CRYOSCOUT: A DESCENT THROUGH THE MARS POLAR CAP M. H. Hecht[1] and R. S. Saunders[2], [1]Jet Propulsion Laboratory, California Institute of Technology (michael.h.hecht@jpl.nasa.gov), [2]NASA Headquarters, Washington, D.C. (ssaunde1@hq.nasa.gov)

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.

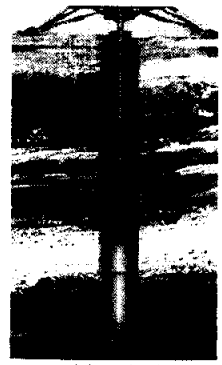

Figure 1: Fueled by continuous sunlight on Mars' North Pole, the cryobot uses heat to sink through undisturbed polar layered deposits.

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.