leads and all organizational components (see Figure 5). This approach is based on a prototype of the IDE that was developed at UC-Berkeley (see section 13). The IDE will provide the following:

- Information exchange
- Intra/inter university team communication
- Up-to-the-minute daily news reports about Mars and team activities
- Team chat-rooms
- Threaded discussions accessed by date, author or subject
- Data archives
- Brainstorming support
- Archived meeting minutes to facilitate quick learning curves
- Access to links, subject matter, experts and peer reviewers
- Access to tools outside each university's domain
- Digital prototyping and virtual mockups through "whiteboards"
- Peer Review input

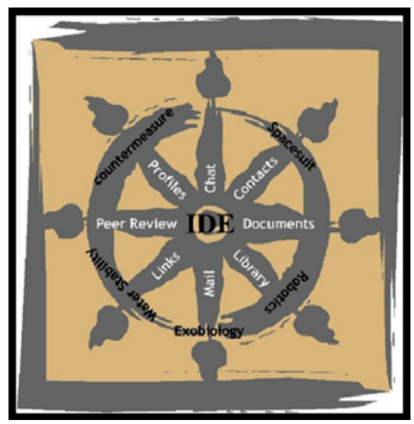


Figure 6. Interactive design environment.

The IDE, operated through the USRA/CASS, will be standardized and password-accessible for all MarsSuit Project team members, with appropriate firewall protection. The primary benefit of the IDE is to provide evolutionary growth in the face of constant student workforce turnover. Project maturity will result from constant feedback from the NASA/faculty/industry community to the IDE (Figure 5).

9.0 MEASURES TO DETERMINE PERFORMANCE

The proposed MarsSuit Project Review and Evaluation Plan will address both Project Merit and Evaluation, and the collection and review of descriptive statistics targeted towards Project Monitoring. As an external evaluator, the USRA will develop and execute the Project Review and Evaluation Plan. USRA will continually monitor the project's progress in order to conduct an independent, yearly evaluation of the overall effort.

The goal of Project Evaluation will be 1) to create an information base through which the MarsSuit Project Team can communicate the value of the project to NASA and all relevant stakeholders, and 2) to identify aspects of the project that require improvement to enable the project to reach its mission goals and objectives. Project Evaluations will be annual systematic examinations conducted by external evaluators; e.g., expert university panels charged with assessing overall program outcomes. This group will review the use of best practices, and suggest improvement. These may be of the summative or formative variety.

Project Monitoring will be completed by the USRA evaluation staff with input provided by participants and Project Team members. The purpose is two-fold: to collect data on project characteristics and events on a continuous basis, and to build evaluation competence among participants. Such assistance is intended to inform the project leads about the extent to which program goals and management objectives are being met. Project monitoring begins with consultation between the evaluation staff and the cognizant team leads. The performance of all student projects will be evaluated to determine their effectiveness, efficiency, and equity. Through this evaluation, USRA will document the progress and performance of goals established in the planning process. In addition, USRA will conduct impact studies to evaluate outcomes. These internal staff studies will yield a report on outcomes that focus on data collection, and analysis. Key project evaluation criteria will answer the following 3 questions:

- *Program Evaluation: Why do we do it?*
- *Program Monitoring: What do we do?*
- *Impact Studies – How do we use the results?*

This three-tiered evaluation process serves two, complementary functions: In one context, the aim is prospective or *formative* - to improve, to understand strengths in order to amplify them, or to isolate weaknesses to mend. The other context is retrospective, or *summative* - to assess concrete achievement. For more details on the process that address the 3 questions, see Appendix 7.

10.0 MEASURES TO ADDRESS PITFALLS

In an academic setting emphasizing math and science skills, discouragement, intimidation, and a sense of rejection or failure can frequently result from competition against others. This is especially worrisome in a project that pairs traditional centers of excellence such as MIT and Stanford with underrepresented minority institutions. To avoid this serious pitfall, The MarsSuit Project will stress a sense of accomplishment within the TEAM concept. Based on a model similar to that used by NASA branch chiefs and section heads, each team leader will use milestone markers and inputs from other team members to assess individual performance. In lieu of standardized tests, the traditional measure of performance, the achievement of goals within the team will be paramount. Evaluations must still be objective, quantifiable and measurable, as with standardized tests, but in this case, *achievability,* or *the accomplishment of realistic, individualized goals* within the organization will be emphasized

- To avoid the pitfall of programmatic failure, each university program will be continually monitored by the peer review and feedback mechanisms described in the previous section. In this framework, each university team is responsible for one or more MarsSuit project elements. Each is assigned an expert advisor to provide input and critique overall performance on a semester-by-semester basis. When appropriate, progress will be evaluated as it is at NASA, with Preliminary and Critical Design Reviews (PDR and CDR) or similar milestones.
- It should be emphasized that while building a fully-qualified, pressurized MarsSuit suitable for the human exploration of Mars is not an expectation of this project, creative student breakthroughs contributing to its design certainly are. In this case, the “not invented here, can’t do” attitude frequently expressed by overworked program managers towards outsiders may be the single biggest obstacle to accomplishments. This attitude will be overcome by the unbridled enthusiasm, exuberance and limitless boundaries of the youthful student workforce comprising the MarsSuit teams. Insight is provided in solar car design, where breakthroughs are the norm in a project strikingly similar to the MarsSuit Project (please see Appendix 12.)

11.0 ACHIEVEMENT OF OUTCOMES

The expected outcomes of The MarsSuit Project fall into 3 categories: Research Outcomes, Education Outcomes and Outreach Outcomes.

Research Outcomes fall into 2 categories: hardware and software

- Hardware. The first hardware components of a human-testbed, pressurized MarsSuit will begin to take shape as a technology demonstrator by the end of 2008. These products will demonstrate such concepts as separate helmet/torso isolation systems, automated sensors to assess crew health and placement of the CG to optimize mobility and work performance.
- Software. Phase 1 will culminate with software studies targeting substantial mass reductions from existing EMUs. A design target of 132 pounds Earth mass (50 pounds on Mars) will be used as the upper limit sum

for all components. Other software studies will provide parametric tradeoff studies of candidate EMU design concepts, thermal and life support models of these concepts and improvements in IDE/UCC architecture.

Education Outcomes. By being in the forefront of the design team process, students will:

- acquire schedule, milestone and delivery skills, including PDR and CDR
- be exposed to the interaction of cross-disciplinary fields such as engineering, life sciences, astrobiology, physics, space science, geology and chemistry in a real world setting
- take an active role in the research process
- learn to organize, write and present technical papers
- experience career-shifting or strengthening motivation (see Appendix 3)

Using the UC Berkeley pilot project as a basis (see section 13), 9 publications with the names of over 50 students per year can be expected from each undergraduate university team, or a total of 108 technical papers or presentations in the first year of The MarsSuit Project alone.

Outreach Outcomes. The opportunity to participate in the design of a key component of the first human exploration of Mars will draw great interest from the outside community. As indicated by news articles and a CNN special report on the subject (see Appendix 6), interest from the media reflecting on NASA in a positive way is an early expectation. Based on the number of technical papers and presentations described above, invitations to many technical conferences and venues is also to be expected, with associated job offers, scholarships, etc. Other Outreach outcomes expected during Phase 1 include:

- Expansion of the concept to other Mars-related projects
- Involvement of more students through outreach efforts
- Grassroots support for the new exploration initiative
- Congressional and political support
- Interest from diversified, non-traditional and minority students
- Fostering of other university/NASA/industry cooperative projects
- Participation by external advocate groups such as The Mars Society
- Opportunities for participation by the International community (International Space University, ESA and others)

12.0 PROJECT SCHEDULE

The MarsSuit Project will begin in late 2004 or early 2005 with the selection of the:

- Twelve teams (universities including Historically Black Colleges and Universities, NASA and industry affiliates)
- Technical Assessment Panel
- Educational Assessment Panel
- Systems Engineering Working group

The project plan utilizes the spiral development process that includes incremental development for each cycle with a reassessment of requirements, risk, and assumptions; development of a conceptual design; evaluations of selected key technologies; and an evaluation of lessons learned. Each cycle will include review by the key stakeholders of the proposed operational concepts, technology status, requirements, architecture, prototyping results, and feasibility rationale. Anticipated milestones are summarized as follows with detailed planning to involve the representatives from the participating institutions. Following a start-up year, it will take three major cycles of three-years each to achieve the ultimate goals of a Mars Space suit. Within each major cycle are yearly cycles to incrementally enhance the development to assure that a useful product is developed that includes the latest technology capabilities.

Startup Year 2005

- Establish the 12 university lead teams
- Establish Education and Technical Assessment Panels
- Establish the Systems Engineering Working Group
- Hold planning telecon with team and institutional leads
- Kickoff telecon involving all participants project leads
- Syllabus, texts, lecture derived from Berkeley pilot disseminated
- Web IDE linkage to UCC and Virtual Project Office (USNA) established
- Initial requirements established
- Begin technology assessments
- Monthly status meetings over IDE with teams
- Mid-year telecon involving all teams
- End of Year Status
    - Technology assessment completed
    - Requirements updated and reviewed
    - Risk assessment
    - Preliminary system concept established
    - Technical assessment completed
    - Education assessment completed
    - Year-end report completed
- Effect organizational changes if necessary

First and Second Year of Major Cycle, Years 2006, 2007, 2009, 2010

- Review and update requirements
- Evaluate applicable technologies
- Develop system concepts
- Monthly status meetings over IDE with teams and faculty
- System and subsystem tradeoff studies initiated
- 6 month status telecon, all teams,
- End of year Status
    - Technology assessment updated
    - Requirements updated and reviewed
    - Risk assessment updated
    - Preliminary system concept updated
    - Conceptual design updated
    - Technical assessment updated
    - Education assessment updated
    - Year-end report completed

Final Year of Major Cycle, 2008, 2011

- Review and update requirements
- Continue evaluation of applicable technologies
- Continue conceptual design
- Update system concept
- Monthly status meetings over IDE with teams and faculty

- System and subsystem tradeoff studies initiated
- 6 month status telecon, all teams,
- End of major cycle status
    - Technology assessment updated
    - Requirements updated and reviewed
    - Risk assessment updated
    - Preliminary system concept updated
    - Conceptual design updated
    - Technical assessment updated
    - Education assessment updated
    - Major cycle summary report completed

MarsSuit Project milestones are illustrated above and will be implemented in three major spiral phases each containing a yearly spiral development after the start up year. Each major spiral contains a yearly spiral development. Each successive major phase will be funded *if* and *only if* the success-oriented metrics discussed in Sections 9-11 are achieved. Initial kickoff will begin in early 2005 with the selection of the university teams and their designated NASA/industry peer reviewers. A standardized syllabus will be available for dissemination to the teams by the fall 2005 semester, including texts, lecture modules and design project guidelines. Teams will be linked to their point contacts through the UCC by the last quarter of 2005, forming the first Virtual MarsSuit Project Office. In 2006, additional teams will be added to the project, and project element reports will begin to flow over the IDE between teams and the project element leads for peer review. Likewise, NASA/industry subject matter will begin to flow over the IDE from the UCC. In 2007, more teams will be added to encompass greater geographical and non-traditional student involvement. The first integrated design of the MarsSuit will also begin to take place in 2007. Although peer review of the individual project elements will be ongoing over the UCC and annually at an Annual Design Review, the first detailed review of an integrated MarsSuit prototype will not take place until the end of Phase 1 in late 2007 at the PDR. Funding for phase 2 will be contingent on satisfactory completion of PDR and the programmatic metrics of Sections 9-11. Assuming this occurs, Phase 2 will be dedicated to maturation of the design process culminating with a CDR in late 2009/early 2010. As before, funding for Phase 3 will be contingent on CDR and programmatic evaluation metrics. Phase 3 will then focus on building hardware prototypes and testing in simulated environments such as Haughton Crater or Antarctica or thermal chambers provided by NASA. If the program continues beyond Phase 3, its scope will expand beyond MarsSuits to additional elements of NASA's Design Reference Mars mission, such as Habitat Design, Power Systems, etc. (see Appendix 8).

13.0 RELATION TO PREVIOUS WORK

The MarsSuit Project is grounded in the 5 year "Mars2012" proof of concept pilot program directed by Dr. Lawrence Kuznetz at the University of California, Berkeley (NASA/CR-2002-210914, NASA Ames Research Center, Moffett Field, Calif., and http://mars2012.berkeley.edu). Dr. Kuznetz, skilled in a background of Mars science, operations and EMU design and the coordination of multiple undergraduate design projects, created "Mars2012" at UC Berkeley for the express purpose of identifying new technology that could be used in a Mars space suit and also to narrow the science literacy gap. Using space exploration as its vehicle, the program targeted a diverse, multi-disciplinary and multi-ethnic group and enlisted their support in solving real problems related to human and robotic Mars missions. The program combined lectures given by experts in the field from NASA-JSC, Ames Research Center and Jet Propulsion Laboratory with design projects as diverse as space suits for Mars, drilling for water, extremophile survival in Mars environments and countermeasures to bone loss. Students took an active role in the planning and research process with the assistance of senior citizen mentors having expertise in the relevant fields of study. Student teams were organized into subgroups focusing on specific questions about living and working on Mars, while studying the atmosphere, soil and biological properties of the planet itself. The program was highly interdisciplinary and attracted faculty sponsors from Physics, Molecular and Cell Biology and Integrative Biology, including Dr. Walter Alverez, the author of the prevailing theory of species extinctions due to meteorite collisions with Earth. The success of the program received national attention. In 1999-2000 alone, 9 publications with the names of over 50 students, all undergraduates, were presented at national and international meetings, and the course was the subject of CNN special report on education (see Appendix 6). The supporting faculty considered this a stunning accomplishment (see Appendix 3). This is by no means the only undergraduate program targeting Mars mission

studies, however. Similar accomplishments have been achieved by Professors Dava Newman of MIT; David Aiken of the University of Maryland; Professor Vincent Pisacane of the USNA; Jay Buckey of Dartmouth College; Barry Padgett of the University of Alberta.
See: http://www.engineering.ualberta.ca/nav02.cfm?nav02=27242&nav01=18430) and others.

In addition, the MarsSuit Project will be based on practices and lessons developed from precursor/current programs such as:

Undergraduate

- NASA/KSC Spaceflight & Life Sciences Training Program
- NASA Space Grant College & Fellowship Program
- NASA/USRA Advanced Design Program

Team Projects

- Secondary and College Education for the Next Generation of Space Life Scientists
- Northwest Outreach Program on Space Biomedical Research (University of Washington)
- Defying Gravity: Embracing Life in Space (Mt. Sinai)
- Space Biomedical Sciences & Engineering Curriculum and Outreach (MIT)

14.0 ROLES AND RESPONSIBILITIES

Project technical leadership will be under the auspices of Professor Vincent L. Pisacane of the USNA, and Dr. Lawrence Kuznetz, who will report to the EVA Program Office at NASA-JSC and the NASA Exploration Office at NASA HQ for technical input and contract management respectively (see figure 5).

Dr. Vincent L. Pisacane is the Robert A. Heinlein Professor of Aerospace Engineering at the USNA and teaches courses in spacecraft communication and power, astrodynamics, thermal control systems, space environment, and space physiology. Dr. Pisacane has extensive experience in the development of space systems, extensive teaching at the graduate and undergraduate levels, and has edited a textbook undergoing it second edition on space systems printed by Oxford University Press, [Pisacane and Moore, 1994]. He has held a Summer Faculty Fellowship at NASA/JSC and worked with Dr. Kuznetz in evaluating the effect of increased cabin temperature on the thermoregulatory system of astronauts wearing the Advanced Crew Escape Suit (ACES), [Pisacane et al 2004a]. He will direct the overall program especially from the aspect of systems engineering that is required to develop an integrated design. Dr. Pisacane has carried out extensive NASA research having been co-investigator on development of a mini-mass spectrometer, and dual energy X-Ray absorptiometer for space. He has been the leader of the technology team of the National Space Biomedical Research Institute (NSBRI) and principal investigator on the development of a space qualifiable MRI and is currently funded by NSBRI grants to develop a space qualifiable solid-state microdosimeter and for the flight test of an early version on the MidSTAR-I spacecraft being developed by the USNA for the Space Test Program of the Air Force. Dr. Pisacane is an experienced space systems engineer with experienced in managing large complex organizations; experiences that are most appropriate to his role in this program. He was the Department Head of the Space Department of the Johns Hopkins University Applied Physics Laboratory where he had responsibility for approximately 400 people and an annual budget of over $100 million dollars and Leader of the NSBRI Technology Team. He has written on space systems engineering [Pisacane and Moore, 1994] and teaches short courses on the subject. In the area of space suit design, Dr. Pisacane and Dr. Kuznetz collaborated on the assessment of the effect of increased cabin temperature on astronauts while in the ACES used in the shuttle. A paper on that research has been submitted for publication in the AIAA Journal. Dr. Pisacane will spend 15% of his time on this project. Please see curriculum vitae for additional details of his capabilities.

Dr. Lawrence W. Kuznetz, currently with the NSBRI, will be co-project manager with Professor Pisacane. Dr. Kuznetz will relocate from his post at the NASA Johnson Space Center to the USNA in the position of research professor (see Appendix 2) for appointment letter). Dr. Kuznetz will spend 100% of his time devoted to this activity. As the director and creative force behind the Mars2012 pilot project at UC Berkeley, Dr. Kuznetz is familiar with the university community, experienced in the coordination of multiple undergraduate design projects and skilled in a background of Mars science, operations and EMU design (see resumes, Appendix 14). He will use this experience to administer the MarsSuit Project with Dr. Pisacane. His duties and responsibilities as such will be technical project management, including selection of texts, guest lecturers and syllabus for the project; coordination of university teams, including designation of roles and responsibilities; selection, coordination and communication with project consultants, industry partners, external contributors and media; travel between partnering sites, including guest lectures; organization and implementation of all reviews, including annual design reviews, kickoff and midyear teleconferences; and evaluation of overall team and project performance, including attainment of milestones and budget guidelines. In addition, Dr. Kuznetz will use his background in Mars planetary science and EMU design to contribute technology alternatives to the project and solicit external solutions from the external research community, including industry, the Mars Society and others, [Kuznetz, 2002a, 2002b, 2000, 1991a, 1991b, 1992, 1990].

