Wednesday, October 15, 2003
MID-CONFERENCE FIELD TRIP

Evening Session
SPECIAL SESSION: MARS POLAR AND CLIMATE SCOUT CONCEPTS
7:00 p.m. Victoria Room

McBride K. S. *
Scout Missions and Future Exploration of the Martian Poles **[#8090]**

Pascal Team Haberle R. M. * [INVITED]
The Pascal Mars Scout Mission **[#8075]**

Sims M. H. * McKay C. P. [INVITED]
Long Day's Drive: An Alternative Paradigm for Martian Robotic Exploration **[#8053]**

Hecht M. H. * Saunders R. S. [INVITED]
CryoScout: A Descent Through the Mars Polar Cap **[#8078]**

Mahaffy P. R. * Atreya S. A. Fairbrother D. A. Farrell W. M. Gorevan S. Jones J.
Mitrofanov I. Scott J. [INVITED]
The Mars POLar Aerobotic Reconnaissance (POLAR) Balloon Scout Mission **[#8038]**

Smith P. H. * [INVITED]
The Phoenix Scout Mission **[#8107]**

GENERAL DISCUSSION

SCOUT MISSIONS AND FUTURE EXPLORATION OF THE MARTIAN POLES.

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Introduction: NASA's Mars Exploration Program, (MEP) complemented by missions in operation by ESA and the Japanese space agency, is revolutionizing the study of Mars as a planet and potential home for life, past, present or future. Within the MEP there are a number of significant opportuntieis for the study of the Mars polar regions—from the ongoing Mars Global Surveyor and Odyssey missions, the upcoming Mars Reconnaissance Orbiter, and the soon-to-be-defined Mars Science Laboratory. As an internal complement to the Mars missions being developed by JPL for the MEP, Mars Scout investigations can provide substantial future opportunities to study the polar regions of Mars. These relatively small, PI-led missions provide substantial flexibility within the overall MEP, providing the capability to respond to scientific targets of opportunity in Mars science, with special-interest small missions, or to be developed to respond to instrument opportunities for missions developed by international partners.

Status and Future Plans: In the summer of 2003, NASA will select the Scout investigation planned for the 2007 mission launch opportunity. For future opportunities, Scout will respond to pathways of Mars exploration that are being studied by NASA and others, with the expectation that a Scout mission will be launched approximately every other launch opportunity during the next decade. Such mission opportunities are also anticipated to be supplemented by future instrument opportunities that will both make use of new technologies and to provide US participation on missions now being studied by ESA and CNES.

Irrespective of the opportunities in question, a rigorous selection process that includes both science evaluation and a detailed technical, management, and cost analysis will be applied to all Scout proposals. Through ongoing Scout investigations, the MEP should provide a substantial source of competitive opportunities for PI-led teams to participate in the future exploration of Mars and its polar regions.

THE PASCAL MARS SCOUT MISSION.

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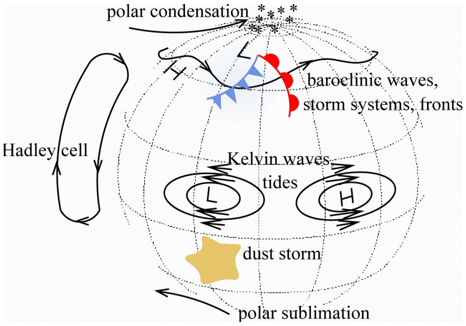
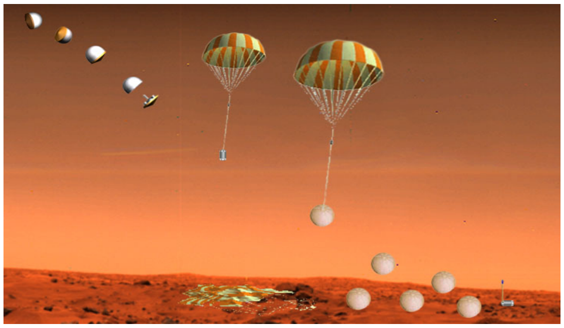
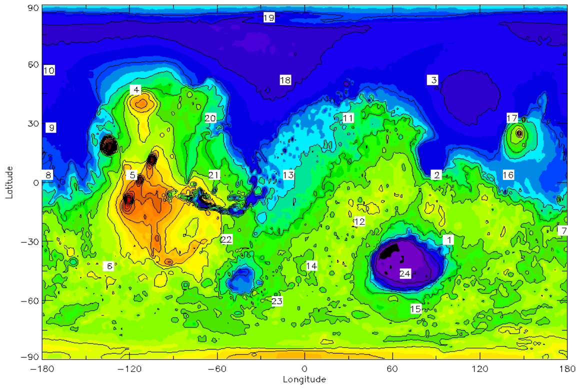
Introduction: Pascal is a Mars Climate Network Mission that is being developed for NASA's Mars Scout Program. The mission would establish a network of 18 science weather stations distributed across the entire surface of Mars that operates for 3-10 Mars years (5.6-18.8 Earth years). Pascal’s instrument suite combines entry data from accelerometers and descent cameras, with landed data from pressure, opacity, temperature, wind speed, and water vapor to create a detailed global picture of Martian climate and weather. A panoramic landed camera system acquires images every 30 Sols to monitor changes in the landing environment due to winds. Analysis of data from the science stations, taken as often as once every 15 minutes, will provide a depth of understanding that will vastly increase our knowledge of Mars, and significantly impact site selection for future NASA missions. Pascal is the first mission ever to sample - in situ - the full global diversity of Mars and provide a continuous long-term presence on its surface.



