HEDS GOALS.
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Introduction: In November of 1996, NASA made the decision to fully integrate several areas of robotic and human Mars exploration study and planning. As a result of this decision, requirements for unmanned robotic missions to support human Mars exploration were identified and a plan to meet these requirements was developed. Concrete progress in the implementation of this plan has been made. Three experiments have been selected and are in development for the Mars Surveyor Program 2001 Orbiter and Lander missions which will provide critical data for the planning of human missions to Mars. An Announcement of Opportunity for the Mars Surveyor Program 2003 Lander mission has recently been released which solicited proposals related to planning for a human mission.

In order to define HEDS objectives for Mars robotic missions, it is important to understand what information is required as a foundation for mounting a program of exploration of this magnitude. We identify areas of research on robotic missions that will enable future human missions. These areas include Site Selection for Human Missions, Hazards to Human Explorers, Living off the Land, and Testing Critical Technologies in the Mars Environment.

Site Selection for Human Missions: Landing sites for Human missions must meet three critical criteria. They must be of scientific interest, they present the opportunity for long duration productive research, and they must be safe. Current and planned robotic missions are expected to make considerable contributions toward the identification of such sites and others that may also yield significant biologic, geologic, and climatologic data. The broad spectrum of data from past and planned missions should be sufficient for identification of a number of candidate sites with suitable scientific interest for human exploration. Following the identification of these sites, and prior to actual human missions, additional imaging or surface missions to those sites will be critical in order to validate both the scientific interest of the landing site and the conditions at the landing site to ensure safety of the human mission. Human mission objectives and hardware designs could then be optimized to address specific science goals and accommodation of known conditions at a targeted landing site.

Hazards to Human Explorers: Hazards to human explorers need to be understood and relevant data must to be collected and analyzed in order to design missions, spacecraft and infrastructure to support future human missions. Currently we have identified the major hazards as Space Radiation and Soil, Dust and Environmental Interactions.

Space Radiation: Space radiation presents short- and long-term risks to crew health and has a significant impact on design of spacecraft and habitats, as well as mission duration. Space radiation consists of galactic cosmic rays (GCR) and solar particle events (SPE). GCR provides a constant background source of radiation, the intensity of which varies with the solar cycle. This radiation is characterized by very high energies and high penetrating ability. In fact, nuclear interactions which occur as GCR propagate through spacecraft material, the Martian atmosphere, and the surface of Mars and create secondary radiation which can be more harmful than the original radiation spectra. SPEs are associated with short term solar phenomena such as coronal mass ejections, and are therefore periodic, relatively short term, and intense in nature. However, the particle types and energies produced by SPEs are of a nature that can be relatively easily shielded and therefore the primary danger would be to crew members who are outside the shielding afforded by the spacecraft for a sufficient length of time during one of these events.

Two specific types of radiation risk are associated with highly charged energetic particles (HZE). Exposure to high doses, such as generated by an SPE, can result in nausea or vomiting caused by the destruction of cells in the intestinal lining. Long-term effects to exposure to GCR and SPE may include cataracts, organ atrophy, sterility, and increased probability of cancer. Clearly, understanding the expected radiation environment in transit and on the surface of Mars is essential to predict the anticipated exposures, assess their consequences, and develop mitigation options.

Uncertainties in our ability to predict radiation risk arise from three major factor: accuracy of our models of the radiation environment; accuracy of our models which predict the changes to the radiation as it passes through spacecraft materials, the Mars atmosphere and surface, or the human body; and uncertainty in our knowledge of the specific biological effect of exposure to the anticipated radiation environment over the mission's duration.

It is essential to measure radiation dose and radiation quality on the surface of Mars. No such surface data exists at this time, and it is not possible to obtain such data by another means with sufficient confidence. This is due mainly to the large uncertainties in the radiation transport models and the complexity of the radiation environment expected at the surface of Mars where the radiation intensity, content and quality are altered as the primary radiation is attenuated or converted to secondary radiation.

An instrument to measure the radiation environment on the surface of Mars is in development and will be carried on the MSP 2001 missions. This experiment, named the Martian Radiation Environment Experiment (MARIE) will include radiation dosimeters on both the orbiter and the lander, allowing a quantitative measurement of the effect of the Mars atmosphere on the radiation environment on the surface of Mars. The contribution of neutrons, which are a critical component of the predicted secondary radiation induced risk, will be characterized by their contribution to the total dose. Plans are in place to select an experiment for the MSP 2003 Lander mission which will allow greater characterization of this hazard by measuring the neutron spectra.

