SCIENCE CONSIDERATIONS DRIVING THE CHOICE OF THE PHOENIX MISSION LANDING SITE.

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Introduction: The Phoenix mission will be the first of a series of planned Scout missions to Mars. Launching in August 2007, the spacecraft will land on the northern polar plains in May 2008. During the summer season, a robotic arm (RA) will dig a trench and provide samples to instruments on the deck of the spacecraft. A set of experiments is planned to help us understand the chemistry and mineralogy of the surface materials down to a layer where ice is stable. Because our landing site is selected with the expectation of finding water ice near the surface, the Phoenix mission may provide the first in situ examination of water on Mars.

Science Objectives: Our science objectives are all based on NASA’s crosscutting theme to “follow the water.” Previous missions have found this to be a difficult task; only tiny abundances of water vapor in the thin atmosphere and exposed water ice on the northern polar cap have been characterized.

This situation changed early in 2002 when large amounts of water ice were clearly seen by the Odys- sey Gamma Ray Spectrometer (GRS) [1] in the circumpolar regions. Modeling the gamma ray and neutron fluxes, the GRS team calculated that high concentrations of ice, up to 80% by volume, are to be found within 50 cm of the surface from the poles down to about 60° latitude.

The Phoenix mission derives its goals from the scientific characterization of the subsurface ice: its interaction with the atmosphere, the effects on surface morphology, the history of the ice, and its biological potential.

Phoenix science goals are achievable in the absence of ice-layers at our single landing site. The fact that we are in an ice-rich region with ice in close proximity is sufficient. Regional melting and atmospheric exchange will affect all the soils.

Science goal #1: Study the history of water in all its phases. The circumpolar plains are active today and a primary reservoir in the cycle of water transport on Mars. Orbiter measurements show large seasonal variations in the atmospheric humidity and CO2 frost blanketing the surface. “Freeze-thaw” processes appear to be similar to those on Earth causing hummocky and polygonal terrain features. Quantifying the volatile inventory locked into the arctic soils and its seasonal exchange with the atmosphere through the soil overburden, even at one location, is a giant step toward understanding the formation of the subsurface ice.

As on Earth, the history of water is located in the subsurface. Liquid water changes the soil chemistry and mineralogy, as well as the shapes of the grains, in characteristic ways. Obliquity wander and precession are known to strongly influence the climate on time scales of 50,000 years or more. It may be that the water ice melts and wets the overlying soil on cycles commensurate with orbital dynamics. Phoenix will determine the aqueous mineralogy, grain morphologies, and wet chemistry of the soil as a function of depth beneath the surface.

Science goal #2: Search for evidence of a habitable zone and assess the biologic potential of the ice-soil boundary. Microbial colonies can survive in a dormant state for extremely long periods of time. Recent work [2] shows that as water ice melts onto soil crystals at temperatures as cold as −20 °C microbes are activated and are able to search for food. As temperatures increase, growth and reproduction begin. Can this cycle take place on Mars?

Instruments on the Phoenix lander receive soil samples and test for signatures related to biological potential. Complex organic molecules are detectable in small concentrations. Other experiments determine the chemical and paleo-hydrological properties of the soils in both dry and wet conditions.

Phoenix determines the habitability of the soil by assessing the periodic presence of liquid water as seen in the modified chemistry and mineralogy, understanding the energy sources in the form of organic molecules and redox potentials, looking for the presence of the elemental building blocks of life, and determining whether hazards destabilize complex organic molecules.

It is unlikely that a single trench in the vast northern plains will find evidence for biological communities even if they exist there. Our goal is to determine whether conditions favor their preservation.

Science goal #3: Study the climate and weather of the northern polar region throughout the summer season. The interaction between the atmosphere and the volatiles sequestered within the regolith has been the object of intense study for a long period of time. In order to make progress on this difficult subject, the boundary layer processes must be better understood. Therefore, the MET station provided by the Canadian Space Agency measures wind direction, temperature
(air and surface), and pressure. Phoenix will include a humidity sensor and the capability to measure aerosol backscatter and cloud heights using vertical lidar profiles and aerosol extinction by solar imaging.