As discussed earlier, Professor Pisacane and Dr. Kuznetz will be assisted by a NASA advisory panel and an industrial advisory panel. Although a background in Mars science, EVA operations and EMU design is imperative, it is essential that the makeup of these panels also include individuals familiar with the university community and experienced in the coordination of multiple undergraduate design projects. As such, selected individuals from NASA, industry, the university community and institutes such as the USRA, the Texas and National Space Grant Consortium, the NSBRI and others have been contacted and offered their support (see Appendix 1). Key personnel serving on these advisory panels are identified in the preliminary staffing and human resource list of Table 1.

The USNA is the appropriate place to host the MarsSuit Project since it:

a. Has a strong aerospace engineering department
b. Is the parent institution of more than a dozen astronauts that still have a relationship with the institution and can be used in advisory roles
c. Carries out research for NASA, Navy, Air Force, and other DOD agencies
d. Develops small satellites for the Air Force Space Test Program and other NASA missions of opportunity (PCSAT-1, PCSAT-2, MidSTAR spacecraft)
e. Has been a participant in the NASA KC-135 reduced gravity test flight program at the Johnson Space Flight Center
f. Recipient of NASA and NSBRI research funding

The USNA fared well in the recently published U.S. News and World Report's annual edition of "America's Best Colleges." In that publication, USNA was ranked as the #6 engineering school in the country. Similarly, our Aerospace Engineering program was ranked #3 in the nation.

The Aerospace Engineering Department offers one of the most exciting and challenging academic programs at the USNA. The program is structured to produce naval officers who will meet the challenges of serving in such areas as naval aviation, naval research, and the Naval Space Command. The major is accredited by the Engineering Accreditation Commission of the Accreditation Board of Engineering and Technology. The Aerospace Department offers two specific tracks of study in Aeronautics and Astronautics. The USNA's aerospace laboratory facilities are some of the most advanced and extensive in the country. These facilities include structures, propulsion and rotor labs, various wind tunnels with flow velocities ranging from subsonic to supersonic, computer labs, the Satellite Artificial Intelligence Laboratory, and the USNA satellite tracking station. Graduates from the aerospace engineering major are also fully prepared to undertake postgraduate education programs in engineering disciplines either at the Naval Postgraduate School or any other academic institution. The aerospace major provides a great foundation for many opportunities including the astronaut program. *More than a dozen astronauts are graduates of the USNA's Aerospace engineering Department.* A yearly colloquium of USNA astronauts is held with the next scheduled for 1 March 2005.

15.0 BUDGET AND COST SHARING

The program budget, with phased funding profiles from 2005-2012 is shown in Table 2. The USNA is a government facility and the project lead and co-lead will be government employees. All costs are actual costs based on full cost accounting. The USNA does not charge overhead on its research grants and contracts. Consequently, all supplies and equipment needed to carry out the proposed research must be budgeted on the grant. Cost sharing is generally accomplished at other institutions by reduction of overhead. With no indirect charges, there is no ability to cost share. However, the lack of overhead can be interpreted as equivalent cost sharing at a level of over 60%, the overhead at most universities.

Table 1. MarsSuit Project Staffing -Projected or Identified

Individual	*Org.*	*Role*	*Funding source*	*P/F/A time part/full/advis*	*Cost*
L Kuznetz	SPLS JSC	lead	NSBRI/ NASA	F	1 FTE
V. Pisacane	U.S. Naval Academy	Co-lead	MarsSuit budget	P	
P. Gannon	Mt Sinai	Co-lead	MarsSuit budget	P	
J. McBarron	NASA-JSC (retired)	Consultant	MarsSuit Budget	P	
T. Budinger ***D. Gan***	UC Berkeley	Consultant	MarsSuit Budget	P	
H. Vykukol	NASA.ARC (retired)	Consultant	MarsSuit Budget	P	
Joe Kosmo ***Mike Rouen*** ***Amy Ross*** ***Dave Mckay*** ***S. Doering*** ***L. Kearney*** ***L. Trevino*** ***R. Trevino*** ***W. Mendel***	NASA JSC	Peer review	N/C	P	
K Hudkins ***D. Cook***	NASA HQ	Peer review		P	
C. McKay ***C. Stoker*** ***M. Cohen***	NASA ARC	Peer review		P	
M Seibert ***TBD-sensors***	NASA GRC	Peer review		P	
M. Hecht ***D. McCleese***	NASA JPL	Peer review		P	
M.Gernhardt	NASA-JSC	Advisor		A	
Ed Hodgson	Ham Sunstr	Advisor		A	
Paul Webb	Honeywell	Advisor		A	
C Gilman	Global Fxs	Advisor		A	
J. Bucky	Dartmouth	Advisor		A	
D. Newman	MIT	Advisor		A	
J. Cardenas	USRA	Advisor		A	
W. Fowler	Texas Space Grant Chair	Advisor		A	

<u>Table 2. MarsSuit Project Phased Funding Profile</u>

Year	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*
Teams	0	12	14	16	16	16	16	16	16
Team budget	0	480 K	560 K	620 K	620 K	620 K	620 K	620 K	620 K
Leads/Co-leads	200 K	200 K	200 K	200 K	200 K	200 K	200 K	200 K	200 K
Consultants	50 K	100 K	100 K	100 K	100 K	100 K	100 K	100 K	100 K
Manuf. costs		50 K	100 K	150 K	150 K	150 K	150 K	150 K	150 K
Travel	10 K	20 K	40 K	40 K	40 K	40 K	40 K	40 K	40 K
Conferences			60 K	60 K	60 K	60 K	60 K	60 K	60 K
Web (IDE)		20 K	20	20 K	20 K	20 K	20 K	20 K	20 K
Miscell.	5 K	20 K	20 K	20 K	20 K	20 K	20 K	20 K	20 K
Total	265 K	890 K	1.1 M	1.21 M	1.21 K	1.21 K	1.21 K	1.21 K	1.21 K

Prelim Design Review   Critical Design Review

Phase 1 (2004-2007) = $3.46M (4 yrs)
Phase 2 (2008-2009) = $2.42M (2 yrs)
Phase 3 (2010-1012) = $3.63M (3 yrs)

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Pisacane, V.L., Ziegler, J.F., Nelson, M.E., Caylor, M., Flake, D., Heyen, L., Youngborg, E., Rosenfeld, A.B., Cucinotta, F.A., Zaider, M., Dicello, J.F., "MIDN: A Spacecraft Microdosimeter Mission," 14th Solid State Dosimetry Conference, Yale University, New Haven, 27 June -2 July 2004 b, (being reviewed for publication in Radiation Protection Dosimetry).

APPENDIX 1. LETTERS OF SUPPORT

1. Hamilton Sundstrand
2. ILC Dover
3. Johns Hopkins School of Medicine
4. Massachusetts Institute of Technology
5. Dr. Mike Gernhardt, NASA Lead Astronaut, Exploration Suit Development
6. Mr. Joe Kosmo, JSC Senior Project Engineer, EVA and Space suit Systems
7. Purdue University
8. Rice University
9. Stanford University
10. Universities Space Research Association
11. University of California Berkeley
12. University of Texas
13. University of Washington
14. Mr. Steve Doering and Mr. Glenn Lutz, EVA Program Office, NASA-JSC

Hamilton Sundstrand
Space Systems International, Inc.

One Hamilton Road
Windsor Locks, CT 06096-1010
Tel: 860-654-6000

Hamilton Sundstrand
A United Technologies Company

September 2, 2004
BD 04-171

Professor Vincent Pisacane
Aerospace Engineering Department
United States Naval Academy
590 Holloway Road
Annapolis, Maryland 21402-5042

Subject: NASA Research Solicitation - NNH04ZUU003N-NSBRI – Letter of Support for MARSSUIT Project

Dear Professor Pisacane,

Hamilton Sundstrand Space Systems International, Inc. (SSI) is very interested in your proposed work in the area of Mars Suit component design concepts and engineering, and we would encourage the NASA NSBRI program to fund your proposal entitled "MARSSUIT Project."

Hamilton Sundstrand Space Systems International has a core interest in Space Suit life support and thermal management systems. The development of design concepts in the areas of Mars Suit life support and environmental control, PLSS design, life sciences, smart systems, sensors, smart operations, and systems engineering would be very useful in our efforts to develop components and systems for use in future planetary exploration space suit systems.

We support your proposal, and would be pleased to provide consultation to assist you in the development and review of your design concepts.

Sincerely,

HAMILTON SUNDSTRAND SPACE SYSTEMS INTERNATIONAL, INC.

William F. Higgins
William F. Higgins
Advanced Systems Program Manager

Cc: E. Hodgson

ILC DOVER, INC.

Designer and Manufacturer of
Apollo, Skylab and Shuttle Space Suits

September 2, 2004

Vincent L. Pisacane, PhD
R. A. Heinlein Professor of Aerospace Engineering
United States Naval Academy
Aerospace Engineering Department (Stop 11B)
590 Holloway Road
Annapolis MD 21402-5042

Subject: Interest in MARSSUIT Project

Dear Vince,

This letter is to confirm ILC Dover's interest in participating in the project you intend to propose in response to NASA research solicitation NNH04ZU003N-NSBRI in the area of New Technology for development of an advanced spacesuit known as MARSSUIT.

ILC's forty years of experience in developing advanced spacesuit concepts and technologies for NASA can be directly applied to the proposed development project. And, because ILC has been NASA's supplier of spacesuits since Project Apollo, we offer an extensive base of practical applications and solutions to the team.

I appreciate you considering ILC Dover for your proposed project.

Sincerely,

for: Philip M. Spampinato
Product Manager, Space Systems
ILC Dover LP
302.335.3911, ext. 350
spampp@ilcdover.com

ILC–Innovation, Leadership and Commitment

One Moonwalker Road · Frederica, Delaware 19946-2080
Telephone (302) 335-3911 · Fax (302) 335-0762

JOHNS HOPKINS
MEDICINE

Department of Radiation Oncology and Molecular Radiation Sciences

401 North Broadway / Weinberg Building / Suite 1440 / Baltimore, Maryland 21231-2410

John F. Dicello, Ph.D.
Professor of Radiation Oncology
Professor of Oncology
Joint Appointment in School of
Hygiene and Public Health
Department of Environmental Health Sciences

410-614-4194 / 410-502-1419 Fax
diceljo@jhmi.edu

September 2, 2004

Vincent L. Pisacane, PhD
R. A. Heinlein Professor of Aerospace Engineering
United States Naval Academy
Aerospace Engineering Department (Stop 11B)
590 Holloway Road
Annapolis MD 21402-5042
Joint Appointment, Part-Time
Johns Hopkins School of Medicine
Department of Biomedical Engineering
Email: pisacane@usna.edu
Phone: 410-293-6412; Fax: 410-293-2591

Dear Vince:

I am writing to assure you of my interest in the proposed research on a Mars space suit for astronauts by Dr. Lawrence Kuznetz to be submitted to the NSBRI for consideration. Radiation exposure, as you know, is a major hazard for a long-term Mars mission, and the level and type of shielding is crucial, particularly in reference to skin cancers. Our discussions indicated that there are scenarios under consideration that would encase large portions of the body in gases other than air or free oxygen. You realize, of course, that even partial hypoxia can significantly alter the sensitivity of cells to radiations.

The proposed project would mesh well with our present studies of cancer from Space radiations, the mechanisms leading to such cancers, and means to reduce the risks. I enthusiastically support the efforts of you and Dr. Kuznetz in this regard.

Sincerely

John F. Dicello, Ph.D.
Professor of Radiation Oncology
Professor of Oncology

NCCCC
A Comprehensive Cancer Center Designated by the National Cancer Institute

The Sidney Kimmel Comprehensive Cancer Center

DAVA J. NEWMAN, PH.D.
PROFESSOR OF AERONAUTICS AND ASTRONAUTICS
& ENGINEERING SYSTEMS
DIRECTOR, TECHNOLOGY & POLICY PROGRAM
HARVARD-MIT HEALTH, SCIENCES AND TECHNOLOGY
ELECTRONIC MAIL: dnewman@mit.edu

ROOM 33-307
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
77 MASSACHUSETTS AVENUE
CAMBRIDGE, MA 02139
(617) 258-8799
(617) 253-4196 (FAX)

July, 2004

Support Letter for "The Marssuit Project"

Dear Dr. Lawrence "Larry" Kuznetz,

I write in support of your proposed Marssuit project submitted to the National Space Biomedical Research Institute (NSBRI-RFP-04-02). NASA's new Space Exploration Vision sets the charge for enhanced educational materials at Universities across the US. As you are aware, I am actively involved in education and research projects funded by NASA to investigate advanced spacesuit design, which are entirely necessary to realize the new National Space Vision. At MIT, we are fully engaged in hands-on, active learning in the Dept. of Aeronautics and Astronautics and have demonstrated increased student learning and knowledge based on these teaching methods. A Marssuit educational project offers unique educational and outreach possibilities to participating students.

MIT is home to the student-run Mars Gravity Biosatellite project, whose aim is to study the physiological effects of Martian gravity on mice in low Earth orbit (other participating universities include the University of Washington and the University of Queensland, Australia). We believe that the Marssuit project has the potential to become an exiting educational project to further increase students' awareness and interest in Mars exploration, and we look forward to participating with you in this educational enterprise.

Sincerely,

Dava J. Newman

Note: This letter was written for a companion proposal and we were unable to contact Dr. Newman but this clearly indicates her interest in the MARSUIT project.

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
2101 NASA Road 1
Houston, Texas 77058-3696

July 19, 2004

Reply to Attn of: EC-04-125

I am writing this letter in support of the MarsSuit Project initiative, as conceptualized by Dr. Lawrence H. Kunetz.

The MarsSuit Project concept for stimulating interest in student academic research and advancing education opportunities represents an initiative that would be a direct link to the future support of NASA's development activities in a number of critical human space flight technology areas. This initiative would help focus a broad sector of academia research and provide a catalyst for student-based scientific project activities and training in support of future space research and development efforts.

In support of the proposed MarsSuit Project initiative, I agree to serve as a technical point of contact on an "as available" basis to provide insight and expertise relative to selected student projects.

Joseph J. Kosmo
Senior Project Engineer
EVA and Spacesuit Systems Branch
Crew and Thermal Systems Division

Mail Message

Novell

From: "KUZNETZ, LAWRENCE H. (JSC-SK) (NSBRI)" <lawrence.h.kuznetz1@jsc.nasa.gov>
To: albena@purdue.edu
CC: Vince Pisacane
Date: Monday - August 30, 2004 11:43 AM
Subject: RE: The Mars Suit Project

dear albena, the Marssuit Project is indeed a revolutionary approach that we hope nasa uses to build the next generation space suit and other hardware for mars exploration. However, it has not officially been funded yet and the talk at the mars society was an introduction to the program as we envision it. Do not be discouraged, however, as the reality may be much closer to happening than ever before. A grant proposal has been submitted for the project and we expect an answer by october for program start. In addition, we are having meetings next month at nasa headquarters in washington that may kick start the program with enough funding to get 16 universities involved in the first round. If that happens, we will schedule a marrsuit conference in which interested universities will be invited, during which we will decide who the initial candidate teams will be. Part of the project, i should add, will entail each major institution partnering with an underrepresented minority institution of their choice, and a local manufacturer of hardward in their immediate geographical area, if possible. I hope this helps and i encourage you to keep in contact with me as the process evolves. Thanks, Lawrence Kuznetz

-----Original Message-----
From: Albena Ivanisevic [mailto:albena@purdue.edu]
Sent: Friday, August 27, 2004 9:42 PM
To: KUZNETZ, LAWRENCE H. (JSC-SK) (NSBRI)
Subject: The Mars Suit Project

Dear Dr. Kuznetz,

My name is Albena Ivanisevic and I am an assistant professor in the Biomedical Engineering Department at Purdue University.
I learned about the Mars Suit Project from your talk at the Mars Society Conference in Chicago. I am very interested in learning how can a team from our university be involved in this project. We just started an undergraduate program in biomedical engineering that has attracted some outstanding students eager to do research. Any information you can provide with respect to the application process, web site, etc. will be greatly appreciated. Thank you for your time.
Best regards,

Albena Ivanisevic
Assistant Professor
Department of Biomedical Engineering
and Department of Chemistry
500 Central Drive
Room 374C
W. Lafayette, IN 47907-1296
tel. 765-496-3676
fax 765-494-1193

RICE

Enrique V. Barrera, Ph.D., P.E.
Professor, Chair

July 23, 2004

KUZNETZ, LAWRENCE H. (JSC-SK) (NSBRI)

RE: The Marssuit Project

Dear Dr. Kuznetz,

George J. Hirasaki forwarded me the e-mail you sent him about involvement in The Marssuit Project and the Department of Mechanical Engineering and Materials Science at Rice University would be happy to participate. I understand that this program aims to involve undergraduate students in research and is focused on attracting universities involved in space suit and extravehicular mobility unit (EMU) research. I know that a number of our faculty were involved in space suit related research including myself. I spent two summers as an ASEE Summer faculty fellow at the NASA Johnson Space Center in the Crew and Thermal Systems Division. I also conducted projects with Dr. Chin Lin and Evelyn Orndoff on some undergraduate project highly directed toward space and space suit applications. I am currently involved in a project to develop next generation thermal undergarments that could be well directed for a Marrssuit. Therefore, we are pleased to support the Marssuit project proposed to NSBIR by you. The need for new suit designs is apparent since the length of time astronauts will be in EVA will be longer than that for shuttle and space station activities. The Mars environment requires that a new suit be designed to safely enable the astronauts in their space and planetary studies. The ideas you propose are timely and well directed toward the lunar/Mars missions. The scope of the project also provides for opportunities to identify and train the next generation scientists and engineers needed to develop needed EMUs that are flexible, repairable and can see multiuse.