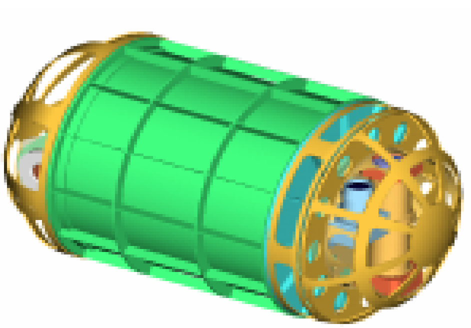
Science goals and objectives: Pascal’s primary science goal is to characterize the Martian climate system and ho(Fig. 1). This goal naturally includes the nature of aeolian processes, the role of global and small-scale circulations, and comparative planetary meteorology. Pascal’s science objective is to measure the seasonal cycles of dust, water, andCO_2; measure the near surface signature of global and small scale circulation systems; relate those measurements to understanding how these circulation systems control the climate system and modify the surface; and provide a basis for comparative meteorology.

Mission design: The Pascal carrier spacecraft delivers its 18 Probes on direct approach using three separate release events, and propulsive time-of-arrival adjustments to facilitate global coverage. The probes utilize an areoshell for thermal protection and initial deceleration; a parachute and an air bag provide final deceleration for the 9 kg stations. Accelerometers record the deceleration history throughout the entry, descent, and landing phase (Fig. 2), while a descent camera acquires images every 5 seconds while on the parachute. On the ground, the science stations orient and deploy the camera system and begin autonomous operations. Pascal's long life is enabled by its power system: a lightweight radioisotope-heating unit coupled to a thermoelectric converter. Communication with the Pascal landers occurs through the telecommunication infrastructure of the Mars Exploration Program. A sample network achievable for the 2007 opportunity is shown in Fig. 3.





With this kind of a robust long-lived global network, Pascal will be the first mission ever to sample - in situ - the global diversity of Mars and provide a continuous long-term presence on its surface. In this sense, Pascal is a true “Scout” mission. Humans have long been fascinated with the prospect of an extended stay on Mars, and NASA’S MEP has identified a sample return mission as its ultimate near-term goal. Pascal can provide the information needed to enable such missions. Questions such as where should we land, what are the expected environments, and how can we adapt to them, are all readily addressed by this mission.



Pascal Science Station

LONG DAY'S DRIVE: AN ALTERNATIVE PARADIGM FOR MARTIAN ROBOTIC EXPLORATION.

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Introduction:. The Log Day's Drive proposed Martian polar exploration rover mission represents a different place in the space of designs from previous missions including MER, and in part represents an alternative to future deep drilling missions. This mission design is characterized by:

-High power and continuous power afforded by the northern polar region in summer sunlight.

-No nighttime operations; small thermal variability over the day.

-Rapid acquisition of data by virtue of instrument selection - the full suite of instruments can collect their data in under an hour. Stylized transects and previously demonstrated pattern recognition algorithms (e.g., the recognition of rock like objects in a terrain) will be used.

-Mobility during a large fraction of the Martian day

-Vehicle self-safing. This is the fundamental technology needed for long range mobility. This ability of the vehicle to be responsible for its own well being is commonly used on earth based autonomous vehicles and is the crucial element for long traverses.

-Sufficient mobility in rover design to allow access beyond the landing ellipse. Hence, specific locations are then targetable.

-Excellent access to orbital communication facilities

Mission Overview: LDD will investigate the north polar layered deposits (PLD). The overarching science rationale for LDD is the belief that the PLD preserve within their stratigraphy an interpretable record of recent climate and geologic history for Mars. Our primary goal is to obtain data that can provide a basis for interpreting that record. In addition, we will test the hypothesis that the ice of the PLD contains organics at higher concentrations than the aeolian dust sampled at the two Viking sites. Finally, we seek to contribute to the understanding of Mars' total volatile inventory by detailed determination of the ice content of the PLD over the traverse

Science Goals: It is widely believed that the Martian polar layered deposits record climate variations over at least the last 10 to 100 million years, but the details of the processes involved and their relative roles in layer formation and evolution remain obscure.

