**CHRONOS: A journey through martian history.**  M. H. Hecht¹ on behalf of the Chronos Team. ¹Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109. (mhecht@jpl.nasa.gov.)

**Introduction:** In analogy with Earth’s ice sheets, the key to martian climate history lies below the surface, recorded in pristine stratigraphy that has not been scoured by modern surface processes and is not readily visible from orbit. Following methods established in Greenland and Antarctica, Chronos proposes to tell the story of martian climate history as a simpler analog to that of Earth’s, devoid of the influences of oceans, tectonics, and biology.

Four years ago, for the 2007 Scout opportunity, some of us proposed the CryoScout mission, designed to drill tens of meters through the polar ice of Mars. From the lessons of that proposal we developed and tested a new, low power approach to drilling in ice with up to 50% dust content.

**Scientific Objectives:** The largest visible reservoir of water on Mars, the North PLD is the only known unmodified and accessible record of recent Mars climate history. Chronos proposes to examine the conditions under which the north PLD were laid down over the past million years, thereby determining the recent climate history of Mars. Chronos’ log of images and compositional data would reflect the influence of meteorology, depositional episodes (volcanic, impact, dust storms), and planetary orbital/axial modulation.

By studying stratigraphy and sedimentology Chronos proposes to explore the historical relationship between meteorology and morphology. As secondary objectives Chronos proposes to characterize present-day polar surface/atmosphere interactions and to take advantage of the ideal geophysics platform offered by the polar cap to determine the geothermal gradient of Mars and explore its inner structure with seismometry.

**The Stratigraphic Record:** The PLD are believed to preserve a stratigraphic record of climate change over millions of years, modulated by quasi-periodic changes in the planet’s orbit and obliquity [1-3]. During accumulation periods, layers of water ice and dust are deposited and form chronological units characteristic of global and local conditions at the time of deposition [e.g., 4-7]. During some periods in their history the PLD have experienced net ablation, causing discontinuities in the record by removing earlier layers [8].

Chronos proposes to resolve uncertainty about the characteristic timescale represented by individual layers. Early estimates based on Viking-era imagery assumed that the ~30 m layer packets correspond to $10^5$–$10^6$ year periodicity in Mars’ obliquity, suggesting that annual layers may be as thin as 0.01 mm [9]. Since then, high-resolution MOC images [10] combined with MOLA topography have offered new insights into layer formation (Fig. 1), suggesting that the layers may have formed on 51,000 year scales corresponding to precession of perihelion [11-12]. This rate would imply annual layers on average ~0.5 mm thick, consistent with resurfacing rates derived by Herkenhoff and Plaut [13] from the lack of craters on the North PLD (though resurfacing may be due to annual cycles of ablation and deposition).

The Chronos objective is to reconstruct a polar chronology from the observed stratigraphy, the chemical and isotopic data, and orbital models. In Greenland ice cores this method has achieved an absolute accuracy of 1% in the top 2500 m [14-15].

**Proposed measurements:** Chronos proposes to drill from 10-75m below the surface of the ice and to perform the following measurements and analyses:

- Image visible stratigraphy as an indicator of ice and dust deposition rates, resolving $10^{-3}$m features. Counting layers will be the simplest approach to dating the polar stratigraphy.
- Measure the concentration of dust as a function of depth and constrain its size distribution.
- Measure isotopic ratios as a direct indicator of ice accessibility and sublimation or condensation rates, and an indirect indicator of temperature and other primary meteorological parameters. These ratios will also be sensitive to the solar cycle, which affects the upper atmospheric ablation rate, possibly offering an alternative clock for the chronological record.

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Fig. 1: Estimated depth for a sequence of layers in the PLD; depth values are from MOLA data. These are not the exact layers Chronos will traverse but are typical of the overall structure.
• As a function of depth, identify, quantify and characterize the dissolved inorganic chemical components in the meltwater resulting from the deposited martian dust. Monitor the pH of the meltwater to constrain the total atmospheric pressure.
• Image the surface topography and morphology of the ice and ascertain the surface reflectance in order to constrain the thermal budget.
• On the surface, Measure humidity, T, P, and wind to determine net flux of water to/from surface. Constrain seasonal deposition & removal rate.
• Determine the geothermal gradient in the PLD
• Constrain the internal structure of the planet from response of the ice sheet to seismic activity

Technology: Chronos drills passively create a melt front at the nose, then pump melt water to the lander deck (Fig. 2). Pumping meltwater to the lander not only provides an effective method for sample collection but also minimizes thermal contact between the drill and the ice, saving significant amounts of power. A 7.5 cm diameter drill, with the application of 200–400 W, can descend at speeds of 20–45 cm/hr in 163 K ice. The drill is suspended from a tether, which provides down-hole power and data transfer and keeps the meltwater liquid all the way to the surface.

Each drill carries a downhole camera to record visible stratigraphy, acquiring full-color stereo images at $10^{-5}$ m per pixel, sufficient for observing annual layers. The longer of two drills also determines the geothermal gradient with a temperature sensor, while the shorter carries a miniature seismometer to explore the inner structure of the planet. On the lander deck an isotopic laser spectrometer measures variations in relative hydrogen- and oxygen-isotope abundance in the meltwater, reflecting source and climate conditions under which the ice was deposited. A companion instrument uses electrochemical sensors to characterize embedded dust in the meltwater, determining the salt composition and abundance. The surface payload includes a panoramic imager and a meteorology station that measures pressure, temperature, humidity, and wind. Together, they characterize surface dynamics to determine both thermal and water balance at the ice/atmosphere boundary [16].

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