I would also like to note that we actively work with universities that have high populations of underrepresented groups of students in science and engineering. We actively work with the University of Texas Pan American, Texas Southern University, and Prairie View A&M University. UT Pan Am is a Hispanic student serving university, TSU and PVAMU are historically black colleges and universities. I am sure that we could engage them in this activity through our current collaborations and interest. Rice University and the Department of mechanic al Engineering and Materials Science welcome this opportunity when the funding opportunities arise. Please feel free to contact me at ebarrera@rice.edu or at 713-348-6242 as this program takes shape.

Sincerely,

Enrique V. Barrera

Enrique V. Barrera, Ph.D., P.E.
Professor and Chair

Rice University • Department of Mechanical Engineering and Materials Science - MS 321
P.O. Box 1892 • Houston, Texas 77251-1892 • 6100 Main Street • Houston, Texas 77005
Phone: 713-348-6242 • Fax: 713-348-5423 • Email: ebarrera@rice.edu • http://www.mems.rice.edu/barrera/

CENTER FOR INTERNATIONAL COOPERATION IN SPACE

STANFORD UNIVERSITY

STANFORD, CALIFORNIA

July 21, 2004

Lawrence Kuznetz
The Marssuit Project

Dear Larry,

I've read over your project abstract and find it very interesting and important. As you know, we have been working on Mars studies for over 25 years. As a doctoral student I participated in the Mars Radio Occultation experiment under Dr. Von Eshleman at Stanford. As director of Stanford's "Space Systems Engineering" course, Engr. 235, I've studied a pre-Viking robotic mission in the "SAMPLER" report.

In the Engr. 235 in the 1990's we did the Stanford-Russian manned exploration studies with contributions from NASA, the Russian Space Agency and interaction with University of California at Berkeley.

As you know, I directed two doctoral students on Mars Suit designs. Dr. Leslie Wickman did her thesis on caloric energy consumption with different placement of weights on a space suit. She tested subjects in NASA Ames's reduced gravity facility for Earth, Moon and Mars gravity. The second student, Dr. William Mills, modeled the thermal control of a Mars suit, incorporating the semi-porous membranes to allow cooling by evaporation of sweat. He modeled the heat produced during typical Mars exploration tasks, using Dr. Wickman's test results.

With this background and the continuing interest on Mars Exploration at Stanford I would be very happy to work with you again. We might like to include interaction with other universities in the U.S., Europe and Japan that I and Professor Twiggs in the Aero and Astro Department have been in contact with. Also we would like to contribute analyses of how Mars suit concepts could be tested on the International Space Station and on a Moon base before the Mars mission.

Once again count me in on the Marssuit Project. I will be glad to organize a group of enthusiastic Stanford students to interact with students at U.C. Berkeley and other universities.

Best Regards,

Bruce Lusignan

Bruce Lusignan
Director
Stanford Center for International Cooperation in Space

UNIVERSITIES SPACE RESEARCH ASSOCIATION

3600 Bay Area Blvd. • Houston, Texas 77058
Tele: 281.244.2026 • Fax: 281-244-2006

6 July 2004

The Universities Space Research Association (USRA) enthusiastically supports the MarsSuit Project initiative, as conceptualized by Dr. Lawrence Kuznetz. This initiative is based on previous, successful programs linking academic research and education to NASA's development activities in critical areas. We believe initiatives such as this greatly contribute to the scientific and technical education, learning, and training of America's youth. Moreover, these types of projects provide the mechanism and focus for academia's contribution to the Nation's space research and development endeavours.

Established in 1969 by the National Academy of Sciences at the request of NASA, the USRA is a nonprofit corporation chartered to "provide a means through which universities and other research organizations may cooperate with one another, with the Government of the United States and with other organizations toward the development of knowledge associated with space science and technology." The USRA consortium now numbers ninety-five research universities and institutions of higher learning.

The USRA has long been recognized as a leader in managing university programs that afford researchers, faculty, and students the opportunities to gain hands-on experience and involvement with current and planned space science and engineering research projects. Moreover, these programs serve to address the continued crises in the nation's scientific and technological workforce needs. USRA is committed to provide the key leadership and assistance to the government, to industry, and to the research and education community in the area of academic research initiatives, and in the development and implementation of supporting educational programs. USRA's educational programs act as a career catalyst for students at the high school, undergraduate, and graduate levels, and are aimed at expanding educational opportunities for students in the space sciences and aerospace engineering, as well as encouraging young student to stay in school and pursue careers in science, engineering, and technology.

USRA is working to improve the cost and efficiency of space operations; to continue to prove that successful missions can be carried out by small, low-cost, university-designed and built payloads and free-flying satellites; to create teams of university researchers to carry out government and industry contracts in diverse areas; and to facilitate collaboration between government and industry scientists/engineers and university researchers/educators in the areas of space science, engineering, and technology. Through efforts such as the MarsSuit Project, we believe that academia and the Agency can work together to achieve our mutual objectives in space research and education.

Jeffery A. Cardenas, Director
USRA-Space Operations/Education Programs

UNIVERSITY OF CALIFORNIA, BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO   SANTA BARBARA • SANTA CRUZ

CENTER FOR ENVIRONMENTAL DESIGN RESEARCH
390 WURSTER HALL, #1839
BERKELEY, CALIFORNIA 94720

TEL: (510) 642-2896
FAX: (510) 643-5571

July 24, 2004

To: Whom it may concern,

Re: MarsSuit Teaching Project

The Center for Environmental Design Research has a valued record of doing interdisciplinary research and teaching on building energy topics together with the Departments of Mechanical Engineering (Professors Paul Wright, David Auslander, and Alice Agogino) and Bioengineering (Professor Boris Rubinsky), and the Department of Architecture. Within the Department of Architecture, its Building Science Group has a long history of human thermophysiological and comfort research (Professor Gail Brager, Zhang Hui, Charlie Huizenga, and myself) applied to buildings and automobiles. This MarsSuit teaching/research proposal is very interesting to all of us mentioned above, and we see it as a great opportunity for us to extend the range of topics within which we already collaborate.

We would be very interested in participating in developing a long-term curriculum project centered on the various problems involved in designing a new space suit. The opportunity to work with other universities through the resources of the internet is also appealing. This is a central tenet of UC's CITRIS program (www.citris.berkeley.edu), which a number of us are involved in as well. Prof. Wright is leading CITRIS's undergraduate education and outreach program. This program fits very well with the ITR education programs he is developing.

If you have any questions, please feel free to contact me at the CEDR number above. I will however be out of the country until August 21.

With best wishes,

Edward Arens, Ph.D.
Professor of Architecture
Director, Center for Environmental Design Research
Director, Center for the Built Environment
www.cbe.berkeley.edu
www.arch.ced.berkeley.edu

AEROSPACE ENGINEERING & ENGINEERING MECHANICS
THE UNIVERSITY OF TEXAS AT AUSTIN

210 E. 24th Street, WRW • Tel: 512-471-7593 • Fax 512-471-3788
1 University Station C0600 • Austin, Texas 78712-0235

July 25, 2004

RE: The MarsSuit Project

The Department of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin strongly supports the Marssuit project proposed to NSBIR by Dr. Lawrence Kuznetz. This project is strongly aligned with NASA's new space exploration initiative and accelerate the pace and safety of mankind's efforts to place humans on Mars. Dr. Kuznetz's proposed multi-university project will provides immense leverage to NASA's efforts toward human exploration of Mars.

Students at UT Austin have been involved in Mars-related design studies since the mid-1980s and our history of Mars related mission and trajectory definition studies goes back to the mid-1960s. Our past involvement has focused on trajectory definition, mission design, and surface infrastructure design. We see participation in Dr. Kuznetz's project as a natural extension of activities that we have been involved in for decades.

Most recently, we have added a human factors focus to our program. Dr. David Musson, a medical doctor and PhD in psychology, has worked with our students to provide expertise not normally found within an engineering school. He provides a very strong multidisciplinary thrust to our participation in the MarsSuit Project.

We strongly endorse this proposal and look forward to participation in the MarsSuit project.

Sincerely,

Wallace T. Fowler

Wallace T. Fowler
Paul D. and Betty Robertson Meek Centennial Professor in Engineering
University Distinguished Teaching Professor in Aerospace Engineering and Engineering Mechanics
Director, Texas Space Grant Consortium

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195-2400

College of Engineering
Department of Aeronautics and Astronautics
Telephone: (206) 543-1950
Fax: (206) 543-0217

July 16, 2004

RE: The Marssuit Project

The Department of Aeronautics and Astronautics at the University of Washington is pleased to support the Marssuit project proposed to NSBIR by Dr. Lawrence Kuznetz. NASA's new space exploration initiative will bring forward the day when humans will set foot on the Red Planet, but there are currently no viable designs for an Extravehicular Mobility Unit (EMU) suitable for the conditions on Mars. Dr. Kuznetz's proposed multi-university project is timely and responsive to the need to develop a lightweight and practical EMU for Mars. It will bring together the intellectual resources to develop the necessary technology and hardware, while providing a superb educational and outreach experience to the participating students.

Our department has been involved in manned and unmanned Mars mission studies since 1992, particularly as they relate to the issue of studying and developing technologies for *in situ* resource utilization (ISRU). More recently, we became one of the three universities participating in the Mars Gravity Biosatellite project, whose aim is to study the physiological effects of Martian gravity on a group of mice in low Earth orbit (the other members of the team are MIT and the University of Queensland, Australia). We believe that the Marssuit project will be an excellent vehicle to further increase our students' awareness and interest in Mars exploration, and we look forward to our participation in this worthy endeavor.

Sincerely,

Adam P. Bruckner
Professor and Department Chair

cc. L. Kuznetz

From: LUTZ, GLENN C. (JSC-XA) (NASA)
Sent: Tuesday, October 19, 2004 7:28 AM
To: KUZNETZ, LAWRENCE H. (JSC-SK) (NSBRI)
Cc: DOERING, STEPHEN C. (JSC-XA) (NASA)
Subject: Presentation strategy

Larry,

I talked to Steve and the EVA Office is in agreement with serving as a co-lead organization if Code T is looking for an internal NASA group in that position. The EVA office feels your program fits well with our charter to utilize the academic community in the exploration mission. Best of Luck on November 8 when you give your presentation. If you have any questions or comments feel free to give me a call.

APPENDIX 2. LETTER OF INTENT TO HIRE DR. KUZNETZ AS MARSSUIT PROJECT CO-LEAD

APPENDIX 2
LETTER TO HIRE DR. KUZNETZ
FOR MARSSUIT PROJECT

DEPARTMENT OF THE NAVY
UNITED STATES NAVAL ACADEMY
121 BLAKE ROAD
ANNAPOLIS, MD 21402-5000

1 September 2004

From: Chairman, Aerospace Engineering
To: Dr. Vincent Pisacane

Subj: Plan to hire Dr. Lawrence Kuznetz

If the United Sates Naval Academy's proposal for the MARSUIT is successful, we plan to hire Dr. Lawrence Kuznetz as a Research Professor using the funds from the NASA Research Announcement NRA-NNH04ZUU003N, 4 June 2004.

DARYL G. BODEN

APPENDIX 3. LETTERS OF TESTIMONY OF EDUCATIONAL BENEFITS OF MARSSUIT RESEARCH PROGRAM

July 30, 2003

The Baylor College of Medicine
National Space Biomedical Research Institute.

Attention Search Committee

It is a pleasure to write this letter of support. I worked with Dr. Kuznetz for three years in my role as faculty sponsor for an undergraduate group study/research class that he organized at UC Berkeley. The class offered an opportunity to undergraduate students to participate in research and design projects for a human mission to Mars. The students were organized into subgroups focused on specific topics suggested by Dr. Kuznetz. In developing the curriculum, he expanded the topics beyond the engineering aspects of the manned mission to questions about living on the Martian surface, as well as the atmosphere, soil and biological properties of the planet itself. The program was highly interdisciplinary and although I have hosted it in the Department of Earth and Planetary Science, Dr. Kuznetz attracted other faculty sponsors from Physics, Molecular and Cell Biology and Integrative Biology, including Dr Walter Alverez, the author of the prevailing theory of species extinctions due to meteorite collisions with Earth.

Dr. Kuznetz was and remains the intellectual and creative driving force for this course. His ideas for the research projects and his enthusiasm for the subject and for science in general galvanize student interest. His broad knowledge of the physical, physiological and engineering factors that will affect manned space travel and exploration of Mars have led to a series of student projects which have been presented at national and international meetings. In 1999-2000 alone, 9 publications with the names of over 50 students, all undergraduates, were presented and the course received the additional distinction of a CNN special report. The supporting faculty considered this a stunning accomplishment. Before leaving for Houston and the NSBRI, Dr. Kuznetz led the class into several intriguing laboratory projects simulating the low temperature, pressure and atmospheric composition of Mars, culminating in a peer reviewed article in the prestigious journal, Astrobiology. This led naturally into questions on the existence and longevity of extremophiles that might still exist and to his current area of interest.

Dr. Kuznetz's graduate research was in engineering heat transfer in particular, but his background is much broader due to his experience at NASA and his research interests at the University. He has worked closely with members of our faculty and outside specialists on topics of physiology, biology and medicine and I have been impressed by the depth of his knowledge. More importantly I have been very impressed by his ability to identify the important questions and to define simple clear experiments to provide answers. This is the mark of a first rate researcher.

For informational purposes, I have been at Berkeley for over 30 years, have been a Department Chair and have participated in hundreds of faculty appointments and promotions. I have also been involved in many interdisciplinary research projects and currently hold appointments in two departments and at Lawrence Berkeley National Laboratory. Based on that experience, I can state unequivocally that Dr Kuznetz is the kind of innovative and well-qualified scientist/engineer that this position requires to delve into the multifaceted mysteries of planetary science and exploration. In addition to a wide breadth of knowledge with respect to human life sciences, smart technology, geology and education outreach, Dr. Kuznetz possesses the most crucial tool of all for the position you seek, people skills.

Yours truly,

H. Frank Morrison Professor
Malozemoff Chair

To whom it may concern:

I am writing to you to discuss the profound effect the Mission to Mars class (formerly To Mars By 2012) has had on my undergraduate experience and professional life. I graduated from UCB in Dec. 2000 with a BA in Integrative Biology. During my time at Berkeley, I participated in an eclectic group of activities: Cal Men's Soccer Club; fraternity; numerous intramural sports; volunteer in the Berkeley Suitcase Clinic; volunteer in the Emergency Department at San Francisco General Hospital; DECAL classes such as "Groundbreaking Films of the 1960's;" Research Apprentice in Dr. Rodger Kram's Locomotion Laboratory; and the Mission to Mars course. I in full confidence tell you that *the* most influential and meaningful of my Cal experiences was my involvement with Mission to Mars.

Its unique, interdisciplinary format of presenting lecture material to stimulate real-time formulation and implementation of design projects provided me with ample opportunities to apply material from a number of my courses toward solving real-world problems, a feature often lost sight of in undergraduate education. The course also provided many opportunities to learn and enhance skills necessary to success in a wide range of professional fields: teamwork, leadership, technical writing, oral presentations, literature searches, and communicating and collaborating with other professionals and experts. Students joined one of the many research teams, each headed by a team leader. The teams then defined a project, obtained the necessary background information and materials, established communication and collaboration networks with NASA and academic researchers, and carried out the design project. At the completion of the course, students were required to submit a written technical report and give a PowerPoint presentation to the class. The project team judged the best was then sent to compete against other university teams from around the country in the Human Exploration and Development of Space-University Program (HEDS-UP) Competition at the Lunar Planetary Institute in Houston, TX. I should mention that while others schools fully funded their teams, UCB students always paid their own way, with class mentors providing significant financial and logistical support.

I participated in Mission to Mars for six consecutive semesters. I was team leader for the Exercise Countermeasures group for four semesters and served as an ad hoc T.A. for Dr. Lawrence Kuznetz for fours semesters. I attended the first three HEDS-UP Competitions during which Dr. Kuznetz arranged numerous VIP tours of the NASA Johnson Space Center facilities and private meetings with NASA researchers and astronauts. Through my work for the class, I published and presented a paper with my classmate Diana Chai to international experts at the International Conference on Environmental Systems in Toulouse, France during July 2000. In preparation for the conference Dr. Kuznetz helped me arrange meetings and teleconferences with researchers at NASA Ames, Johnson Space Center and NASA Headquarters. Through the Mission to Mars class and Dr. Kram's Locomotion Laboratory, three other students and I were selected by NASA to conduct a research experiment in "zero-gravity" on the "Vomit Comet" through NASA's KC-135 Reduced Gravity Student Flight Opportunities Program. We were the first, and I believe only, UC Berkeley team to participate in the program.

I am now a medical student at the Baylor College of Medicine in Houston, TX. I want to emphasize the importance of the Mars class in helping me successfully get into the medical school of my choice. When applying to medical school or to another graduate or professional school, guidance counselors at Berkeley always stress the importance of participating in activities you are passionate about and which make you stand out against other qualified applicants. Having all of these Mars class-related experiences to write and talk about made my applications and interviews a cakewalk; the admissions officers and interviewers were generally fascinated by the passion with which I wrote and spoke about the positive experiences I had with the course. I tell you this not to expound on how great I think I am, but because I want you to understand how valuable a tool this class is to the university and its students. Its faculty and students should not be treated as "the bad apple," passed from department to department year after year and deprived of facilities, funding, and exposure, but rather as pioneers of an innovative and forward-thinking method of putting one's education to immediate use to solve a real problem.

I recently did a clinical rotation in the Aerospace Medicine Clerkship at NASA JSC and am currently on a one-year academic leave of absence to continue my undergraduate research efforts in the Exercise Laboratory at NASA JSC. My project is to continue developing the exercise device we designed, built, and tested at Berkeley and on the "Vomit Comet." I have for many years aspired to be a physician. However, my experiences with the Mars class have taken in my career interests in new directions I never would have thought possible and have shown me what I am truly passionate about and what I want to work on the rest of my life: making space a habitable place for human beings.

With all this said, I have hardly even begun to mention the heroic efforts of Dr. Kuznetz, who made all this happen, and the numerous mentors who donated incalculable amounts of their time, experience, and financial resources. Without their invaluable input and assistance, the class would never have achieved what it has. I have even managed to forge some great friendships along the way (I even had the good fortune of visiting Dr. Franco Navazio, M.D., a retired cardiologist, current Human Physiology professor at UCB, Mars class mentor, and great friend, in Rome, Italy one summer).