Variations in axial obliquity and orbital eccentricity are thought to influence the climates of both Earth and Mars, but are of greater amplitude in the Martian.

A common presumption among Mars researchers has been that the polar layered deposits are the result of variations in the proportions of dust and water ice deposited over many climate cycles but their density and composition are poorly constrained. There is evidence for both topographic and albedo variations between layers in the north polar layered deposits, based on analysis of springtime images.

Traversing the PLD over the surface is the most effective way to collect a long-term record of their variation. If the LDD rover traverses 10 km up or down a 5% slope, perpendicular to the layering we could have a record corresponding to a drill depth of 500 m. If the nominal deposition rate of dust on Mars is of order a few microns per year, then the climate history captured by the layers covered would be about 10 to 100 M-yr. This time scale is significant because variations in Mars' obliquity, eccentricity, and phase of perihelion vary significantly on time scales of millions of years. As the obliquity changes the total radiation received at the polar regions changes and this changes the amount of CO_2 in the atmosphere and the amount of water vapor released in the summer from the polar deposits. Changes in the pressure of CO_2 and the annual water cycle should both change the amount of dust and ice deposited in the winter in the PLD. This climate record is preserved in the PLD layering and the LDD traverse will be able to document this recored.

Organics. detection for organics on Mars would have important implications for astrobiology and future Martian missions. Any future search for organics on Mars must follow up from the Viking results. The Viking results were puzzling in three respects. First, was the total absence of organics as measured by the GCMS. The second unexpected result was the rapid release of O_2 when soil samples were exposed to water vapor in the Gas Exchange Experiment (GEx) at levels of 70 - 770 nanomoles per gram. The third unexpected result was that organic material in the Labeled Release (LR) Experiment was consumed as would have been expected if life was present --- the presence of life being in apparent contradiction with the results from the GCMS.

Currently, the most widely held explanation for the reactivity of the Martian soil is the presence of one or more inorganic oxidants.

It has been observed that the level of oxygen release from the GEx experiment was lower at the northernmost Viking site and suggested that the oxidant might decrease systematically toward the poles with a concomitant increase in the stability of organics. Chemically this might be due to the role of ice and thin films of water in destroying oxidants.

Thus we hypothesize that organics may be present in the PLD at concentrations significantly higher than the upper limit determined at the Viking sites.

Ice content. A recognized goal for Mars exploration is to map the 3D distribution of water in all its phases. We propose to contribute to the understanding of Mars' total water inventory by detailed determination of the ice content of the PLD over the length of our traverse.

Proposed payload: The proposed payload consisted of

- copy of MER PanCam system
- one shot panoramic camera (fish eye or mirrored sphere lens for panorama)
- Distant microscopic imager – By using telescopic optics creating microscopic quality images from a few inches to a meter or more distant
- Laser Induced Breakdown Spectrometer – Los Alamos to generate elemental analysis quickly and up to 10's of meters distant
- Raman spectrometer integrated into above Laser Induced Breakdown Spectrometer allows for organic detection
- Neutron spectrometer
- Ground penetrating radar

CRYOSCOUT: A DESCENT THROUGH THE MARS POLAR CAP

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Introduction: Recent discoveries on Mars—from the numerous gullies seen by Mars Global Surveyor (MGS) to the vast expanses of near-surface ice seen by Odyssey—draw attention to the importance of a modern hydrological cycle and the possibility of extreme climate variations driven by orbital forcing. The surface/atmosphere interactions that define this cycle are presumably reflected in the stratigraphy of the polar layered deposits (PLD), comprising a climate archive that possibly spans many millions of years. If a terrestrial ice sheet were so endowed it would be studied by coring, in order to retrieve the most pristine record of past chemical and physical properties, and to evaluate modification induced by time and stresses within the ice. On Mars' north polar cap, thermal probes are feasible and can provide a reasonable approximation of coring. Optical and spectroscopic analysis of the layers, which are presumably demarcated by embedded dust, would contribute to the reconstruction of a timeline. Meltwater analysis is a convenient way to determine the soluble chemistry of that embedded dust, and to monitor gradients of the isotopic ratios of hydrogen and oxygen that reflect atmospheric conditions at the time the layer was deposited. As on Earth, local thermal measurements can be used to determine bulk mechanical properties of the cap, as well as the geothermal gradient.

