PALMER QUEST: A FEASIBLE NUCLEAR FISSION "VISION MISSION" TO THE MARS POLAR CAPS.

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Introduction: We are engaged in a NASA Vision Mission study, called Palmer Quest after the American Antarctic explorer Nathaniel Palmer, to assess the presence of life and evaluate the habitability of the basal domain of the Mars polar caps. We address this goal through four objectives:

- Determine the presence of amino acids, nutrients, and geochemical heterogeneity in the ice sheet.
- Quantify and characterize the provenance of the amino acids in Mars' ice.
- Assess the stratification of outcropped units for indications of habitable zones.
- Determine the accumulation of ice, mineralogic material, and amino acids in Mars ice caps over the present epoch.

Because of the defined scientific goal for the vision mission, the Palmer Quest focus is astrobiological; however, the results of the study make us optimistic that aggressive multiplatform in-situ missions that address a wide range of objectives, such as climate change, can be supported by variations of the approach used on this mission.

Mission Overview: The Palmer Quest baseline mission will be accomplished by softlanding on a site such as the north polar cap at 83°N, 0°E. The landed system will conduct core science aboard a thermal probe, the Cryobot, a surface station, and a robotic vehicle (see Figure 1). The Cryobot will melt through and chemically analyze the Polar Layered Deposit (PLD) [1,2] down to the bed where it contacts the Lower Platy Unit (LPU) [3, 4], the site chosen for astrobiological exploration. The Cryobot utilizes nuclear power for its high thermal output and long life; a thermal probe is an environment in which reactor heat normally regarded as waste heat makes an essential contribution. The surface station, placed at a distance from the lander to avoid its thermal and flow effects, will examine the annual cycle of accumulation on the ice cap. The rover will laterally explore the polar cap, providing information relating to structure, stratigraphy, history and processes as well as providing a regional context for the cryobot and surface station measurements. The rover traverse (Figure 2) provides access to the LPU-PLD contact near the head of Chasma Boreale as well as outcroppings of PLD exposed in several troughs.

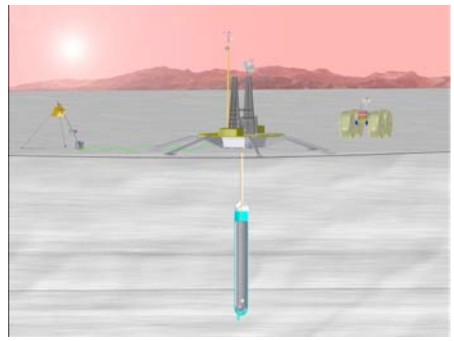

Fig. 1. Palmer Quest on the surface of Mars

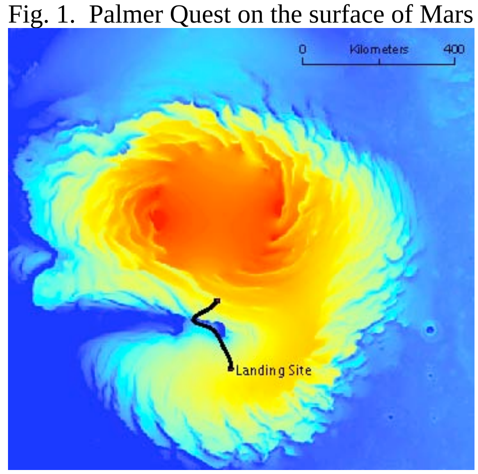

Fig. 2 Palmer Quest Rover Traverse (black line)

Team: The team for this study consisted of:

- JPL for mission design, astrobiology and the Cryobot,
- Brown University for stratigraphy, sedimentology and the robotic vehicle,
- UCLA for the ice cap accumulation and the surface station, and
- Los Alamos and Sandia Laboratories for nuclear and power systems.

Astrobiology Approach: The key astrobiology is conduced on the Cryobot. The tasks are to:

1. Characterize the biological potential of the basal layer,

2. Characterize the chemical composition of the Martian north polar cap from the surface to the bed, and
3. Characterize the solid materials in the ice sheet and at the bed.

To accomplish these tasks, a strawman Cryobot instrument suite was designed consisting of sensors that are currently part of future missions or in advanced stages of development. While the specific instrument selection for the mission would occur ~5 years prior to launch, a realistic candidate payload was necessary to specify the Cryobot sub-systems.

The payload consists of an optical imager to profile the borehole wall, a tunable diode laser spectrometer to measure H/D and C_{12}/C_{13} ratios of material through descent, inorganic sensors to determine salt and metal concentrations as well as measure pH, eH, and redox potential, a microscope with a nested Raman spectrometer for analysis of particulate matter captured on a filter, and an analytical suite. The analytical suite consists of 2 different organic detection instruments that make complementary measurements and a mass spectrometer.

Mars North Pole Basal Environment: We speculate that the PLD-LPU contact constitutes a striking site as a candidate habitable domain. One possible origin for the LPU [4] is as lag material from past ice caps, presumed to have formed and ablated during climate change cycles. In the course of ablation, especially if largely by sublimation, the resulting lag deposit would contain atmospheric dust, meteoritic material, and organic infall (protected by seasonal frost and dust) over the preceding millions of years. This input into the basal domain could contain nutrients and carbon to sustain environments conducive to life over geologic intervals. Microbes could have been recruited from the underlying Vastitas Borealis Formation (VBF). The historical presence of liquid water in both LPU and VBF is well established, although the sources of water and/or heat are open to speculation. Some have proposed relatively recent volcanic activity [5] while others have proposed basal melting due to the accumulating thickness of the overlying cap [6]; these environments are somewhat analogous to a hydrothermal vent.

Nuclear Power: The combination of subsurface exploration and long-duration surface observations calls for extended, substantial power. These requirements have resulted in the selection of nuclear power. The baseline nuclear power system is the HOMER-15 fission power system, a compact, heatpipe-cooled reactor developed by DOE specifically for the Mars surface and modified for the cryobot.

The reactor is designed for an output thermal power of about 15 kW for a full-power lifetime of 5 years. The cryobot application uniquely makes use of the full thermal power output by incorporating the reactor directly into the cryobot. In addition to efficiency of power utilization, this concept has significant advantages over a surface-mounted nuclear system powering an electrically heated drill, since the polar ice will very effectively shield all surface assets from the reactor once it has begun drilling. An important advantage is the minimization of the reactor’s thermal impact to the laner environment, allowing accurate measurement of surface processes over the duration of the mission. The reactor will provide electricity to the surface elements to support science, telecommunications, and survival heating.

At the outset, those of us not in the nuclear technology community naively assumed that flying a fission reactor would bring in a staggering array of difficulties; this has not been the case. Radiation protection has been straightforward; power conversion technologies are well advanced (although they have not flown); the reactors are well characterized; launch safety issues are bounded and can be addressed; but costs are clearly a factor. We encourage NASA to continue the examination of high-priority fission-powered Mars missions.

Preliminary Findings: Our mission study has progressed to near maturity, and we have very encouraging results. A mission such as Palmer Quest can be launched on available US systems, and an opportunity for a readily workable trajectory exists in 2022 (and some more demanding opportunities occur prior to that time). No technology barriers exist and the technologies required for the 3 science platforms are clearly obtainable by 2022 and for the robotic vehicle and the surface station much sooner. Missions with this scope are scientifically breathtaking and technologically feasible in optimistic programmatic environments.

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