Mission to Mars provided me with invaluable life experience, enhanced the quality of my Cal education, and motivated my academic and career aspirations. It is a mistake for any science or engineering department at UCB to not participate in a course with the potential of Mission to Mars. I strongly urge all those in charge of making such decisions to take note of the tremendous and diverse opportunities this course presents to students (I can even think of two students who were offered jobs, on the spot, while at the HEDS-UP Competition). I hope I have conveyed to you the importance of this class not only to me, but to the University of California, Berkeley and all future Cal students. This course provides the kind of experience that gives Berkeley its outstanding reputation for innovative, academic excellence. If you would like, please contact me for further information and/or comments (see below). Thank you very much for your time and consideration of this important matter.

Sincerely,

Lanny Rudner, MSI
Baylor College of Medicine
(713)795-8530
Lann_man@hotmail.com

To Whom It May Concern:

I am a third-year Bioengineering major here at Cal. I am writing in support of the Mission to Mars class. Over the course of my undergraduate career, I have had the opportunity to participate in cutting-edge research with Professor Bertozziís lab in Organic Chemistry; to attend interesting classes; and to participate in a wide variety of student organizations such as California Engineer Magazine, Eggster Hunt and Learning Festival, and the Blue&Gold yearbook. In all of my experiences, the Mission to Mars class (formerly known as the To Mars by 2012 class) has been one of the most rewarding.

In this class, I had the opportunity to participate in design projects that challenged the skills that I have acquired in my class here at Cal. During the course of the projects, I learned how to find scientific papers, read and interpret their significance, and how to use past research to enhance my project. As a direct result of this class, I was also able to participate in NASA's Reduced Gravity Student Flight Opportunities Program, in which I designed an experiment and flew with in on NASA's KC-135, a research plane that simulates microgravity. Most importantly, these design projects have motivated me in my major by showing me real-world applications of my knowledge.

Through the class's participation in the HEDS-UP program, I was able to present my research project to NASA researchers working in my field of interest. I have developed my presentation skills and my ability to converse intelligently with those working in careers that I may consider in the future. The paper I wrote with Lanny Rudner in this class was also accepted to the International Conference on Environmental Systems in Toulouse, France. At the conference, Lanny and I presented our research to experts from all over the world. This is just another one of the valuable opportunities this class has offered it to me.

It is impossible to describe the full-impact that this course has had on my undergraduate experience and my perspective on my future. The Mission to Mars class and its instructor, Professor Lawrence Kuznetz, are true assets to this University, and future students deserve the opportunities that this class has provided me. If I can provide any additional information on my experiences with this class, please do not hesitate to contact me. Thank you for your consideration.

Sincerely,

Diana Chai
(510) 705-8785

Daily Cal: Student Newspaper of the University of California

COURSE OPENS MARS PLANNING TO STUDENTS

By Ogechukwu N. Arum
Contributing Writer

Next semester, students have the chance to forego one of their usual classes and take a class based on a possible mission to Mars. The course, "To Mars By 2012," will be taught by Dr. Lawrence Kuznetz, a doctoral graduate of UC Berkeley's engineering and physiology Departments. Kuznetz is arranging for guest lectures including NASA Ames Research Center scientists, NASA jet propulsion scientists, astronauts and those who will consider the ethical implications of a mission to Mars. The lecture format will aim to present the students with basic information on various topics and then to let their minds develop those ideas further. The first half of the lecture series will provide the history of human conceptualization of Mars, Martian exploration missions and what robots learned while exploring Mars. The second half will deal with human factors such as the contingency of life-support systems, habitat design, botany, the possibility of contaminants being brought to Mars or brought back to Earth, and economics, which includes convincing the public that exploring Mars is a worthwhile project. Throughout the course, students will be compiling their own information from various sources, which includes an Internet feature created by NASA that allows students to interact with NASA scientists on a regular basis. At the end of the course, students are required to do a final report and presentation in front of distinguished guests.

"NASA doesn't have the time and energy to do the imaginative thinking and (consider the) intricate ideas," adds NASA Ames researcher Dr. Geoffrey Briggs. "Contributions that universities could make could be quite substantial." Briggs hopes that students can lend unbiased opinions in debates on various topics which would otherwise be monopolized by professionals who would be in support of their interests. "I personally believe that there is room for university participation (in the planning of) a Mars mission."

Comments? Write to opinion@dailycal.org

July 30, 2003

The Baylor College of Medicine
National Space Biomedical Research Institute.

Attention Search Committee:

It is a pleasure to write this letter of support. I worked with Dr. Kuznetz for three years in my role as faculty sponsor for an undergraduate group study/research class that he organized at UC Berkeley. The class offered an opportunity to undergraduate students to participate in research and design projects for a human mission to Mars. The students were organized into subgroups focused on specific topics suggested by Dr. Kuznetz. In developing the curriculum, he expanded the topics beyond the engineering aspects of the manned mission to questions about living on the Martian surface, as well as the atmosphere, soil and biological properties of the planet itself. The program was highly interdisciplinary and although I have hosted it in the Department of Earth and Planetary Science, Dr. Kuznetz attracted other faculty sponsors from Physics, Molecular and Cell Biology and Integrative Biology, including Dr. Walter Alverez, the author of the prevailing theory of species extinctions due to meteorite collisions with Earth.

Dr. Kuznetz was and remains the intellectual and creative driving force for this course. His ideas for the research projects and his enthusiasm for the subject and for science in general galvanize student interest. His broad knowledge of the physical, physiological and engineering factors that will affect manned space travel and exploration of Mars have led to a series of student projects which have been presented at national and international meetings. In 1999-2000 alone, 9 publications with the names of over 50 students, all undergraduates, were presented and the course received the additional distinction of a CNN special report. The supporting faculty considered this a stunning accomplishment. Before leaving for Houston and the NSBRI, Dr. Kuznetz led the class into several intriguing laboratory projects simulating the low temperature, pressure and atmospheric composition of Mars, culminating in a peer reviewed article in the prestigious journal, Astrobiology. This led naturally into questions on the existence and longevity of extremophiles that might still exist and to his current area of interest.

Dr. Kuznetz's graduate research was in engineering heat transfer in particular, but his background is much broader due to his experience at NASA and his research interests at the University. He has worked closely with members of our faculty and outside specialists on topics of physiology, biology and medicine and I have been impressed by the depth of his knowledge. More importantly I have been very impressed by his ability to identify the important questions and to define simple clear experiments to provide answers. This is the mark of a first rate researcher. For informational purposes, I have been at Berkeley for over 30 years, have been a Department Chair and have participated in hundreds of faculty appointments and promotions. I have also been involved in many interdisciplinary research projects and currently hold appointments in two departments and at Lawrence Berkeley National Laboratory. Based on that experience, I can state unequivocally that Dr. Kuznetz is the kind of innovative and well-qualified scientist/engineer that this position requires to delve into the multifaceted mysteries of planetary science and exploration. In addition to a wide breadth of knowledge with respect to human life sciences, smart technology, geology and education outreach, Dr. Kuznetz possesses the most crucial tool of all for the position you seek, people skills.

Yours truly
H. Frank Morrison Professor
Malozemoff Chair

APPENDIX 4. UCC HISTORY AND NASA HQ PEDIGREE

National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

JUL 10 2000

TO: B/Comptroller

FROM: AE/Chief Engineer
M/Associate Administrator for Space Flight
R/Associate Administrator for Aerospace Technology

SUBJECT: Concurrence on University Collaborative Center Human Exploration and Development of Space University Partnership (HEDS-UP) Functional Initiative

An opportunity exists to provide engineering education in an advanced engineering environment for undergraduate students. The enclosure details an effort to partner with 12 university undergraduate programs to utilize an advanced engineering environment to address NASA research problems in undergraduate design classes. The activity will leverage the existing HEDS-UP Project infrastructure at the Johnson Space Center (JSC) and the Interactive Design Environment tool developed in the HEDS-UP Program by the University of California at Berkeley.

The Office of the Chief Engineer is requesting an overguide in FY 2001 and funds in FY 2002 and 2003 to sponsor the deployment and implementation of the University Collaborative Center at JSC and 12 universities. The activity will be coordinated with the Collaborative Engineering Environment efforts part of the Intelligent Synthesis Environment Initiative.

This memorandum documents concurrence and endorsement of the above by the offices or Enterprises involved in the effort.

W. Brian Keegan NASA Chief Engineer	Joseph H. Rothenberg Associate Administrator Office of Space Flight	Samuel L. Venneri Associate Administrator Office of Aerospace Technology

Enclosure

University Collaborative Center (UCC)
Utilizing HEDS-UP
Projects Initiative

Johnson Space Center

June 2000

UCC Activity;Initial;06/19/00

University Collaborative Center

Task Objective

Develop a center in which the university community can compete for NASA-sponsored design projects. The center shall provide the collaboration tools to allow teams of universities to work together in a virtual project office. The center shall also provide an organized repository for all project data so that project continuity is maintained of the life of the project despite the large turnover of students that can be expected

Capabilities/functions to be included initially:

- Information exchange
- Chat
- Threaded discussion accessed by time, author, or subject
- Data archive
- Brainstorming support\
- Access to subject matter experts
- Access to tools outside the university domain
- Digital prototyping and virtual mockups

Products

- A server-based collaborative center supporting project development among the university community
- Access through the center to tools within government support projects conducted by the university community
- Project designs in support of NASA missions
- The UCC capability and processes used by the university community will be shared with the ISE program. Any ISE developments useful to the university community will be incorporated into the UCC.

Technical Approach

- AE/Office of Chief Engineer is the customer for this activity
- The collection of 12 universities currently working together defined in the UC/Berkeley (UCB) activity will comprise the users whose requirements must initially be satisfied
- Where commercial, per-user applications are used to satisfy requirements, the initial capability will be sized for 60 individual participants (56 per university). Functionality, which is not on a per-user basis, will be made available to the university community at large.
- For expediency, a server outside JSC firewall will be pursued. Critical data will be backed up and brought behind JSC firewall.

Schedule/Cost

- Initial capability 7-9 months after authority to proceed
- Progress reviews with the user community used to address additional capability desired over time.
- First year funding to review initial capability in USC tool and/or develop UCC initial capabilities, required per-user seats for 12 universities, and initial funding for universities to do three to four project plans for NASA review/selection
- FY02/03 funding includes maintenance of UCC, development of additional capabilities, and funds for university projects (transferred to/borne by sponsoring NASA office).

COST:	FY01	FY02	FY03	FY04	FY05	FY06	FY07
NOA FY$K	571	325	294	80	80	80	80

UCCpp† Initial 6/5/00; JSC/Nick Lance

APPENDIX 5. DESIGN PROJECTS AT UC BERKELEY FOR NASA'S HEDS-UP PROGRAM

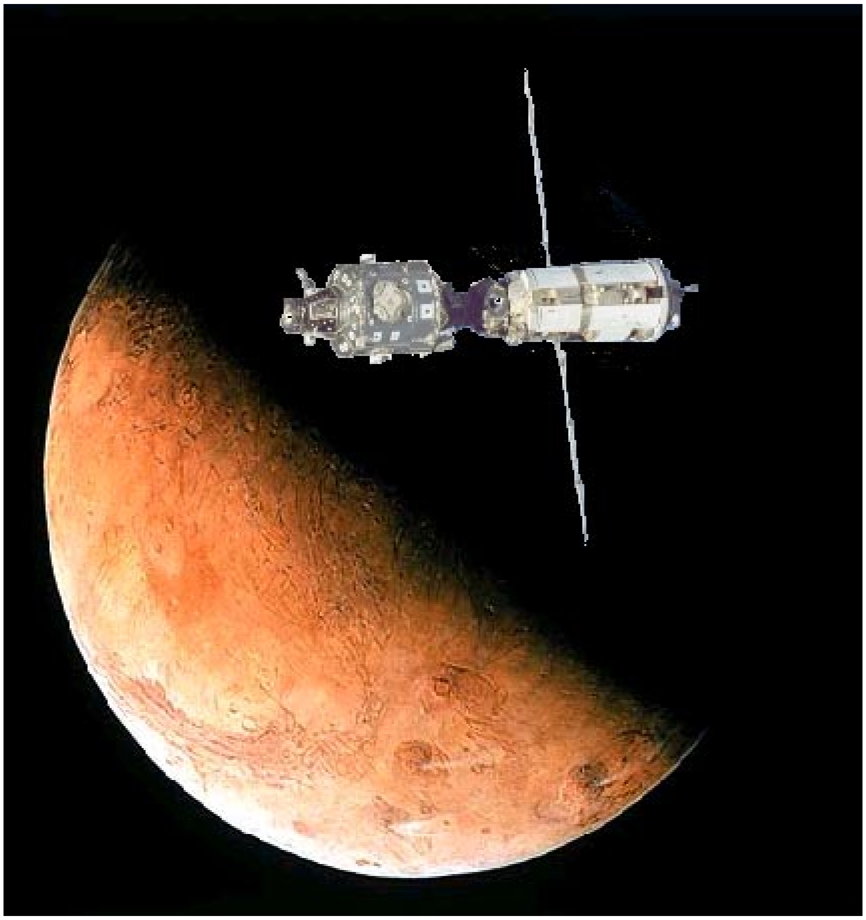
Please go to http://www.lpi.usra.edu/publications/reports/CB-1106/CB-1106.intro.html

and to http://www.lpi.usra.edu/publications/reports/CB-979/CB-979.intro.html

Fourth Annual HEDS-UP Forum

May 3–5, 2001

LPI Contribution No. 1106



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- **University of Colorado at Boulder**
- **University of Colorado at Boulder**
- **University of Maryland, College Park**
- **University of Maryland, College Park**
- **University of Washington, Seattle**
- **University of Washington, Seattle**

List of Forum Participants

Second Annual HEDS-UP Forum

May 6–7, 1999

LPI Contribution No. 979

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- University of Texas, Austin
- University of Texas, San Antonio
- Wichita State University

List of Forum Participants

APPENDIX 6. CNN SPECIAL REPORT ON MARSSUIT PROJECT

CD with CNN Special Report on Precursor MarsSuit Projects

……available on request

Cnnclip.ram

APPENDIX 7. NASA OFFICE OF BIOLOGICAL AND PHYSICAL RESEARCH EDUCATION OUTREACH PROJECT PLAN

The following is the Education and Public Outreach Project Plan Requirements Document released by NASA's Office of Biological and Physical Research for the 2004 POP call.

OBPR Educational Outreach Project Plan Profile

I. Project Title

- List the complete name of the Project by which it will be known

II. Project Abstract

- Provide a one-paragraph description of the Project. Include what the Project is intended to do, the audience it directly involves, and the immediate expected outcome.

III. Link to OBPR Research Organizing Question

Guidance: All E/O Projects are to be designed to make direct links supporting one or more of the 4 Research Organizing Questions. While a Project may include links to more than one question, with most Projects there will likely be a primary focus on one.

- Place a PR in the space before the Research Question with which this Project has a primary link
- Place a check mark in the space before other Research Questions only IF the project will include noticeable links to that question within the content of the project.
- Provide 1-3 sentence explanation of how the project will provide the link. Examples provided.

EXAMPLE:

____ How can we assure the survival of humans traveling far from Earth?

____ How does life respond to gravity and space environments?

____ What new opportunities can our research bring to expand our understanding of the laws of nature and enrich lives on Earth?

____ What technology must we create to enable the next explorers to go beyond where we have been?

IV. Lead E/O Program and Project Lead

- List the OBPR Research Division E/O Program that includes this project within its portfolio
- List the name of the Division E/O Program Manager
- List the name, title, location, and contact information for the Project Lead

V. Collaborative Partners and Their Participation

- List all collaborative partners that contribute to this project: both internal and external to OBPR & NASA.
- Provide a short summary of how each partner contributes.

VI. Project's Main Message

- Explain the intended message that each participant will understand, know, or experience as a result of being involved with this project. Simply stated, what is the message the project was designed to enable the participant to "tell their neighbor?"

VII. Targeted Audiences

- State the primary audience for which this project is designed. If the project has targeted indirect audiences, please note that as well.

VIII. Expected Scope of Audience

- State the estimated number of participants in this project.
- Depending upon the type of project, this may be described incrementally.
- Also state the intended geographical reach.

IX. Main Environment of Use

- State the expected environment(s) or venue(s) for delivery of this project.

X. Products

- List the products by type and name (as appropriate or known) that will be utilized by participants of this project
- Place the product in the appropriate category
- Existing Product (note if by OBPR or collaborative partner)
- To Be Developed (note if by OBPR or collaborative partner)

XI. Dissemination/Delivery Mechanisms

State the delivery and/or implementation strategy.

XII. Expected Outcomes

- List the expected outcomes of this project.

XIII. Match with OBPR Educational Priorities

- o **Guidance: All E/O Projects are to be designed to meet the OBPR Priorities directed to Four Primary Audiences. While a Project may meet more than one, with most Projects there will likely be a primary focus.**

  - Place a PR in the space before the Priority to which this Project makes the most significant contribution
  - Place a plus mark (+) in the space before other Priorities only IF the project will include noticeable support of that Priority within the content and delivery of the project.
  - Provide 1-3 sentence explanation of how the Primary or secondary Priorities will be met.

EXAMPLE:

____ **Engage Students**: Increase numbers of students reached and interactivity of student opportunities.

____ **Empower Educators**: Enable educators to enhance STEM instruction with space research concepts.

____ **Expand Audiences**: Increase our reach to non-traditional and underrepresented students and educators.

____ **Enhance Reach to Higher Education:** Review, improve, and strengthen higher education OBPR E/O Programs.

XIV. Match with Code N Operating Principles

Guidance: All E/O Projects are to be designed to meet the six NASA Education (Code N) Operating Principles. The listed 4 secondary principles will assist with understanding of how to interpret each of the six Operating Principles. Your Project may meet more than one. Place a plus mark (+) in the space before each Principle and secondary principle that applies to this project.

- Place a plus mark (+) in the space before the Operating Principle to which this Project makes a significant contribution through the content and/or delivery.
- (Optional) Provide 1-3 sentence explanation of how the primary or secondary Priorities will be met.