CryoScout was proposed as just such a subsurface investigation of the stratigraphic climate record embedded in Mars' North Polar cap (Figure 1). After landing on a gentle landscape in the midst of the mild summer season, CryoScout was to use the continuous polar sunlight to power the descent of a "cryobot," a thermal probe, into the ice at a rate of about 1 m per day. CryoScout would probe deep enough into this time capsule to see the effects of planetary obliquity variations and discrete events such as dust storms or volcanic eruptions. By penetrating tens of meters of ice, the mission would explore at least one of the dominant "MOC layers" observed in exposed layered terrain.

CryoScout's primary objective was to determine the conditions under which the north PLD, the only known unmodified and accessible record of recent Mars climate history, was laid down over the past million years. Secondary objectives were to characterize the present-day polar cap structure and surface conditions. These objectives would be pursued by acquiring data on the present surface mass balance and the variation of compositional, physical, and thermal properties as a function of depth below its surface.

Figure 1: Fueled by continuous sunlight on Mars' North Pole, the cryobot uses heat to sink through undisturbed polar layered deposits.

CryoScout's detailed log of images, temperature, and compositional data, would reflect the influence of meteorology, depositional episodes (volcanic, impact, dust storms), and planetary orbital/axial modulation. Among the questions CryoScout might address are these:

- How has the climate changed with orbital parameters in the past million years? Can such change explain young gullies (MGS) or evidence of ground ice (Odyssey)?
- What is the fine-scale stratigraphy of the North Polar cap?
- What is the inventory of dust, salts, and organic compounds incorporated into the ice?
- What is the inventory of volatiles, including water, CO_2, and clathrate hydrates?
- Has there been recent volcanism on Mars?

Mission Overview: As proposed for the recent Scout competition, a Type 2 trajectory was to deliver a cryobot [1] and surface instruments to the North Polar region of Mars in 2008, arriving at L_s=73, just before the summer solstice. CryoScout would then be in continuous sunlight throughout the 90-day mission, during which the cryobot would penetrate about 80 m into the North PLD. Powered by a large, tracking solar array, the cryobot would descend an average of 4 cm per hour, transmitting data through a tether that slowly unreeled from its aft bay.

Six instruments were selected to accomplish the CryoScout goals. IceCam, the cryobot camera, would record the visible stratigraphy. With 1-mm vertical resolution in nephelometer mode, IceCam would provide a time resolution of months to centuries (assuming deposition rates of 0.01–10 mm per year [2]). In imaging mode, IceCam would acquire full-color stereo images at 10^{-5} m per pixel, probably sufficient for observing annual layers similar to terrestrial varves.

By analyzing the meltwater with a suite of electrochemical sensors, the Mars inorganic chemistry analyzer (MICA) would determine the salt composition and abundance in the embedded dust, providing clues to its origin. The Mars isotopic laser hygrometer (MILH) would measure variations in relative hydrogen- and oxygen-isotope abundance in that same meltwater, reflecting source and climate conditions under which the ice was deposited.

A fiber thermometer incorporated into the tether linking the cryobot to the surface, the Distributed Temperature Sensor (DTS) would measure the time-dependent ice temperature profile, including the thermal wave penetration in the top ~20 m and geothermal heat flux below. The DTS would determine both conductivity and diffusivity, which are needed for macroscopic models of the ice structure and evolution.

The dynamics of the polar cap surface were to be studied through imaging with the stereoscopic surface imager (SSI), which would also measure the thermal balance by recording atmospheric opacity and surface albedo [3]. A surface version of the MILH would record the movement of water vapor, provide a baseline measurement of isotopic ratios, and monitor basic meteorology.

Additional information could be gleaned from various internal sensors, such as detection of inclusions of CO_2 hydrate-clathrates.

Ongoing work: The cryobot approach suffered from two prominent liabilities. First, the cryobot expended large amounts of energy just to compensate for conductive losses in the cold ice of Mars. As a result, it required approximately 500W just to avoid being frozen into the ice, and an average of over 1 kW to achieve the desired descent rate. Second, the meltwater sampling scheme was far from optimal in that the pool of water surrounding the vehicle contained the accumulated solutes of the entire descent.

To remedy these deficiencies, the Subsurface Ice Probe (SIPR) is being tested as a means to perform an "open-hole" descent. The SIPR drill head sits in the bottom of a dry, open hole and melts a small quantity of water at a time, pumping it to the surface for analysis. The tether reel and all analytical instrumentation stay on the surface. By only requiring a small drill-head to be submerged in water, SIPR minimizes thermal losses, and can achieve its mission with less than 100W average power. Second, by returning samples to the surface, SIPR simplifies sidewall imaging (as compared to systems that image through silt-laden water), retains good depth resolution for chemical analysis, and does not require analytical instrumentation to be miniaturized for down-hole use. The only potential drawback to SIPR is the fact that the eventual flow or failure of the ice limits both the depth and duration of the hole. For planetary exploration, this limitation is of marginal importance. On Mars, in particular, SIPR should penetrate up to a kilometer, more than sufficient to study the polar layered deposits.