With this suite of measurements, the transport of water vapor and dust can be tracked throughout the summer season when volatiles are expected to escape from the regolith. The turbulent eddies and dust devils that characterize and active convective layer can also be monitored sol by sol and compared with mesoscale models developed for the region.

**Factors Influencing the Landing Site Selection:** Both engineering safety constraints and science value must be satisfied in choosing the site. The latitude band of 65 to 72°N was chosen early in the program to avoid the edge of the ice table at the low end and yet maintain sufficient solar energy at the high end. Longitude will be determined from the analysis of remote sensing data for interesting sites and maximizing the chances of finding ice near the surface.

The engineering factors are met when surface slopes are less than 16° at all scales greater than 1 m, when the rock abundances are less than the Viking 2 site (18% areal coverage), when few hazards are seen in the 150 km landing ellipse, and when strong winds are not expected.

The science instruments have been chosen for their ability to analyze the ice and soils of the arctic region. Images from the descent imager (MARDI) and the panoramic camera (SSI) place the site into geologic context. The geomorphology of the surface should reflect the action of subsurface ice processes. Basketball terrain, fingerprint patterns, and patterned ground are examples of desirable landing sites.

Two major science instruments accept and analyze the soil samples; they levy competing desires regarding the depth to ice. The first is the thermal evolved gas analyzer (TEGA). A sample is delivered by the RA to a hopper that feeds a small amount of soil into a tiny oven, which is sealed and heated slowly to temperatures approaching 1000 C. The heating circuit maintains a constant temperature gradient and the resulting power profile contains peaks and valleys that indicate phase transitions in the sample. For instance, ice will show a feature at its melting point of 0 C and carbonates between 200-300 C depending on composition.

Gases driven from the sample are combined with a carrier gas and piped to a mass spectrometer. The spectra of the gases change as a function of release temperature. Isotope ratios for O, C, and N as well as heavier gases like Ar and Xe provide scientific clues to the origin of the volatiles. This instrument will determine the water content of the soil and the D/H ratio of the ice to be compared with atmospheric composition measured with the same instrument. The TEGA team strongly desires to quickly find the ice/soil boundary, validate the GRS models, and understand the mineralogy of soils associated with the ice.

The second instrument (MECA) provides a microscopic, electro-chemical, and conductivity assessment of the soils. Microscopic examination of tiny grains (less than 200-μm diameter) with a resolution of 4 μm/pixel gives clues to the emplacement process: aeolian, lacustrine, or fluvial. A probe on the RA scoop measures the electrical and thermal conductivity of the soil.

The MECA wet chemistry laboratory accepts small samples that are delivered and sealed into a warm beaker; water brought from Earth is added to the soil while stirring. Special chemical sensors return data concerning the water chemistry including: the salt content and its composition, the oxidation potential, the acidity, and the trace mineral concentration. Because MECA adds water to the sample and simulates the melting of the ice, there is little value in adding ice to the sample. A good landing site for MECA has 30 cm of soil above the ice and allows measurements of chemical gradients.

This experiment provides basic information that every farmer or biologist requires in order to assess the habitable potential of the wet soils. On Earth, alkaline soils are limestone rich and acidic soils contain sulfur; micro-organisms adapt differently to these environments. Are the soils capable of sustaining life during a wet period on Mars?

Throughout the first 90 sols of the missions the RA trenches either to an impenetrable ice layer or to 0.5 m. As scientifically important layers are uncovered, MECA and TEGA analyses are repeated. TEGA has eight ovens giving depth resolution of a few cm. The microscopy can be repeated at least 10 times, but there are only 4 wet chemistry cells. The MECA wet chemistry will be performed at the surface, below the surface, and just above an ice layer; one cell is reserved as a spare.

**Summary:** The lower latitudes are likely to have more soil overburden and more solar power throughout the mission while the higher latitudes provide a better communication path to the orbiters. We have selected 3 regions of the latitude band for detailed analysis and the process by which the final site is selected is underway [3].