____ **Content** – Programs make direct use of NASA content, people or facilities to involve educators, students, and/or the public in NASA science, technology, engineering, mathematics.

____ 1. The program is based on NASA's scientific and technical activities, reflecting "As only NASA can."
____ 2. Program content is technically accurate.
____ 3. The program engages the public in shaping and sharing the experience of exploration and discovery.
____ 4. The program is aligned with endorsed education reform efforts.

____ **Customer Focused** – Programs have been designed to respond to a need identified by the education community, a customer, or a customer group.

____ 1. The program is based on a compelling mutual need.
____ 2. NASA can make an effective content contribution.
____ 3. Participants find the program valuable.
____ 4. The program is accessible to its intended audience.

____ **Pipeline** – Programs make a demonstrable contribution to attracting diverse populations to careers in science, engineering, technology, mathematics.

____ 1. The program promotes improvement of STEM skills.
____ 2. The program creates linkages to other STEM educational opportunities.
____ 3. The program includes diverse populations of students.
____ 4. The program promotes careers in STEM.

____ **Diversity** – Programs reach identified targeted groups.

____ 1. The program serves individuals from underrepresented groups and ensures accessibility to people with disabilities.
____ 2. The program promotes opportunities for faculty at minority serving institutions to engage in research consistent with NASA's requirements
____ 3. The program supports closing identified gaps in STEM proficiencies among diverse populations
____ 4. The program provides awareness and understanding through culturally appropriate materials to targeted communities of how NASA's research and innovations affect and improve the quality of life for all citizens

____ **Evaluation** – Programs implement an evaluation plan to document outcomes and demonstrate progress toward achieving objectives.

____ 1. The program is evaluated regularly by credible sources following professionally accepted standards for educational evaluations.
____ 2. The program collects, analyzes, and reports output and outcome data to a common NASA database to determine program effectiveness and meet the requirements of program stakeholders.
____ 3. Evaluations are based on models and techniques appropriate to the object of evaluation.
____ 4. The program implements improvements based on evaluation evidence.

____ **Partnerships/Sustainability** – Programs or products achieve high leverage and/or sustainability through intrinsic design or the involvement of appropriate local, regional, or national partners in their design, development, and dissemination.

____ 1. The program is replicable in educational institutions.
____ 2. The program identifies partners and clearly defines the terms of the partnership.
____ 3. The program provides cited or estimated figures for the fiscal contribution of each partner.
____ 4. The program is sustainable beyond initial NASA funding.

XV. Metrics to Measure Outcomes

- List the metrics that will be used.

XVI. Required People Resource

- List the total anticipated people resource requirements for the project.

XVII. Phased Funding

- Provide a summary of the phased funding needs for this project.

XVIII. Milestones

- Provide a listing of major milestones for this project.

<u>Excerpts from OBPR Project Plan prepared for The MarsSuit Project</u>

a. Lead E/O Program and Point of Contact (PoC)

- **OBPR Research Division E/O Program: Bioastronautics**
- **Division E/O Program Manager: Charles Lloyd**
- **Project Lead: Lawrence H Kuznetz, PhD (lkuznetz@ems.jsc.nasa.gov)**

Collaborative Partners & Participation

- NASA
  - o JSC Space and Life Sciences Directorate
    - Contributes space/life sciences expertise and peer review
  - o JSC Crew and Thermal Systems Division
    - Contributes EMU design requirements, expertise and peer review
  - o HQ Exploration Office (code T)
    - Contributes Mars Design Reference Mission requirements
  - o JPL Mars Science Office and NASA-ARC
    - Contributes exploration objectives, ties to robotic missions and peer review
- Universities
  - o University of California + Stanford + MIT + 13 TBD universities
    - Provide primary workforce and facilities
- Institutes
  - o USRA
  - o National Space Grant Consortium
  - o Mars Society space suit task force
    - Augments workforce and provides external input and critique
- Industry
  - o Provide design and manufacturing expertise, including in-kind production of prototypes and hardware
    - Oceaneering Corp
    - International Latex Corporation (ILC)
    - Global Effects
    - Hamilton Sunstrand
    - Others

Match with OBPR Educational Priorities

- PR -Engage Students:
  - o The opportunity to participate in the design of a key component for the first human exploration of Mars will draw great interest from the academic community and increase the number of students reached because:
    - ▪ Interest in Mars is at an all time high.
    - ▪ The number of hits at the Mars Exploration Rover website exceeded the population of the Earth within 3 months of touchdown-- 6.5 billion hits, 225 million in the first day alone, both internet records.
    - ▪ The highest percentage of hits are from students.

        - Experience in the pilot project demonstrated that students are most engaged when they can participate in the learning process through design projects, "build" something that can be seen, touched and tested or be part of a team applying real world skills. The MarsSuit Project does all of these.
    - Based on experience noted in the 5 year pilot project at UC Berkeley, student interaction opportunities will increase as well. Interactivity will be manifested primarily through the IDE website of the UCC, a venue which will reach educators and students alike through the 12 features listed in paragraph X.

- Expand Audiences
    - A vital component of **The MarsSuit Project** is that it cuts across multiple disciplines, thus appealing to diverse, non-traditional and underrepresented students and educators. The scope of these disciplines covers a broad range including: human factors for mobility, dexterity and human performance; forward/back contamination reduction; radiation control; food and nutrition; temperature and pressure control; gender and size-friendly issues (such as anthropomorphics for maximizing fit an function); life support system design; power and mass concerns; utilization of in-situ resources to promote self sufficiency; exploration envelope optimization; sensors, controls and displays; photography, graphic design, space law and many more. The pilot program experienced 33% female and 33% multi-ethnic enrollment with contributions from nontraditional majors in economics, history, English, architecture and physical education as well as traditional engineering and science majors. Four or more universities representing underrepresented, minority institutions will be targeted for initial team membership in The MarsSuit Project.

- Empower Educators
    - The wide accessibility of the IDE together with a strong focus on seamlessly integrating STEM instruction within the design projects will empower educators with space research concepts.

- Enhance Reach to Higher Education OBPR E/O Programs.
    - The ability to interact with multiple universities structured in a multi-tiered "virtual NASA" is a new concept that if successful, can enhance, improve and possibly revolutionize OBPR E/O programs.
    - The review and redistribution of unrelated programs under the umbrella of a single unified goal such as the President's new Exploration Initiative will focus, strengthen and enhance OBPR E/O. The MarsSuit Project is an expression of that goal.

Match with Code N Operating Principles

The Code N Priorities/Principles are:

- Content – directly tied to or make direct use of NASA content, people, or facilities
- Customer Focused – respond to needs identified by the education community, a customer, or customer group
- Pipeline – attract diverse students to NASA STEM careers
- Diversity – reach identified targeted audiences
- Evaluation – have goals expressed in an objective, quantifiable, and measurable form
- Partnerships/Sustainability – achieve high leverage and sustainability through intrinsic design or the involvement of appropriate local, regional, or national partners in the design, development, and dissemination.
- Content
    - The MarsSuit Project contains content grounded in NASA's ongoing efforts to improve and develop new Extravehicular Mobility Units for planetary operations. Intimately tied to work being performed at JSC's Crew and Thermal Systems Division and its suit contractors, the program is based on scientific and technical activities and will be technically accurate. Through its IDE website and links to advocate

groups such as the Mars Society, the program engages the public in shaping and sharing the experience of exploration and discovery.

1. The program is based on scientific and technical activities
2. Program content is technically accurate
3. The program engages the public in exploration and discovery
4. The program is aligned with endorsed education reform efforts

- Customer Focused
  - The customer-focused needs of the education community embodied in The MarsSuit Project include: inspiration for students to pursue STEM careers; the opportunity to do real research as an undergraduate; being part of a Team with challenging goals, and the chance to participate in the development of a real product as it comes together--a project integrated to a strong STEM curriculum which can be touched, felt and worn and even tested in-situ. This is a compelling mutual need. Based on responses in the pilot program (see Appendix), customers (students and faculty) will find the program valuable. Its IDE website, texts, links and standardized lecture modules will make it accessible to its intended audience and the chance to use NASA facilities and tools will be instrumental in promoting the TEAM approach that is the heart of the program.

    1. The program is based on a compelling mutual need
    2. NASA can make an effective content contribution
    3. Participants find the program valuable
    4. The program is accessible to its intended audience

- Pipeline
  - Inherent in its appeal in attracting diverse populations to STEM careers is the diversity of disciplines embodied in The MarsSuit Project, as elucidated in X111, Expanding Audiences. A diverse multicultural, multiethnic population is more the rule than the exception in the undergraduate teams and student competitions representing UC Berkeley and other universities that are part of NASA's RASC-AL and HEDS-UP program sponsored by the Universities Space Research Association and Lunar Planetary Institute (see http://www.lpi.usra.edu/rasc-al/about.shtml and http://lpi.usra.edu/lpi/HEDS-UP/expmars.html.) These programs, which included precursor studies on MarsSuit development, promoted improvement of STEM skills and careers in STEM.

    1. The program promotes improvement of STEM skills
    2. The program creates linkages to other STEM opportunities
    3. The program includes diverse populations of students
    4. The program promotes careers in STEM

- Diversity

  5. The program will reach identified targeted groups through active solicitation of student teams and faculty from underrepresented minority institutions such as Prairie View A&M; Texas Southern; University of Texas, El Paso, Middle Tennessee State and others. These institutions may be partnered with experienced student teams from more traditional universities to increase the learning curve and interactivity at first but will quickly assume responsibility for the MarsSuit program element best suited to their unique interests and skills.

      1. The program serves individuals from underrepresented groups and ensures accessibility to people with disabilities.
      2. The program promotes opportunities for faculty at minority serving institutions to engage in NASA research.
      3. The program supports closing identified gaps in STEM proficiencies among diverse populations.
      4. The program provides awareness and understanding through culturally appropriate materials to targeted communities.

- Evaluation
  1. Outcomes and progress must be evaluated and documented both internally for every student member of each university team, and externally for the program as a whole. In either case, evaluations must be objective, quantifiable, measurable and *achievable*. Achievability is especially crucial internally, where intimidation, rejection or failure can frequently result from competition against others in an academic environment emphasizing STEM skills. To avoid this, The MarsSuit Project will stress a sense of accomplishment within the team setting. Based on a model similar to that used at NASA by branch chiefs and section heads, each team leader will use milestone markers and inputs from other team members to assess individual performance. Externally, the success of each university program will be continually monitored by the peer review and feedback mechanisms inherent to the IDE and UCC. In this framework, each university team is responsible for one or more MarsSuit program elements. Each is assigned an expert advisor to provide input and critique overall performance on a semester-by-semester basis. When appropriate, progress will be evaluated as it is at NASA, with PDR and CDR or similar milestones. The overall performance of The MarsSuit Project as a whole will be assessed by means of the NASA EDCATS system or similar tools (see XV).
  2. The program is evaluated regularly by credible sources using accepted standards for educational evaluations.
  3. The program collects, analyzes and reports data to a common NASA database to determine effectiveness.
  4. Evaluations are based on appropriate models for subject.
  5. Program improvements are based on evaluation evidence.

- Partnerships/Sustainability
  1. The lynchpin of The MarsSuit Project is partnership. Between the university teams; between faculty and NASA experts and between internal program elements and external industry partners who can help *sustain* the project over its evolutionary lifetime. To reach the multi-university, broad-encompassing participation levels envisioned, these partnerships must be forged from a variety of local, regional and national sources, both inside and outside NASA. Within NASA, participation from JSC, HQ, KSC and ARC will be targeted, as well as JPL and possibly the Department of Education. Outside the agency, industry partners with *suit*-able expertise such as Oceaneering, Hamilton Sunstrand, International Latex, Webb Associates, Allied Signal, Global Effects and others will be sought after to provide manufacturing expertise and support. Institutional support from organizations such as The Mars Society, which already has an active MarsSuit taskforce in place and can provide a simulated Mars environment at their Arctic and Desert habitats, would also be fruitful. Finally, for its initial team makeup, The MarsSuit Project will actively recruit universities with demonstrated prior expertise in some of the key program elements, such as MIT, UC Berkeley, The University of Maryland, Stanford University and others. Underrepresented, non-traditional universities will complement the traditional team members, as discussed in X1V.
  2. The program is replicable in educational institutions.
  3. The program identifies partners and clearly defines the terms of the partnership.
  4. The program provides estimates for the fiscal contribution of each partner.
  5. The program is sustainable beyond initial NASA funding.

MarsSuit concept D, Carter Emmert, 1990

APPENDIX 8. MARSSUIT PROJECT FEATURES AND POTENTIAL FOR GROWTH

MarsSuit Program Features

6. Pipeline to careers at NASA
7. Appeals to diversified, non-traditional and minority students
8. Complements NASA's Educator Astronaut initiative
9. Uses in-place university resources
10. Grass roots program escalating to a tidal wave
11. Ties in international partners
12. Low front-end cost
13. Harnesses proven talent (students) and facilities (universities)
14. Assists education
15. Assists research
16. Promotes technology base
17. Focuses shotgun research programs towards a single goal
18. Fosters NASA/university/industry cooperation
19. Reduces costs by utilizing university labs, facilities
20. Long term, interactive approach with expert feedback
21. Motherhood to Congress and taxpayers

Built-in Growth Potential

- The Mars Exploration Envelope
  - Aquarius
  - Haughton Crater Base (Mars Society)

- The Synergy Project

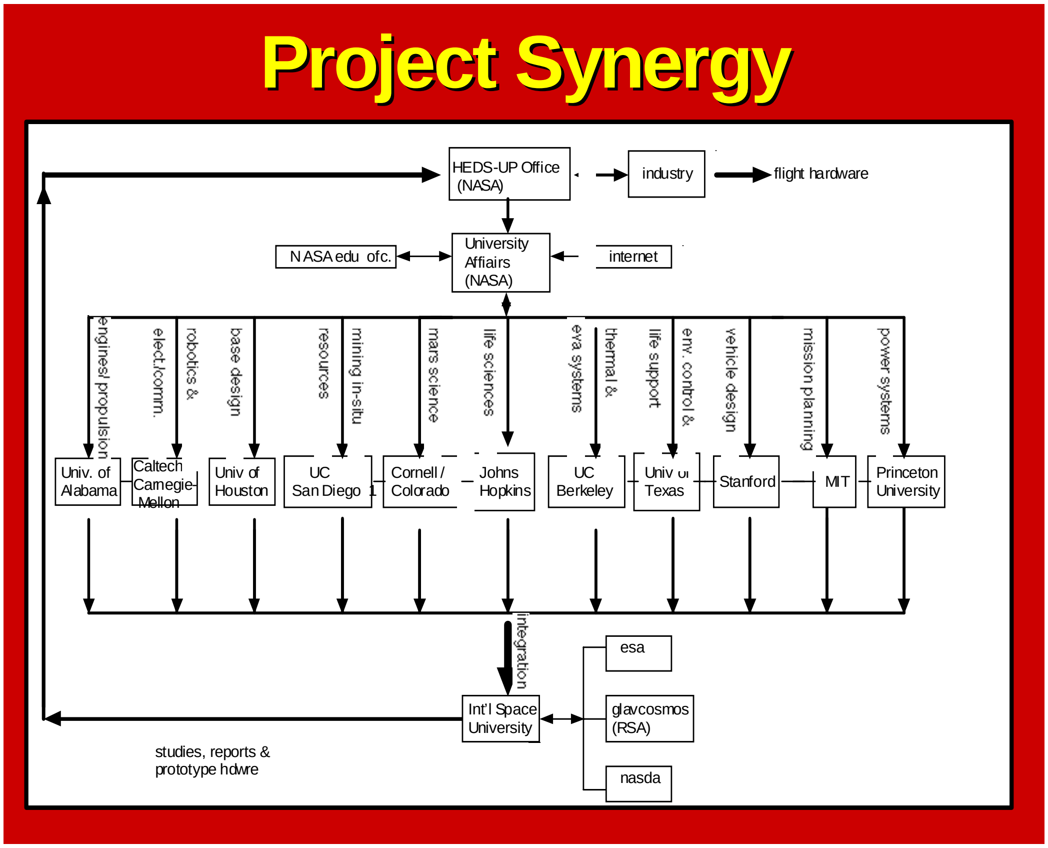
The Mars Exploration Envelope

- Uses Underwater and Mars surface analogs to study operational exploration envelope constraints on Mars surface
- Builds on and applies MarsSuit experience in practical way
- Allow students to "see, feel and touch" the mission through simulations

The Synergy Project

An international mission to Mars based on a university/government/industry synergy.