References: [1] Zimmerman W. et al (2002), Proc. IEEE Aerospace Conf.[2] K.E. Herkenhoff K.E. and Plaut J.J. (2000), Icarus 144, 243–253[3] Smith P. and Lemmon M. (1999) JGR 104, 8975–8986.

ASTROBIOLOGY EXPLORATION STRATEGIES FOR THE MARS POLAR REGIONS USING BALLOON PLATFORMS.

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Introduction: Montgolfiere balloons can provide a unique near-surface platform for an extended traverse over the polar regions of Mars. During the polar summer, such solar powered balloons would remain in the constant sun of the polar summer and could remain airborne for many weeks or even months as the atmospheric circulation would drive the balloons around the polar region many times before the balloon would cross the terminator. Such a platform for scientific measurements could provide in situ sampling of the atmosphere for trace disequilibrium species that might be indicators of present geological or biological activity in this region. It could furthermore provide high resolution imaging, deep electromagnetic (EM) sounding for subsurface stratigraphy and liquid water, and high spatial resolution neutron measurements of subsurface ice. Technologies for robust balloon deployment on entry and controlled encounters with the surface and near subsurface for sample acquisition in otherwise inaccessible regions (Figure 1) are presently being studied and developed with support from NASA.

Pointers to Past or Present Life on Mars: Potential indicators or pointers to ***present life*** in the Martian polar region might be found in the atmosphere in the form of non-photochemically produced species such as trace levels of methane or formaldehyde that might be produced by low levels of near-surface biological activity. The near-surface cryosphere and subsurface aquifers, if they were to exist in the polar region, might provide ecological niches for hardy microbial life. Pointers to ***past conditions on Mars that might have been more conducive to the nourishment of life*** may also be measured in the atmosphere in the form of isotope ratios of light isotopes of carbon, nitrogen, and the noble gases. Their isotopic composition address mechanisms of obtaining the present atmosphere through loss to the surface and space and production through infall and volcanic activity. Likewise, the surface stratagraphic record of the near polar region might be able to reveal elements of its glacial, geological, and climate history[1]. All of these diverse measurements could be implemented from a balloon platform in a future mission to this region.

Unique Characteristics of a Balloon Platform: Key mission elements to complete the astrobiology related science objectives sketched in the previous paragraph are (1) regional mobility over; (2) proximity to; and (3) long duration over the volatizing polar cap. A balloon can float just kilometers above the surface with slow speeds of several m/sec providing the needed mobility, proximity, and dudration. There is a substantial usable science mass with such a platform and platform-unique science features. With an appropriate complement of space-proven instruments these could include:

- An in situ atmospheric chemistry laboratory to search for local sources of anomalous trace species in an extended region over a summertime volatile-producing ice cap.
- A platform positioned well below the attenuating ionosphere to perform radio sounding of the ice cap and the polar layered terrain.
- Imaging with better than 11 cm resolution from an altitude of 4 kilometers and higher resolution in near surface flights.
- Higher order magnetic moments beyond dipole values, of surface magnetic features.

Figure 1. Balloon sampling may enhance our ability to carry out exploration over rugged landscapes on Mars such as the polar caps and erg. Under development for solar driven Montgolfiere balloons is the ability to approach the surface for rapid acquisition with a “touch-and-go” sampler.

- The ability to perform targeted stratagraphic studies of erosion features like Chasma Boreale.
- Neutron mapping of shallow water ice with <3 km horizontal resolution from a balloon at 4 km altitude, ~200 x better spatial resolution than the Odyssey global map.

Balloon Technology Studies: Key balloon technology elements to insure robust implementation of such an investigation continue to advance.

Balloon Deployment Studies. Recent tests at JPL have demonstrated balloons autonomously deployment from the ground or while falling from high altitudes[2,3]. The stratospheric deployment tests, which are more likely anticipated for Mars (Figure 2), are still ongoing, but have been generally successful for polyethylene balloons, although there have been two failures of large balloons due to deployment issues. For these stratospheric tests, a packed Montgolfiere balloon is lifted to 36 km altitude (4 mbar) by a helium balloon. The packed Montgolfiere is then allowed to fall on a parachute at 50 m/sec and is deployed from the bottom of the bag. For a a double Montgolfiere deployment, the empty Montgolfieres fill while falling and are rapidly heated by the Sun, thus providing buoyance. Current development activities include selection of optimal balloon materials, balloon fabrication techniquess, and packing as well as optimization of the deployment sequence to increase the robustness of the deployment.