Soil, Dust and Environmental Interactions: The surface of Mars should be regarded as having a meteorological-aeolian-geoelectrical system, constituted by an integrated dynamic interdependence of a large suite of physical, electrical, and chemical phenomena. The soil and dust on Mars pose potential hazards to both the health of human explorers and to the operation of hardware and systems that will support them. As a first step, a thorough characterization of the soil and dust on Mars is necessary to anticipate potential hazards and how to avoid them. The properties of importance include adhesiveness, particle shape and size distribution, composition and chemical reactivity.

The MSP 2001 Lander mission holds great promise for soil characterization. The MSP 2001 Lander will carry the Mars Environmental Compatibility Assessment (MECA) package. MECA will characterize dust & soil in size, shape, adhesion and abrasion. The addition of this knowledge to the already known chemical characteristics of Martian soil will help to identify undesirable and harmful interactions of the soil/dust with human explorers and associated hardware systems.

The MECA Wet Chemistry Laboratory will look for hazardous chemical components of soil, including peroxides, strong acids/bases, or heavy metals. It will quantify the potential for corrosion and reaction through pH, conductivity, and redox potential measurements. MECA's Microscopy Station will study particle morphology, hardness, adhesion, and abrasion.

While the MECA experiments will measure individual physical characteristics, the next logical step is to take a systems approach to understanding the interactions of the soil and dust with the Mars environment. This systems approach includes the interaction and understanding of the particulate matter, Aeolian transport of surface materials, atmospheric instability, atmospheric electrical phenomena, and geoelectrical factors such as Paschen discharge/ionization and their effects on humans and machines.

While the MECA instrument suite on the MSP 2001 Lander mission will measure triboelectric charging during excavation using an electrometer mounted on the robot arm, there has been no systematic investigation of how the meteorology, resulting in lofted dust and surface dust redistribution, interact to create geoelectrical hazards.

Plans are in place to select an experiment for the MSP 2003 Lander mission which will perform such an investigation. This will be the first comprehensive attempt to understand and characterize these effects to determine the nature and extent of the hazards.

Living off the Land*: In situ* resource utilization (ISRU) means the use of indigenous resources. Living off the land implies that there are resources on Mars that can, if suitably exploited, meet some of the basic requirements for human activity. Any ISRU emphasis for initial human missions to Mars will be on resources that can be easily extracted and used in their purest form. Therefore, fundamental data regarding the composition of the atmosphere and surface composition is required in order to identify potential resources. The composition of the Mars atmosphere has been characterized sufficiently for the purposes of exploring potential for ISRU. Most important are extraction of oxygen from the atmosphere for use as a propellant or for life support systems. The importance of propellant production from Martian resources is the potential for significant launch mass reduction and for increased human mission safety. Use of argon for buffer gas makeup and extraction of water from atmospheric water vapor are two additional possibilities. The potential for extraction of water from the Martian regolith for use in life support systems or for electrolysis to produce hydrogen (a fuel) and oxygen represents a resource of significant potential. More data on locations, form, and quantities of ground water is required.

Testing Critical Technologies in the Mars Environment: Enabling propellant production on Mars is most dependent on *in situ* technology test and demonstration. The Mars *In Situ* Propellant Production (MIP) Precursor package planned for the MSP 2001 Lander will. The Mars MIP package is a set of experiments designed to demonstrate the component technologies required to produce oxygen from the Martian atmosphere. The five experiments comprising MIP will demonstrate the production of power by advanced solar-cell technologies, acquisition and compression of CO_2 from the Martian atmosphere, conversion of the compressed gas to oxygen by zirconia electrolysis, radiation of the waste heat from the compression process to the night sky and methods of mitigation of the effects of dust on the solar arrays.

Building on the MIP experience, HEDS is anticipating further technology demonstrations for the MSP 2003 Lander Mission, which build upon the component level technology demonstrations of the 2001 ISPP experiment. These will involve "end-to-end" system-level demonstrations of propellant and consumable production processes, including acquisition of resources, chemical processing, storage of products, and demonstration level use of the products.