Mission Development Tasks
Mars Mission Elements
Engine & Propulsion Systems
Robotics, Elec., & Comm. Syst.
Base Design
Utilizing in-situ Resources
Mars Science
Systems Integration
Life Science
Thermal & EVA Systems
Power Systems
Env. Control & Life Support
Vehicle Design
Mission Planning



Goals

- Attack science illiteracy
- Build future leaders of science and industry
- Help design a human mission to Mars

APPENDIX 9. SAMPLE SYLLABUS FOR MARSSUIT PROJECT COURSE

SYLLABUS (TYPICAL)

Mars 2012 - Syllabus

Fall 2001

Discussion Class - Mondays, 3 - 6 PM (325 Mc Cone Hall)
Lecture Class - Wednesdays, 4 - 5 PM (325 Mc Cone Hall)

Date		**Topic**	**Speaker**	
September	19	Viking mission	Lawrence Kuznetz	UCB
	26	Water	Lawrence Kuznetz	UCB
October	3	Mars meteorite	Lawrence Kuznetz	UCB
	10	Group work/brain storming	Jane Fulton Suri	IDEO
	17	Space lab-living and working environment	Mark Cohen	NASA Ames
	24	Forward/back contamination on mars	Margaret Race	NASA Ames
	3	Human response to flight mission	Eric Viirre	UCSD
November	7	Radiation	Alan Harnish	UCB
	14	Biosphere/Terraforming/life on mars	Chris McKay	NASA Ames
	21	Mars analogs, Haughton crater in Artica	Pascal Lee	NASA Ames
	28	Program management for Mars mission	Larry Lemke	NASA Ames
December	5	Sample return mission	Brent Sharewood	Boeing

Spring Semester 2000, Mars 2012 updated syllabus

Tuesday, March 10. Dr. Carol Stoker will lecture on the tools and tasks of the first Mars base, including EVA profiles and the role of robotic probes

Thursday, March 12. Dr. Geoff Briggs of NASA Ames will lecture on the latest Mars Design Reference Mission. This is the cutting edge plan for humans to Mars generated by NASA and Mike Duke's HEDS program which has info on all elements of the first human missions. The plan is scanned electronically on one of our URLs and all students should read or at least scan this as a homework assignment prior to Brigg's lecture (note this is the one that's a PDF fire and needs an Adobe workshop reader)

Tuesday, March 17. Jun Okushi, a Space Architect from Japan, who participated in two studies on Space Station habitability for NASA-Ames will present spectacular slides of his drawings from a just completed two year study on the HABs for the first Mars Base. He will be followed during the last 30 minutes by Sachin and/or Alex with the unveiling of the latest class IDE website and directions on how to use them to speed our research up. This class is a mandatory for to attend. Assignment: get Kerry Joels "Mars One Crew Manual" and read. If need be we can post but it's not expensive and should be in many bookstores or orderable from Ballentine Books in NY for $12.95

Thursday, March 19. Dr. Eric Viire, from the International Space University will give the first of two lectures on space physiology and countermeasures to prevent the deleterious effects of long term exposure to space and low gravity

Spring Break

Tuesday, March 31. Dr. Joel Leonard of NASA Headquarters and Prof Howard Finkle of USF medical school will present the concluding lecture on space physiology and countermeasures, including observations on bone demineralization and it's relationship to osteoporosis.

Thursday, April 2. Dr. Bob Zubrin will present Mars Direct, his vision for the first human missions based on propellant manufacture of methane on the Martian surface. Zubrin is quite funny and delivers a brilliant, entertaining and thought provoking lecture. Advise all to come and invite friends. Suggest reading his book, Case for Mars, as assignment. It's on our reading list

Tuesday, April 7. Dr. Kuznetz will deliver the first presentation on human life support systems...the ECLSS. A mandatory. Make sure class reads the ECLSS manual posted on our site as an assignment

Thursday, April 9. Dr. Kuznetz will present the first of two lectures on Mars Space suit design, with a film and fashion show of contemporary suits. Assignment: read Space Suits and Life Support Systems for Mars, which is posted on our website

Tuesday, April 14. Dr. Kuznetz will present the second of two lectures on Mars Space suit design with emphasis on EVAs and suit materials

Thursday, April 16. Dr. Margaret Race will present a lecture on Contamination, the dangers of viruses and Mars bugs, for the crew, people back on Earth and for the pristine surface of Mars itself

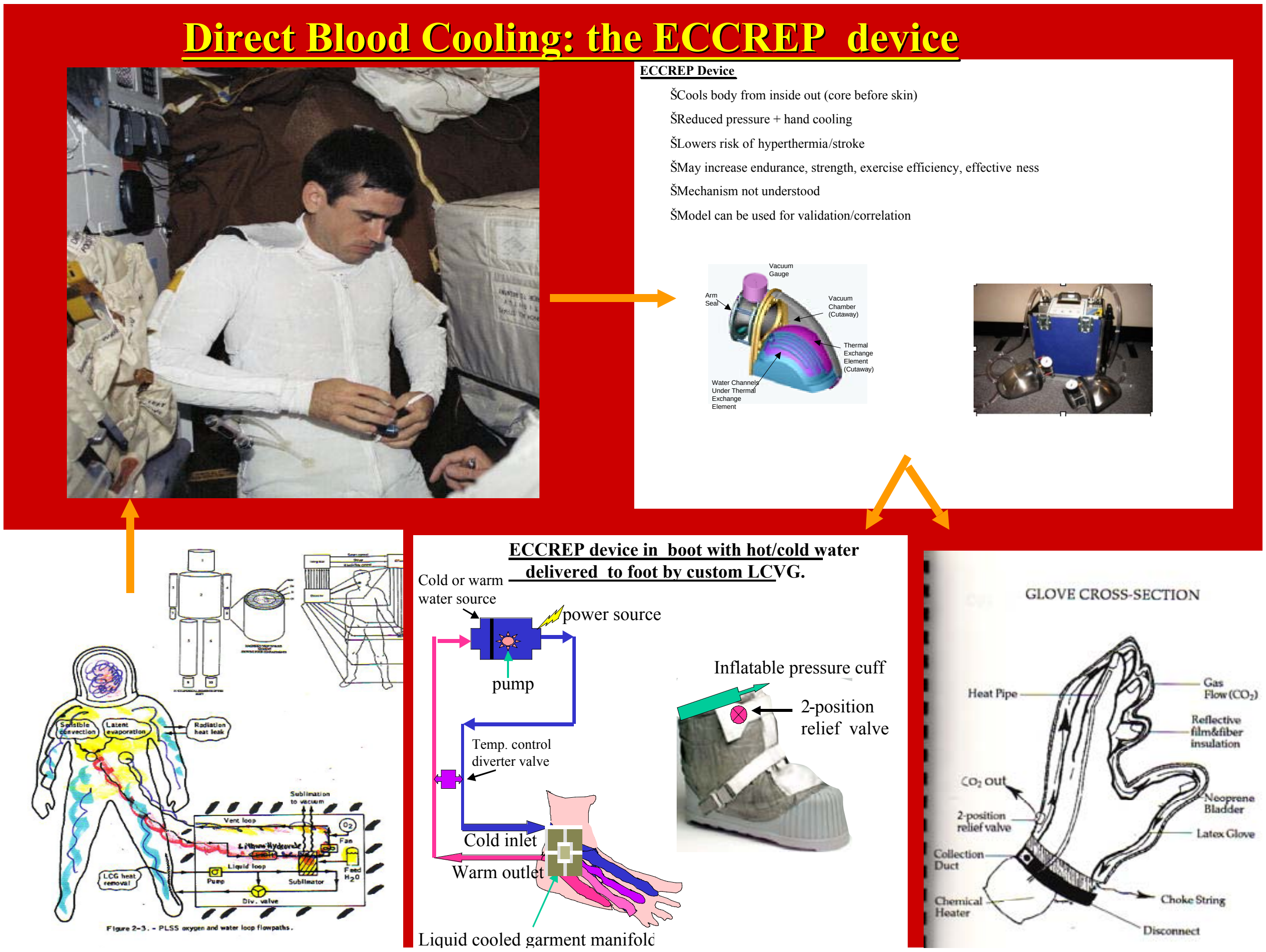
Tuesday, April 21. Getting There....Dr. Kuznetz will present the Orbital Mechanics of getting to Mars. A laymen's guide to the laws of gravity and how they effect the roadmap to Mars. Celestial Navigation and Propulsion will also be presented, time permitting.

Thursday, April 23rd. An Astronaut's Prospective. NASA Payload Specialist Byron Lichtenberg will give an astronaut's eye-view of a shuttle launch and his views on what it will take to go to Mars. An extremely entertaining, informative and fascinating lecture

Tuesday, April 28. Dr. Jack Farmer of NASA AMES on exobiology and exopaleontology....looking for life once you're on the surface. Or possibly Dr. Roger Bourke on the controversial subject of why sending humans to Mars are unnecessary and robots will suffice.

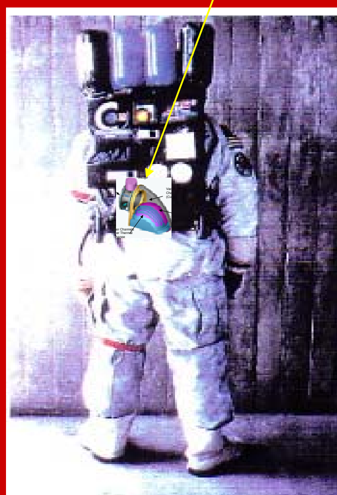
Thurs, April 28. Dr. Kuznetz. Why Mars-- a summary

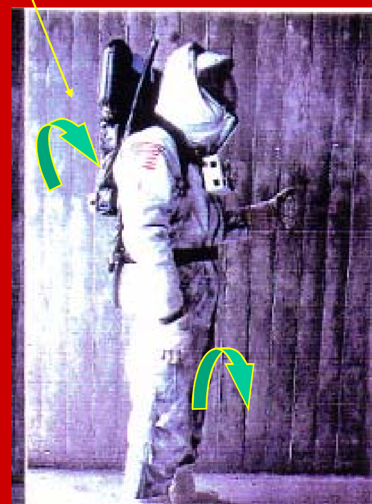
APPENDIX 10. MARSSUIT PROJECT CONCEPTS



Open loop ECLSS design: results in large mass reduction

In-suit compressor blows cool, dry mars atmosphere through torso to remove heat, sweat, toxins, contaminants





Issues: power, size, safety

Dust, surface toxicity protection

Dust bug exo-cover (disposable)

Life Sciences: Mobility and Performance

EMU mobility vs CG issue

Earth case

Muscles move 150 lb man w/ uniform wt distribribution.

Max backpack mass ~ 50 lbs

On Earth, Apollo EMU=220lbs

PLSS=139lbs, suit =81 lbs

Lunar case

Mars case

Moon

Man+EMU wt=62 lbs (25 lb body, 23 PLSS, 13.5 lb suit)

Muscles ŅseeÓ 25 lb body + 37 lb EMU non uniformly

Mars

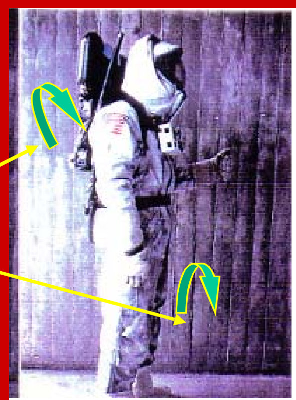
Man+EMU =141 lbs (57 lb body, 53 PLSS, 31 suit

Muscles ŅseeÓ 57 lb body + 84 lb EMU non unifor

Planetary Protection

Problem: ŅEarth bugsÓcontaminating the Moon on Apollo 12 (and Mars)

QuickTime™ and a Graphics decompressor are needed to see this picture.



Solution: Bacterial/Viral filters at compressor inlet & relief valve outlet ofMarssuit

Smart technology: for real time metabolic rates, consumables, suit leak and radiation loads

Thermoregulatory flight monitoring and control during Apollo EVAs

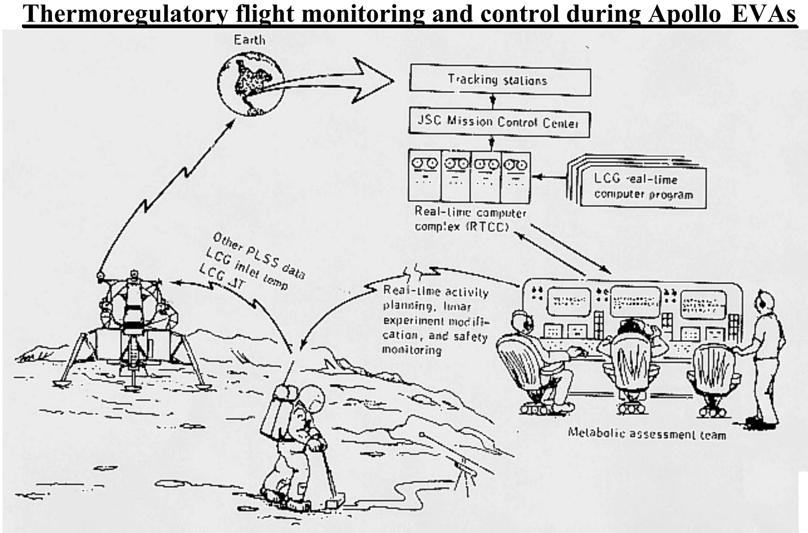


Figure 2-6.- Live data pathways and flight monitoring and control system for Apollo missions.

smart tech.mov

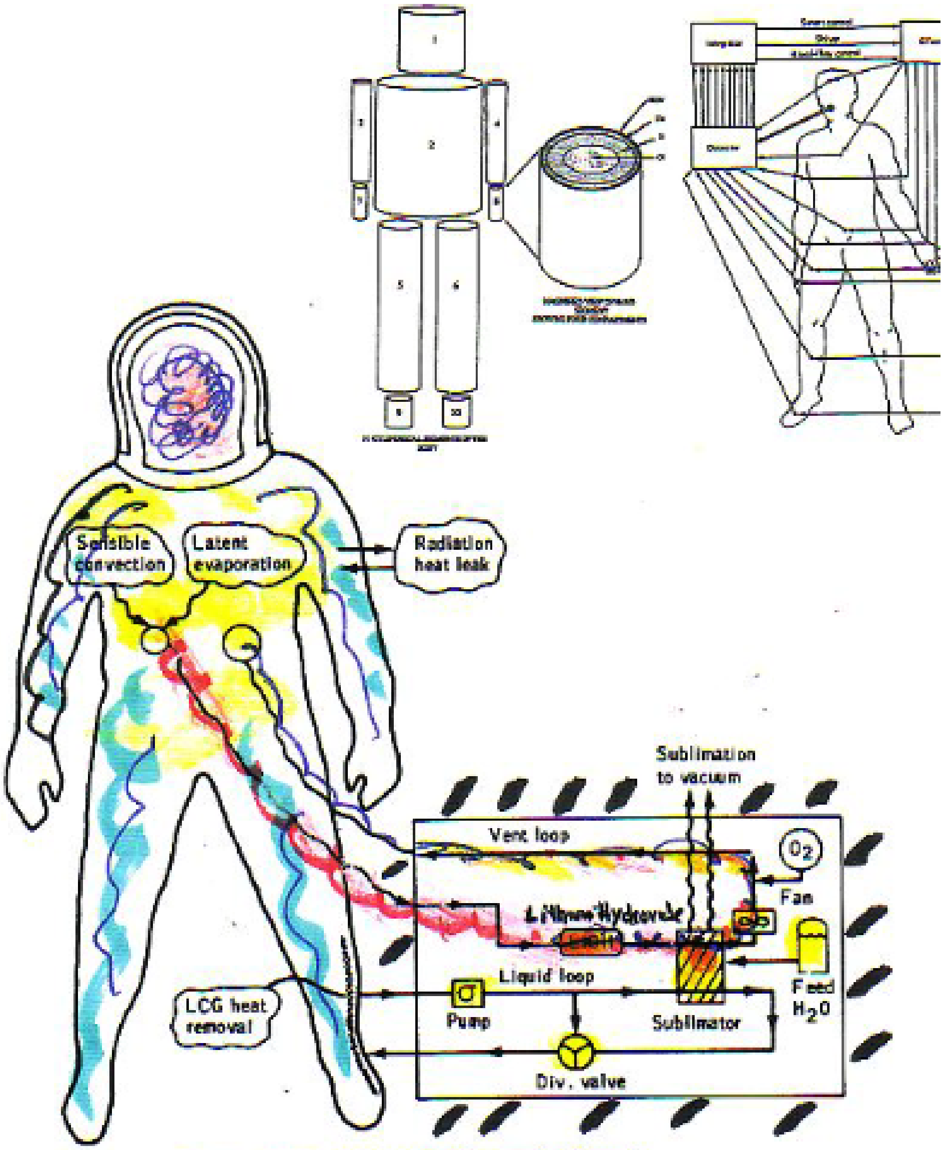
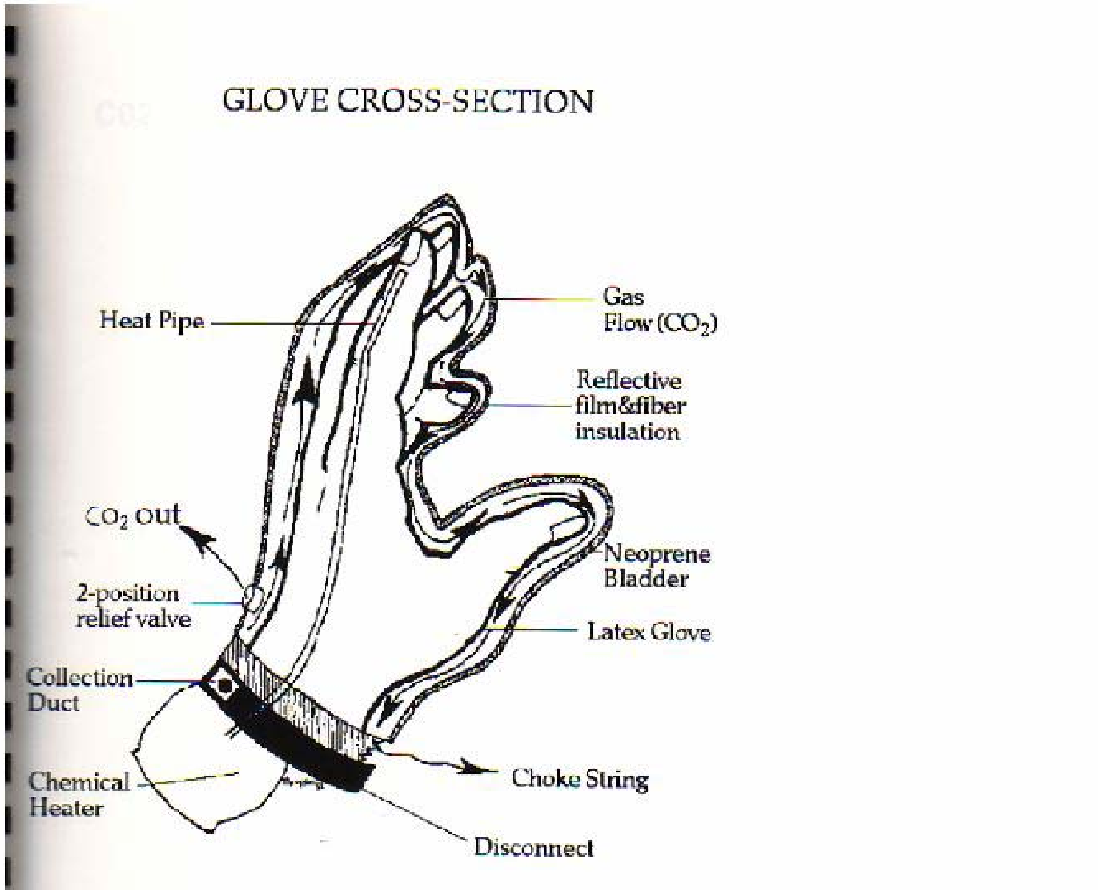


Figure 2-3. - PLSS oxygen and water loop flowpaths.