Controlled Surface Access. Several altitude-controlled tests have also been successfully conducted using black plastic Montgolfiere balloons. In the first field test in California's Mojave Desert in 1998, a radio-controlled vent was placed at the top of the balloon. When the vent was opened, hot air was released and the balloon descended. Conversely, closing the vent caused the balloon to ascend. This initial successful flight of about 15 minutes was followed by a much longer flight over the Pacific Ocean later that year. During this ocean test, the balloon was allowed to climb to about 1 km altitude, and the vent periodically opened to allow descent. The balloon payload was actually soft-landed on the ocean several times before the test was terminated. Post-flight thermal analysis very closely agreed with actual balloon behavior during the entire flight. Development of the next generation autonomous altitude control mechanism is underway.

Sample Acquisition Sudies. A rapid "touch & go" sample acquisition system has been developed[4] and is being tested and refined. This device is is specifically designed to be deployed from a moving platform such as a balloon to provide very rapid acquisition of material from the surface and to some depth below the surface of Mars. Such a balloon/sampler system could enable collection of materials for analysis from a variety of sites in otherwise difficult to reach locations.

References: (1) Clifford, S. M., et al., "The State and Future of Mars Polar Science and Exploration," Icarus, 144, 210-242. (2000). (2) J. A. Jones and J. J. Wu, "Solar Montgolfiere Balloons for Mars", AIAA #99-3852, 1999. (3) J. A. Jones, "Mars Rover Balloon Launch", JPL Video#9910_06, October 1999. (4) S. Rafeek, K. Y. Kong, S. P. Gorevan, and M. A. Ummy, A Balloon Delivered Subsurface Sample Acquisition and Transfer System, Concepts & Approaches for Mars Exploration, Lunar and Planetary Institute, Houston, TX, July 18-20, 2000.

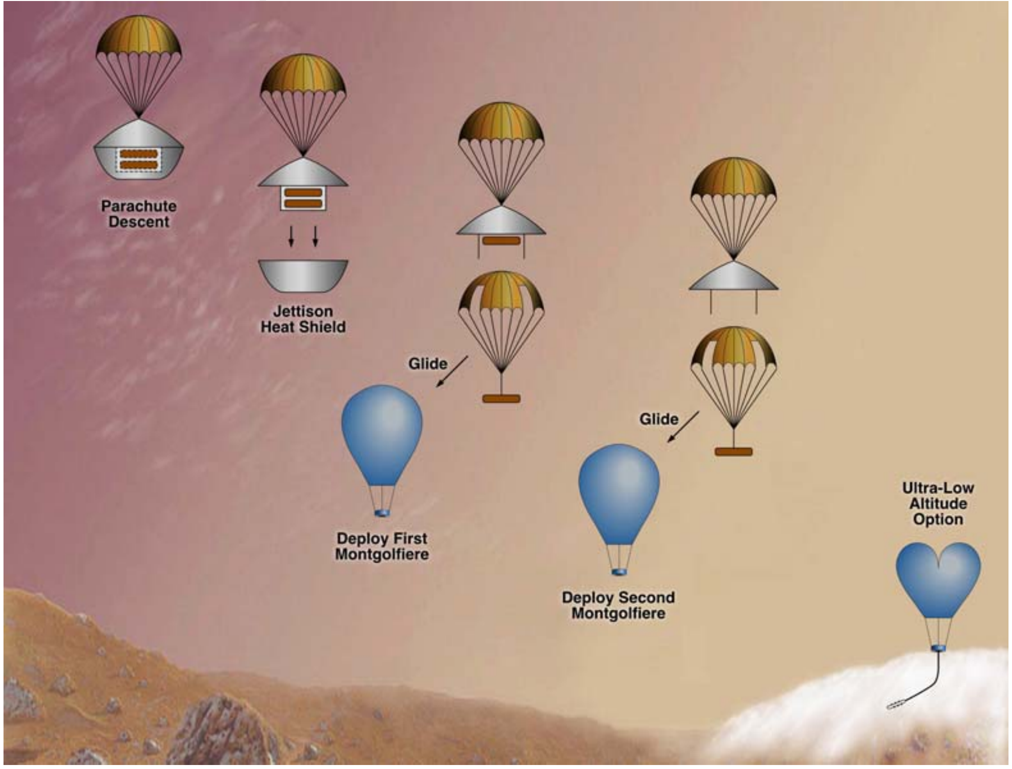

Figure 2. In a deployment scenario studied for a future Mars mission, two Montgolfiere balloons rapidly fill and heat while falling through the atmosphere. Altutude control devices may allow surface soil and ice sampling.