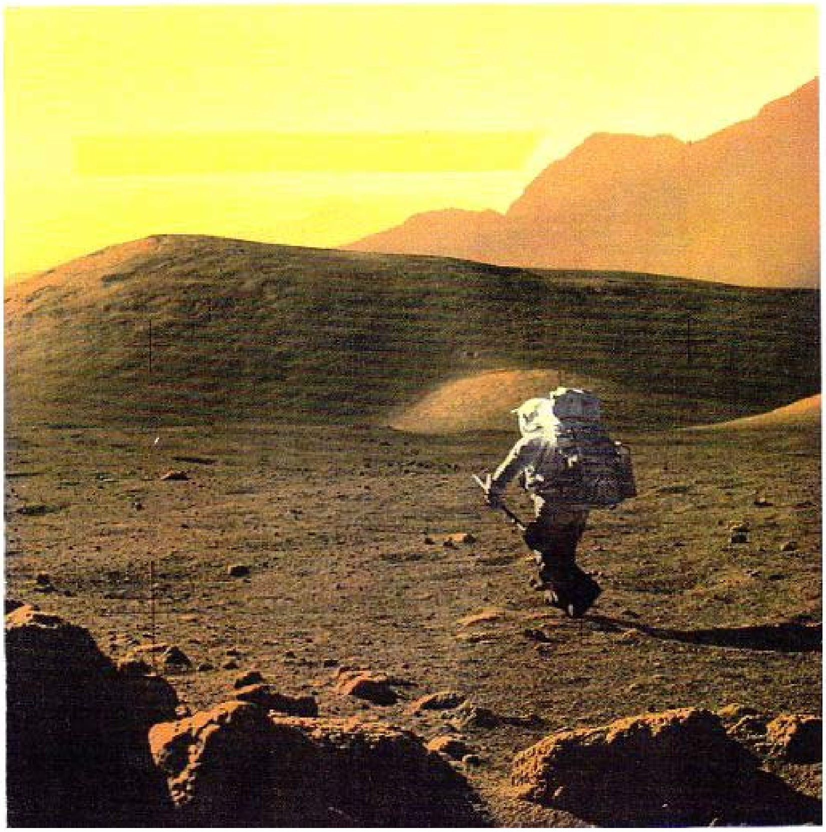
<u>MarsSuit thermal analysis. Concept 2. UC Berkeley, 1997</u>



MarsSuit EMU Glove concept. UC Berkeley, 1990

The MarSuit Baseline

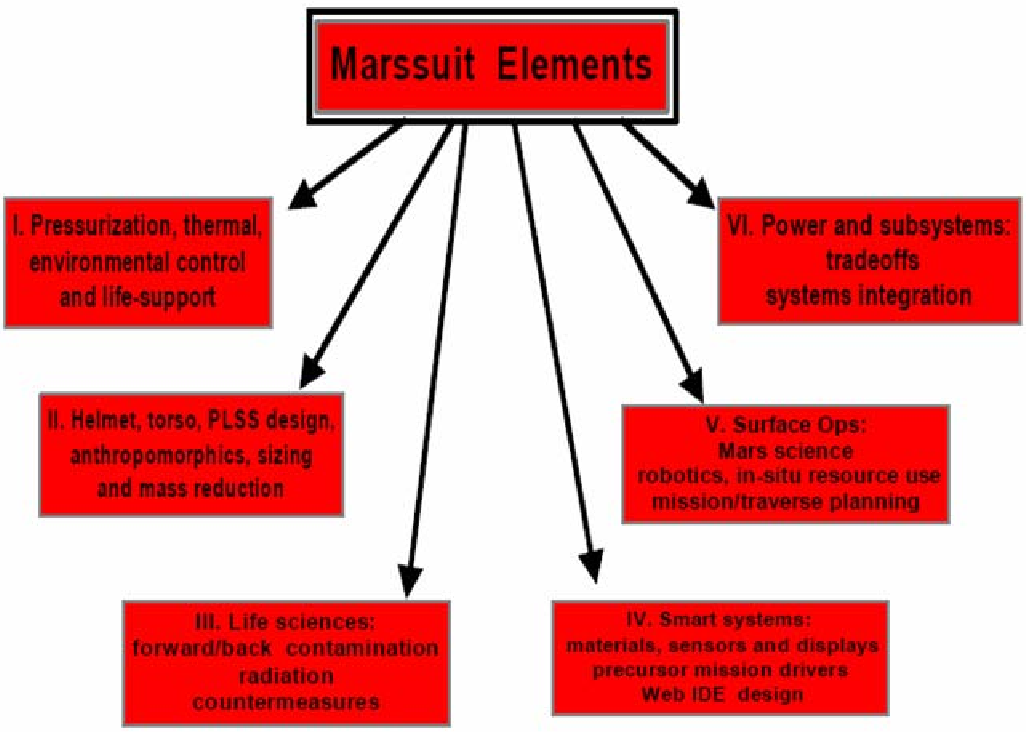
- Redundant system (helmet isolated from torso)
  - Enhances survival time in case of puncture
  - Improves safety; reduces leak rate, conserves O_2
  - Atmosphere pressurizes torso, O_2 pressurizes helmet
- Utilizes native resources to reduce consumable dependence
- New materials for dust, radiation shielding and sweat evaporation
- Variable pressure design
  - Operational ramping: 14.7-8.0 (airlock)-3.2 (ops)-8.0-14, 7 psi
    - Lowers pre-breath time
    - Improves mobility and glove dexterity
    - Reduces decompression sickness risk
- Cuts cost, mass, complexity
  - Open loop pressurization for torso
  - Compressor supplies atmosphere
  - No LCG, simplified ECLSS, DMMs transfer sweat to atmosphere
- Multi-fit (small to large males and females)
- Sensory input advances (HUDS, DCM, Met rate, consumables, etc.)
- Other creative inputs from university teams



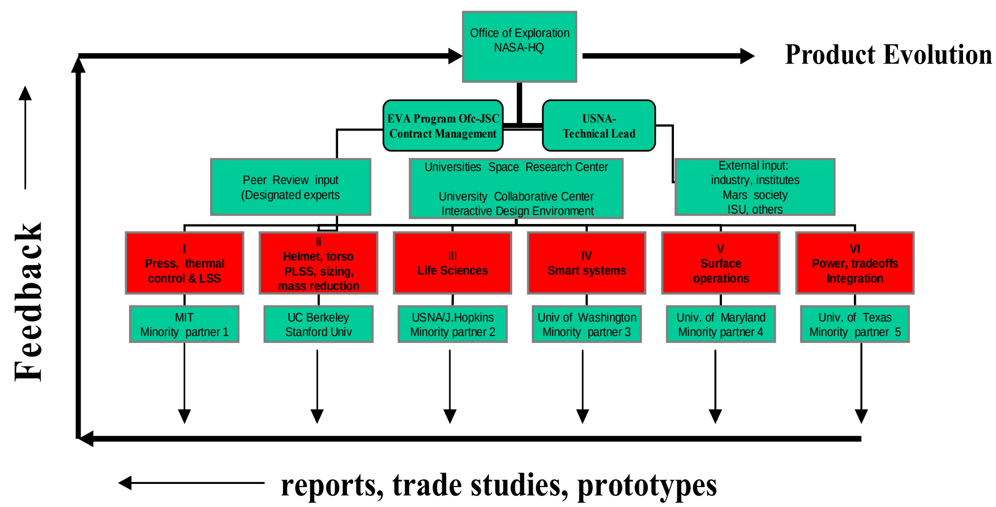
On to Mars….

APPENDIX 11. ENLARGED IMAGES OF MARSSUIT ELEMENT WORK PACKAGES AND ORGANIZATION FLOW CHART

Figure 4. MarsSuit Project Work Packages



Marssuit Project Organization



APPENDIX 12. SOLAR CAR PROJECT ANALOGY

The American Solar Challenge is a Formula Sun Event and is sponsored by the
United States Department of Energy

"Tour a Solar Car"

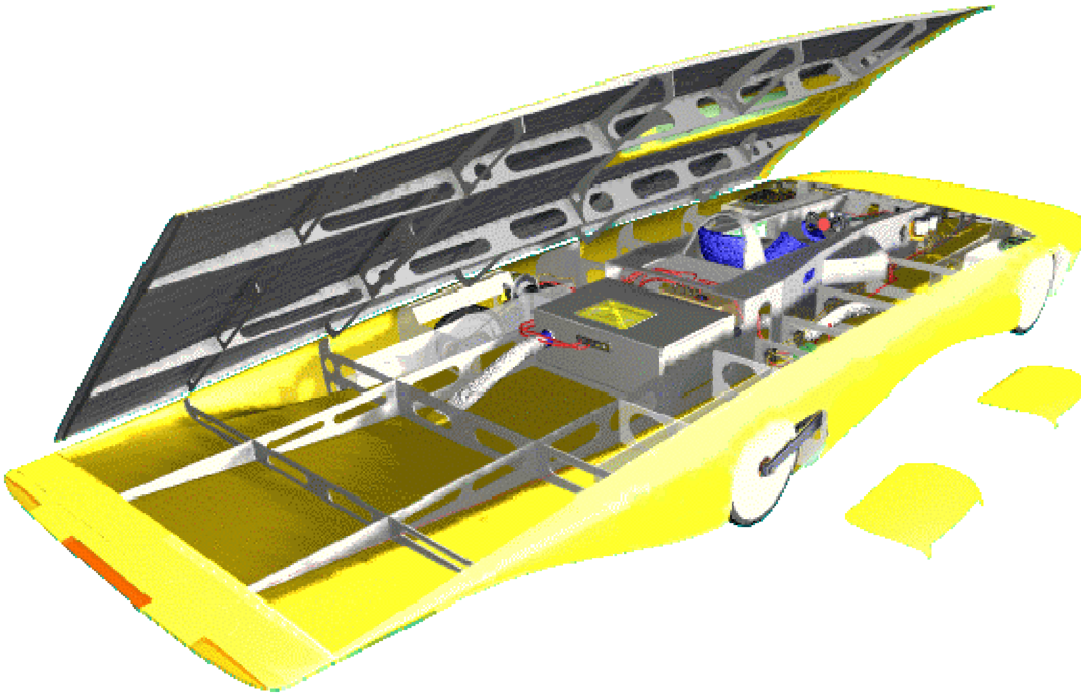
A solar car is a light weight, low power vehicle designed and built with a single purpose in mind: to develop future technologies that can be applied to practical applications.

The design process behind a solar car is based on optimization of an energy flow diagram to maximize the limited power offered by the sun in a safe, reliable, and efficient vehicle.

A solar car is made up of many components that have been integrated together so that they work as a single system. The functional components can be arranged into six primary systems:

- Driver Controls
- Electrical System
- Drive Train
- Mechanical Systems
- Solar Array
- Body and Chassis

Click on component for more detail



Each car in the race must be able to operate without power from any external sources, including gas and batteries. Most of the surface area is covered with solar cells, which soak up the sun's rays and power the car at speeds of up to 60 miles an hour. The cars were designed by engineering students across the United States, who worked diligently to build what they hope will be the fastest car to the finish line.

At the University of Michigan, more than 300 students were involved in building M-Pulse, the winning entry in the 2001 race. M-Pulse crossed the finish line after traveling 2,300 miles in 56 hours and 10 minutes and 46 seconds from Chicago to Los Angeles. It averaged over 40 mph with peaks exceeding 60 mph using only the energy of the sun.

The University of Missouri at Rolla placed second in the Challenge with a total time of 57:30:52. University of Waterloo, Ontario, Canada, finished third at 62:00:18.

The American Solar Challenge (ASC) is an educational sporting event in which university teams, companies and clubs from around the world compete to build and race solar-powered cars across the country from Chicago following what remains of Route 66 through Illinois, Missouri, Oklahoma, Texas, New Mexico, Arizona and California. It is the longest solar car race in the world. The race is sponsored by the U.S. Department of Energy

APPENDIX 13. CRITICAL PATH ROADMAP CPR FORM

See http://criticalpath.jsc.nasa.gov/ for further information on the CPR.

Hypothese	Risk Number (from Critical Path Roadmap)	Critical Question Number (from Critical Path Roadmap)	Critical Question Number (from Critical Path Roadmap)	Specific Aim
Can build variable pressure capability in EMU	20	20k	Prebreathe strategies	Eliminate prebreathe
Construct EMU of special resistant materials and include disposable outer layer	20	20s	Damage to spacesuit	Designed to withstand environmental impacts
Reduce mass allows astronauts to improve workload	29	29e	Job aids and tools to allow crew to accomplish task	Provide comfortable environment in space suit
Reduce mass to lighten load on astronaut	30	30e	Workloads	Reduce workload and mass of spacesuit
Utilize special radiation resistant materials	31	31c	Radiation exposure	Provide improved radiation protection

Hypothese	Risk Number (from Critical Path Roadmap)	Critical Question Number (from Critical Path Roadmap)	Critical Question Number (from Critical Path Roadmap)	Specific Aim
Provide improved EMU system	41	41a to 41n	How to achieve improved EVA system	Design a new Mars unique EMU

Crosscutting Area: *Advanced Human Support Technology* **Discipline:** *Advanced Extravehicular Activity* **Risk:** *(41) Provide Space Suits and Portable Life Support Systems*					
		EQ DRM Priority			
EQ No.	**Enabling Question**	**ISS**	**Lunar**	**Mars**	**EQ Category**
41a	What EVA system design can be developed to reduce the pre-breath requirement?	N/A	1	1	Requirements/Specifications Operations & Training
41b	What suit and PLSS technology must be developed to meet mission requirements for EVA mobility?	N/A	1	1	Technologies
41c	How do we protect against planetary surface dust through suit and airlock system design?	N/A	1	1	Technologies Requirements/Specifications
41d	How do we protect against toxic fluids and contaminant?	2	2	2	Technologies Requirements/Specifications
41e	How do we design space suits to fit multiple crewmembers of various sizes and shapes?	1	1	1	Design Tools Requirements/Specifications
41f	How do we improve glove dexterity?	1	1	1	Technologies
41g	What technologies can be developed to provide passive or active thermal insulation in various environments, including deep-space and lunar vacuum?	N/A	1	1	Technologies
41h	What technologies must be developed to meet mission non-venting and non-contaminating requirements?	N/A	2	2	Technologies
41i	How do we provide and manage increased information to EVA crewmember, including suit parameters, systems status, caution and warning, video, sensor data, procedures and text and graphics?	N/A	2	2	Requirements/Specification Operations & Training
41j	How do we achieve EVA and robotic interaction and cooperation?	N/A	1	1	Technologies Requirements/Specification
41k	What biomedical sensors are needed to enhance safety and performance during EVAs?	N/A	2	2	Technologies Requirements/Specification
41l	How can space suit design accommodate crewmember physical changes after long time in microgravity?	N/A	1	1	Technologies
41m	What technology can be developed to monitor EVA crewmember thermal status and provide auto-thermal control?	N/A	1	1	Technologies Requirements/Specification
41n	Can a practical EMU containment receptacle for emesis be developed? If a vomiting episode occurs, is there a way of refurbishing the suit during the mission? How can suit life support systems be designed to be more resistant to vomiting episode?	1	1	1	Technologies Requirements/Specification Operations & Training

Table 3.1 Bioastronautics Critical Path Roadmap Enabling Questions Provide Space Suit and Portable Life Support Systems, NASA JSC 62577, 2004.

APPENDIX 14. RESUMES

BIOGRAPHICAL SKETCH

Name	*Position*
Vincent L. Pisacane	**R.A. Heinlein Professor of Aerospace Engineering**

EDUCATION/TRAINING

Institution and Location	*Degree*	*Year*	*Field of Study*
Drexel Univ., Philadelphia, PA	B.S.	1955	Mechanical Engineering
Michigan State Univ. East Lansing, MI	M.S.	1957	Applied Mechanics/Mathematics
Michigan Stat, East Lansing, MI	Ph.D.	1962	Applied Mechanics/Physics
Johns Hopkins Univ., Baltimore, MD	Post Doc	1973	Electrical Engineering

RESEARCH AND PROFESSIONAL EXPERIENCE

Capabilities

Application of leading edge technology and system solutions to develop advanced state of the art space instrumentation and space systems; team-based, cross-functional leadership style

Employment

United States Naval Academy 2001-Present Annapolis, MD
Robert A. Heinlein Professor of Aerospace Engineering (Endowed Chair)
Teaches space systems engineering including courses in space physiology, astrodynamics, space environment, and spacecraft design

John Hopkins University School of Medicine 1993-present Baltimore, MD
Joint Appointment, Part-Time Associate Professor Department of Biomedical Engineering

John Hopkins University School of Engineering 1968-present Howard County, MD
Adjunct faculty, Applied Physics (AP) Master Degree Program. Chairman, EE and AP Programs 1981-1985; member, Applied Biomedical Engineering Committee, 1993-2000

Applied Technology Institute 1998-present Clarksville, MD
Teaches short courses in space systems engineering primarily at NASA Centers (JPL, Marshall, Goddard, Wallops)

John Hopkins University Applied Physics Laboratory Howard County, MD
1990-2000 Assistant Director for Research and Exploratory Development, directed the Laboratory's independent research and development program

1993-2001 Assistant Director for Biomedical Programs, directed the Laboratory's biomedical program and formed collaboration with the School of Medicine

1999-2001 Director of the Institute for Advanced Science and Technology in Medicine, founding director of the institute to establish an independent biomedical group

1985-1990 Head, Space Department, directed the department with a staff of approximately 400 and increased the annual business to $100M/y

1962-1985 Held various positions in the Space Department developing space systems and space instrumentation for a number of satellite systems; expertise includes: astrodynamics, space propulsion; space communications; space environment; spacecraft attitude determination and control

National Space Biomedical Research Institute (NSBRI) 1997-2001 Houston, TX
Leader of Multi-university technology development team, team responsible to enhance technology to support the development of countermeasures for space exploration with budget of about $2M/y

Maryland Space Grant Consortium 1989-1996 Baltimore, MD
Associate Director for Interdisciplinary Programs – Responsible to develop the program and identify research opportunities to attract women and underrepresented minorities to science and technology and to increase collaboration between members of consortium and industry. Helped write the winning proposal.

Biography Continuation Page for Vincent L. Pisacane

SELECTED GRANTS

Principal Investigator: NSBRI Grant – MIDN: A spacecraft Microdosimeter Mission; to support a micordosimeter experiment on the DoD MidStar-I spacecraft under construction by faculty and midshipmen; launch is scheduled for Sept 2006, $100K, 2004-06

Principal Investigator: NSBRI Grant – Advanced Microdosimeter System for Spaceflight, $1.4M; to carry out ground based research to enhance the capability of solid state microdosimetry; Co-Is include (Dicello, Hopkins; Rosenfeld, Univ. Wollongong; Zaider, Sloan Kettering; Cucinnotta, NASA-JSC; Ziegler, USNA; and Martin, USNA; 2003-07

Principal Investigator: NASA-JSC Grant – Develop/Evaluate Breadboard Silicon Microdosimeter Suitable for Spaceflight, $15K, 200-03

Principal Investigator: NASA/JPL Contract – Martian Neutron Energy Spectrometer for the Mars 2003 Lander Mission, R. Maurer (PI); $6,049,844, Aug 1999 (Mission cancelled due to failure of prior Mars missions

Principal Investigator: NSBRI Grant – Miniature Magnet Resonance Imager, relinquished role on leaving JHU/APL, $1.2M, 2000-03

SELECTED COMMITTEES

AIAA Committees: Space life Sciences, 1993-present, Chair 1996-97; 1994-present; Space Systems, 1991-94; Computer Systems Tech 1986-91, Chair 1988-90; Academic Affairs, 200-present

NASA Committees: Bioastronautics Facility Committee, 2004; NASA Evaluation Panel on Biologically Inspired Materials and Structures, Chair, May 1999; NASA Utilization and Operations Task Group NASA-SSAC, 1992-94; Space Station Freedom Utilization Workshop, 1992

HONORS

AIAA – Fellow, 1992; Associate Fellow, 1989; Information Systems Award, Oct 1991
Academic – Pi Mu Epsilon, National Mathematics Society, Michigan State University, 1956

SELECTED BOOKS, PUBLICATIONS, PRESENTATIONS

V.L. Pisacane, (Editor) Fundamentals of Space Systems, Oxford University Press, Second Edition (Author of 4 chapters out of 16) now in final editing, available Spring 2005

V.L. Pisacane and R.C. Moor, (Editors) Fundamentals of Space systems, Oxford University Press, (Author of 3 chapters and co-author of 1 chapter out of 14), 1994

V.L. Pisacane, USNA, L.H. Kuznetz, J.S. Logan, J.B. Clark, NASA/JSC and E.H. Wissler, Thermoregulatory Models in the Management of Safety-for-Flight Issues for Space Shuttle and Space Station Operations, (submitted to AIAA Journal)

V.L. Pisacane, J.F. Ziegler, M.E. Nelson, M. Caylor, D. Flake, E. Youngborg, L.Heyen, USNA; A.B. Rosenfeld, UoW; F.A. Cucinotta, NASA/JSC; M. Zaider, Sloan-Kettering; J.F. Dicello JHU/Med, MIDN: A Spacecraft Microdosimeter Mission, 14th International Conf. Solid State Dosimetry, New Haven, Jun 2004

H.D. Charles, Jr., T.J. Beck, H.S. Feldmesser, T.C. Magee, T.S. Spisz, V.L. Pisacane Precision Bone and Muscle Loss Measurements by Advanced, Multiple Projection DEXA (AMPDXA), Acta Astronautica, vol. 49, no. 3-10 pp 447-450, 2001

V.L. Pisacane, Spacecraft Design and Engineering, Encyclopedia of Physical Science and Technology, third edition, 2001

Biography Continuation Page for Vincent L. Pisacane

V.L. Pisacane, National Space Biomedical Research Institute Technology Development, Space Tech. Appl Intern. Forum, Albuquerque, New Mexico, Jan 2000

V.L. Pisacane, Workshop Leader, Healthcare and Human Performance Systems, NanoSpace98 To the Planets and beyond, International Conference on Integrated Nano/Microtechnology for Space Applications, Houston TX, C6, Nov 1998

V.L. Pisacane, National Space Biomedical Research Institute Technology Development, Space Technology Applications International Forum, Albuquerque, New Mexico, January 30-February 3, 2000

V.L. Pisacane, Effective Development of Space Systems (Invited), Presented at the NASA/DoD Space Flight Interchange Meeting, Monterey, CA, October 1992

V.L. Pisacane, Independent Research and Development Programs at APL; John Hopkins APL Technical Digest, Volume 15, Number 4, 1994

V.L. Pisacane, (for the infrastructure Technologies Group); AIAA Assessment of Innovative Technologies for the Exploration of Space – Infrastructures Technologies Summary Report; Proceedings of AIAA Assessment of Innovative Technologies for the Exploration of Space, Washington D.C., September 5-6, 1990

V.L. Pisacane, S.M. Yionoulis, and R.E. Jenkins; "Nature and Reduction of Errors in Near-Earth Autonomous Satellite Navigation" J. of Space and Rockets, Vol. 22, No. 4, July-August 1985, pp405

V.L. Pisacane, and D.B. Debra, "Satellite Technology Developments in Gravity Research; IAF-83-233, 34th International Congress of the International Astronautical Federation, Budapest, Hungary, 1983

BIOGRAPHICAL SKETCH

Name	*Position*
Lawrence H. Kuznetz, Ph.D.	**Manager of Flight Projects**

EDUCATION/TRAINING

Institution and Location	*Degree*	*Year*	*Field of Study*
Columbia University, New York, NY	B.S.	1964	Bioengineering
Columbia University, New York, NY	M.S.	1965	Industrial Engineering, Management
Univ. of California, Berkeley, CA	M.S.	1973	Mechanical Engineering
Univ. of California, Berkeley, CA	Ph.D.	1976	Physiology, Space and Mammalian

RESEARCH AND PROFESSIONAL EXPERIENCE

Curriculum Vitae:

Lawrence H. Kuznetz
Current Address:
2004 San Sebastian Court, #2324
Houston, TX 77058
Tel: (H) 510-205-8056 (W) 281-244-6428
email: n2mars@aol.com

CAREER SUMMARY

Dr. Kuznetz received his Ph.D. in Physiology under the auspices of Professor Emeritus Nello Pace at the University of California, Berkeley, where he developed a mathematical model of human thermoregulation in spacesuits that was used during Project Apollo to manage astronaut safety, consumables and thermal control on lunar surface EVAs. During his tenure with NASA at the Johnson and Kennedy Space Centers from 1965 through 1984, and again from 1989-1991 at Ames Research Center as a National Research Council Senior Fellow, Dr. Kuznetz was involved in a number of projects encompassing a diverse range of fields from spacecraft build and test to astro/exobiology to Mars spacesuit design. In his current capacity as Bioastronautics flight Research Scientist for the International Space Station and Space Shuttle Programs, Dr. Kuznetz oversees some 45 human life sciences experiments targeted at developing countermeasures to the effects of sustained exposure to microgravity. Dr. Kuznetz' research interests span extremophile survival rates in non-terrestrial environments; the existence and stability of liquid water on the Martian surface; countermeasures to the effects of microgravity; hardware and software development relevant to space suit design; human performance and testing; design of EVA management systems and computer simulations of physiological systems. He also has experience in spacecraft build, management and operations and was part of a select team that directed the installation of the thermal protection system for OV-102 (Space Shuttle *Columbia*) at the Kennedy Space Center prior to its maiden flight. Dr. Kuznetz has extensive teaching experience as well, having taught and lectured at the University of Houston, University of Texas, Stanford University, MIT and the University of California, Berkeley, where he created and developed Mars2012, a design project-based research program targeting undergraduates (http://mars2012.berkeley.edu). Dr. Kuznetz has also been an independent consultant to private industry in the areas of thermal control and human performance in extreme environments and holds 8 U.S. patents.

EDUCATION

PH.D., Bioengineering/Physiology, 07/1976 — University of California, Berkeley, Berkeley, CA
Relevant Coursework:
Space physiology, modeling of physiological systems, exercise and mammalian physiology, organic and physical chemistry, bio-heat transfer, thermodynamics, mechanical engineering

M.S., Mechanical Engineering, 06/1973 — University of California, Berkeley, CA
Relevant Coursework:
Heat Transfer, thermal control systems, physiological modeling, engineering mathematics

M.S. Engineering Management—Industrial Engineering, 06/1965 — Columbia University, New York, NY
B.S. Bioengineering, 06/1964
Columbia University, New York, NY

Applied Technology Institute 1998-present — Clarksville, MD
Teaches short courses in space systems engineering primarily at NASA Centers (JPL, Marshall, Goddard, Wallops)

Biography Continuation Page for Lawrence H. Kuznetz, Ph.D.

Honors, Awards, and Special Accomplishments:
- Nominated for NASA Di8stinguished Public Service Medal, 1986
- NASA Achievement Awards
- NSF-National Research Council Senior Fellowship
- United States Patents (8): See Below

Selected Publications and Patents

1. The Use of Thermoregulator Models in the management of Safety-for-Flight Issues Related to Space Shuttle and Space Station Operations, submitted for publication to the American Journal of Physiology, July 2003.
2. On the Existence and Stability of Liquid Water on the Surface of Mars Today, Astrobiology, Volume 2, Number2002
3. The Potential of University Input to NASA's Design Reference Mission, based on the Mars2012 Project at UC Berkeley, NASA/CR-2002-210914, NASA Ames Research Center, Moffett Field, CA, May 2002
4. Approaches to Resolving the Question of Life of Mars. Instruments, Methods, and Missions for Astrobiology, SPIE Proceedings, 4137, 48-62, August 2000.
5. Space suits and Life Support Systems for the Exploration of Mars, AIAA Journal, 1991.
6. Space Suits for Mars; Journal of the British Interplanetary Society, JBIS, 1991.
7. Simulating The Mars Mission Gravity Profile, International Aerospace Federation, IAF Proceedings, 1990, Dresden, Germany.
8. Mars Mission Gravity Profile Simulations Experiment—International Journal of Space Technology, January 1992.
9. Control of Human Thermal Comfort with a Liquid Cooled Garment, Based on a Mathematical Model of the Human Thermoregulatory System, Ph.D. Thesis and NASA-TMX 81190.
10. "Heat Exchange System for Body Skin", U.S. Patent 4,425,917.
11. "Composite Fabric for Severe Environments", U.S. Patent 4,501,025.

References:
Mr. Randy Stone, Deputy Director, NASA Johnson Space Center (JSC)
Dr. David McKay, NASA-JSC
Dr. Chris McKay, NASA-ARC
Dr. Carol Stoker, NASA-ARC
Dr. Geoff Briggs, NASA-ARC
Mr. Keith Hudkins, NASA-HQ
Prof. Frank Morrision, UC Berkeley
Dr. Stan Fink, Director of Research, Guidant Corp
Mr. Neil Jacobstein, President, Tecknowledge Corp
Dr. Dan McCleese, Mars Science Program Manager, NASA-JPL
Dr. Charles Sawin, NASA-JSC
Dr. Jonathon Clark, MD, NASA-JSC

Biography Continuation Page for Lawrence H. Kuznetz, Ph.D.

05/1996 to 08/2001

Program Director, Mars2012 Project – University of California, Berkeley

Annual Salary: $60,000 **Hours Worked per week:** 20

Supervisor: Professor Frank Morrision Phone: 510-642-6000

Job Description:

Dr. Kuznetz has been a lecturer and curriculum innovator of space science and Mars related courses at UC Berkeley since 1986. Courses he has created and implemented include living in Space, in the Physiology Department; Spacesuits for Mars in the Mechanical Engineering Department; Mars2012 in the Interdisciplinary Engineering Department and Living and Working on Mars in the Earth and Planetary Sciences Department. During this time, Dr. Kuznetz has maintained a vigorous cross-disciplinary research agenda through a long standing association with the NASA Ames Research Center at Moffett Field, JSC and the Lunar Planetary Institute in Houston. His work in the field has culminated in the publication of articles in peer reviewed journals such as Astrobiology, boos such as the NASA Ames Report on the "To Mars by 2012 Project," and presentations at forums such as the First and Second Ames Research Center Conference on Astrobiology. Mars2012 and Living and Working on Mars, the most recent curriculum programs at UC Berkeley, offer lectures by experts in the field and design projects covering a wide range of topics related to mars exploration. These include the search for liquid water; survivability of Earth-based extremophiles in a Martian environment; construction of an automated robotics laboratory to search for life; drilling and extracting of in-situ resources; construction of an advanced planetary spacesuit; countermeasures to the physiological effects of microgravity and related projects. The underlying goal of this interdisciplinary program is the enhancement of undergraduate science literacy through the hands-on approach to research. The pilot program, in since 1996, has achieved many of its goals through the construction of an Interactive Design Environment (IDE) collaborative tool. The IDE features links to Mars websites, data archiving of previous and current projects; minutes of team meetings; peer review comments from NASA and industry experts; chat sessions between team members and many other features (see http://mars2012.berkeley.edu). The long range vision for the IDE and the Mars programs built around it, is to serve as a model for other universities and K-12 schools in an effort to improve science education throughout the country. While accomplishments to date include an education grant from NASA's Ames Research Center (Dr. Marc Cohen, administrator); a science education special on CNN television; awards at the HEDS-UP design competition and invitations to present results at the Jet propulsion Lab, National Space Foundation and other venues, perhaps the most lasting achievement has been the plethora of letters and emails from students crediting their admission to medical school and graduate school or nascent careers in aerospace to this program.

06/1982 to 06/2000

Director – Space Spinoffs, Inc.

Annual Salary: $150,000

Job Description:

As Director of Space Spinoffs, Dr. Kuznetz is a consultant to domestic and international companies in the area of extreme environment physiology. He has 8 U.S. government patents in this area and is also the designer of the heat-rejecting Olympic uniforms for the American track and field team. As part of his education outreach activities, he also supervised the construction of a full scale replica of the Space Shuttle *Challenger* from 1986-1989. The replica, involving thousands of students, public volunteers and donations from over 100 companies, culminated in a memorial, public exhibit, space camp and teaching tool at the Lawrence hall of Science, one of the pre-eminent teaching museums in the nation. As a result of this endeavor, Dr. Kuznetz was nominated for NASA's Distinguished Public Service Medal.

Biography Continuation Page for Lawrence H. Kuznetz, Ph.D.

06/1989 to 06/1991

National Science Foundation Senior Fellow – National Science Foundation-NRC

Annual Salary: $50,000 **Hours Worked per week** 40

Supervisor: Dr. Bruce Webbon Phone" 650-604-5000

During this time period, Dr. Kuznetz collaborated with Drs. Chris McKay, Carol Stoker, Geoffry Briggs, Dave McKay and other planetary scientists as an NRC Senior Fellow in formulating requirements and postulating designs for life support systems and spacesuits for the human exploration of Mars. This work also encompassed the search for an exploitation of in-situ resources, recycling techniques for consumables and the definition of Mars surface science activities. It culminated in the publication and presentation of several papers and presentations in professional venues (see publication list)

06/1966 to 12/1984
Aerospace Technologist – NASA

GS-13-8 **Date of last promotion:** 12/06/1980

Employment Type: Permanent **Hours worked per week:** 40

Supervisor: Mr. Kennith Kleinknecht Phone 303-795-1487

Job Description:
Dr. Kuznetz began his career with NSA as an Aerospace Technologist in the area of thermal control and life support systems at the Johnson Space Center. During the Apollo Program, he was responsible for aspects of mission formulation related to the design, development, launch, operation and data analysis of flight hardware such as the flash evaporator system, space radiators, extravehicular Mobility Units and other thermal control subsystems. His work on liquid cooled garment design and simulations of the human thermoregulatory system led to an algorithm that became the primary means of determining real- time astronaut metabolic rate and life support consumables utilization during all lunar surface Extravehicular Activities. This work later formed the basis of the Ph.D. thesis at UC Berkeley. Subsequent to Apollo, in the Skylab and Space Shuttle Programs, Dr. Kuznetz had a range of assignments including the development of human performance and thermal control development programs.

His final assignment prior to leaving NASA for a career in teaching and consulting was at the Kennedy Space Center as part of a select team overseeing installation of thermal protection system tiles for OV-102 (Space Shuttle *Columbia*), during which time he amassed critical learning skills in the area of contract management, contractor operations, safety, reliability and quality assurance and spacecraft Build Operations.

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13. ABSTRACT *(Maximum 200 words)*
The MarsSuit Project is an innovative research initiative that will engage multiple universities in a coordinated and synergistic effort to assist NASA in the formidable task of designing a lightweight, blue-collar Mars Extravehicular Mobility Unit for human exploration of the Mars. It is a revolutionary and evolutionary project, using a collaborative design Web site to link 16 university teams with NASA, industry, and other external institutions in a virtual organization mirroring an NASA Project Office. The MarsSuit Project will add to, focus, and galvanize the efforts of other universities into a nationwide program that will involve technology identification, assessment, and development; systems engineering; systems design; and education enhancing opportunities for participants. It will partner underrepresented minority institutions with established universities having a rich legacy of NASA research experiences. To assure relevance to NASA's requirements there will be a strong NASA presence through a NASA MarsSuit Advisory Panel led by the EVA Program Office; Joseph J. Kosmo, JSC's Senior EVA Project Engineer; and Astronaut Dr. Michael Gernhardt. To assure reality in the design and its ability to be reproduced by industry, an Industry Advisory Panel will be established as well, with representation from Hamilton Sundstrand and ILC Dover, leaders in the design and development of NASA space suits.

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