THE PHOENIX SCOUT MISSION. P. H. Smith, Lunar & Planetary Lab, University of Arizona, 1629 E. University Ave, Tucson, AZ 85721, psmith@lpl.arizona.edu.

Introduction: In December 2002, four Scout missions to Mars, proposed in response to a NASA Announcement of Opportunity (AO), were selected to proceed to Phase A. Phoenix was one of the missions selected. All missions were required to launch in 2007 and meet a cost cap of $325M (FY03$) that encompasses all mission costs including the launch vehicle and a healthy reserve. A Concept Study report was submitted May 15 after a 5-month Phase A study; it completely describes the technical approach and management plan. The cost plan with reserves ensures that the mission can meet all its science goals within the cost cap.

This abstract is being submitted prior to the selection announcement in August 2003. The strategy and goals for exploring subsurface ice layers in the northern plains will still be valid in spite of any negative decision that delays the mission.

Strategy: From the beginning our strategy has been to capture the low cost, low risk, and good science corner of the proposal range. Clearly, low cost comes from building on structures created for previous missions. The AO allowed the use of the 2001 lander that was canceled after the loss of two spacecraft in 1999. The spacecraft was four months into final assembly and test (ATLO) and many instruments were already delivered; the spacecraft and instruments have been mothballed ever since waiting for an opportunity for flight. The name Phoenix symbolizes the rebirth of a new project from the ashes of the canceled mission.

In addition, the Mars Polar Lander with its MVACS instrument package failed to land safely after completion of integrated testing, a Ground Data System (GDS) development, and the mission sequences. The knowledge to rebuild the MVACS instruments still exists. The challenge that faced the Phoenix team was choosing among the wealth of existing hardware and knowledge to produce a scientific mission capable of meeting NASA goals for exploring Mars (MEPAG), a mission exciting both to the public and our team. We have succeeded in this goal by virtue of the exciting discovery of abundant ice in the circum-polar regions.

Phoenix science goals. Phoenix truly 'follows the water' by landing on an ice-rich region and digging up to a meter into the icy soil. The Odyssey Gamma Ray Spectrometer (GRS) team announced in Spring 2002 the discovery of large amounts of water ice poleward of -60 degrees latitude within a few 10s of centimeters of the surface [1,2]. Recently, the ice abundance in the northern plains during summer has been measured and mapped [3]; it appears to contain an even higher abundance of near surface ice than the southern pole. Mellon and Jakosky [4] and other scientists had predicted for some time that ice would be stable near the surface in balance with water vapor diffusion through an overburden of regolith. The actual measurement of ice with 3 independent instruments allowed the GRS team to estimate the depth and abundance of ice with a simple two-layer model. The amount of ice is on the border of being too large for vapor diffusion appearing more like a dirty-ice layer than icy dirt.

Of all the accessible sources of water on Mars this near surface icy layer represents the greatest potential for finding evidence of near surface liquid water. Recent work has verified our hopes [5] that periodically, through variations in obliquity and precession of the polar axis, the temperature of the ice-soil boundary exceeds –20 C and melting can occur. The influence of liquid water on the soil chemistry and mineralogy should be measurable by Phoenix instruments. Granted the melting may only produce a monolayer of water on crystalline surfaces, but this is enough to allow mobility and maintenance in biologic communities on Earth. Higher temperatures will allow reproduction and growth.

Goal #1: Study the history of water in all its phases in the northern polar region. Phoenix will land in the northern near-polar region and dig through the dry regolith searching for an ice-soil boundary. Instruments on the deck will receive samples and analyze the chemistry, the volatile inventory, isotopic ratios, and grain morphologies. Altered minerals created through the weathering of the soil grains in a periodically moist environment will be measured as a function of depth beneath the surface. Samples taken at several depths will also be mixed with water to test the aqueous chemistry of the wet soil. Knowledge of the wet chemistry allows creating similar environments in Earth laboratories and at analog field sites to help understand the properties of the Martian soil.

Even if the ice layer cannot be reached at our landing site, Phoenix will become the first scientific station in the important polar regions to return useful data. Not only will the soil be trenched and surface features examined for evidence of a freeze-thaw cycle, but the weather throughout the polar summer and fall will be monitored. Temperature, pressure, and winds will be measured on an hourly basis. In addition, humidity will be tracked using a mass spectrometer. A lidar will make measurements of the boundary layer for the first time to be compared with mesoscale models that are now becoming an important tool in predicting near-surface weather.

The geomorphology studied over the last 6 years from orbit will be augmented with Phoenix images and will allow visualization of the site in an unprecedented manner. During descent a wide-field camera will produce a set of nested images surrounding the landing site. After landing, these will be compared to panoramic images so that the exact distances (and therefore the size) to features of interest can be computed. The panoramic camera is also stereoscopic and multispectral throughout the sensitive range of the CCD detector; its resolution is equivalent to the PanCam on MER, about 0.25 mrad/pixel. A camera on the robotic arm that digs the trench continues to reduce the scale at which we examine the scene; closeup images of the trench walls will provide insight into the layered structure and grain size of the soil. Samples will be provided to an optical microscope housed on the deck; images of the tiny grains in 4 colors will be taken through focus with a resolution of 4 microns per pixel. Finally, an Atomic Force Microscope has been developed to enlarge our view of selected objects on the microscope stage to resolve structures at the 10 nm scale.

Goal #2: Assess the biologic potential of the subsurface environment. Although there are no "life-detection" instruments on board, we suspect that a long term active biological community will leave observable signatures in the soil horizons and chemical tracers in the ice. The TEGA instrument can detect small abundances of organic molecules in the gases that are driven off of samples as they are heated above

300° C. The association of organic compounds with subsurface layers will indicate the likely origins of these compounds. In addition, the wet chemistry of the soils will test whether any hazards exist that preclude a habitable zone at these latitudes.

To summarize, our goals are to understand the near surface chemistry, hydrology, climatology, and geology of a polar landing site. We will examine the ice-soil boundary for periodic melting and biologic potential, our goal is to detect an accumulation of organic molecules. The hazards to life that exist in the ice layer, particularly salts and oxidants, will be quantified. Finally, we will characterize the polar weather throughout northern summer and fall with particular attention to the distribution of water in all its phases.

Implementation. Phoenix will modify the 2001 lander according to the recommendation of the Young commission [6] and the Casani JPL review board [7]; this lander has probably endured more reviews than any other. The lander has been stored for 2 years at the Lockheed Martin Astronautics facility in Denver; they will be responsible for refurbishment and improvements along the lines of the review boards. Guided entry, a hazard avoidance system, and full communications during entry and descent will reduce the risks to an acceptable level. Communications will include UHF relay to orbiting assets (MGS, Odyssey, and MRO) and a high gain antenna for a direct-to-Earth link.

Many of our instruments are already delivered. The descent imager (MARDI) is already bolted on the lander, the robotic arm with its camera is in bonded stores at JPL, and so is the MECA instrument with its wet chemistry cells and microscopes. Other instruments are build to print from the Mars Polar Lander (MPL): the panoramic camera (SSI), and TEGA. New instruments include the MET station with a lidar, and a mass spectrometer.

The Phoenix project is led by Peter Smith as PI with a 25-member science team. Leslie Tamppari has been chosen as the Project Scientist at JPL. Several of the science team members are also responsible for instrument performance: William Boynton for TEGA at the University of Arizona (UA), Michael Hecht for MECA at JPL, Michael Malin for MARDI at MSSS, Horst Keller for RAC from the Max Planck Institute for Aeronomy in Germany, Alan Carswell for the MET package in Canada, Mark Lemmon for the camera systems at the UA, and Ray Arvidson for the robotic arm at JPL.

An important aspect of any mission is the Education and Public Outreach portion. Two percent of our budget is devoted to this part and all activities will be led by a manager at the UA who reports directly to the PI. Each member of the science team will contribute to the EPO activities. Other important elements contribute to the training of teachers, curriculum support, provide exhibits to museums and science centers, and create exciting visual products that illustrate the mission.

Mission scenario: After a launch in August 2007, Phoenix will land in late May 2008 at Ls=78 (late spring). The engineering data acquired during descent and the descent images plus the first panoramic images will be returned immediately. A successful landing will give the Mars program a much needed landing vehicle for future missions. The first week will be reserved for examination of the landing site with the remote sensing cameras and calibration of the instruments.

The digging phase (first 90 sols). After surface samples are collected and verified, trench digging begins. The sampling strategy requires surface samples, samples from within the dry regolith and samples from the ice-soil boundary. If the robotic arm is capable of digging into the icy soil, another sample will be collected from within the ice. To be sure of getting an ice sample, ripper tines and scrappers are added to the back of the scoop. The digging and sampling activities have been grouped into 8-sol cycles that include 4 days of digging and monitoring the trench and 4 days of examining samples with TEGA and MECA. Seven of these cycles are baselined with adequate reserve added in case digging is more difficult than planned.

Polar climate phase. As the season turns to fall and winter, Phoenix will continue to operate until the Sun is too low on the horizon to charge the batteries. This is period when power must be conserved. Limited imaging will look for the first carbon dioxide frost deposits as the seasonal cap approaches. The MET instruments will record the decrease in temperature and pressure as fall turns to winter and humidity sensors will record the transport of water vapor. We do not expect that the lander will survive the winter and have no plans for its recovery in the spring.

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