The Chronos Thermal Drill and Sample Handling Technology. M. Smith1, G. Cardell1, R. Kowalczyk1, and M. H. Hecht1 1Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA (miles.smith@jpl.nasa.gov).

Introduction: The presence of the distinctive layering visible in images of the Martian polar caps from Mars Global Surveyor, particularly in the north polar cap, suggests in analogy to results from ice-sheets on Earth that the stratigraphy of the polar layered deposits may hold a record of Martian climate history covering millions of years. On Earth, ice sheets are cored to retrieve a pristine record of the physical and chemical properties of the ice at depth, and then studied in exacting detail in the laboratory. On the Martian north polar cap, coring presents difficulties for implementation in an autonomous lander. As an alternative, we have been developing technology for thermal drilling into ice sheets. This technique would be capable of reasonable approximations to the scientific investigations performed on terrestrial cores, and implementation of such a drill for autonomous operation is certainly feasible. The drill descends into the ice sheet suspended from a lander by a tether. The tether carries power and data between the drill and the surface. To minimize energy loss through conduction to the ice, the hole is kept dry, with the meltwater pumped out of the hole to a surface instrument package for analysis. Optical and spectroscopic analysis of the layers, presumably demarcated by embedded dust and possibly by changes in the ice properties, would contribute to the construction of a chronology. Chemical analysis of the meltwater may be used to determine the soluble chemistry of the embedded dust, and to monitor gradients of atmospheric gases, particularly hydrogen and oxygen, and isotopic variations that reflect atmospheric conditions at the time the layer was deposited. Thermal measurements can be used to determine the geothermal gradient and the bulk mechanical properties of the ice.

To explore the dominant climate cycles, it is postulated that tens of meters of depth should be profiled, as this (loosely) corresponds to the vertical separation of the major layers visible in the MOC images [1]. When drilling deep holes in terrestrial ice, it is necessary to “backfill” the hole with fluid to keep it open against the flow of the ice. However, it is practical to drill holes to moderate depths – tens of meters – without backfilling as the flow of ice is sufficiently slow that the hole will not close over the time required for drilling. Mission designs performed here at JPL for the Chronos Scout Proposal indicates that a goal of between 30 and 100 meters is practical for a single summer of operations at the martian north pole. It is therefore possible to demonstrate the technology for a 100-meter descent of a thermal drill for the martian polar cap in terrestrial ice sheets.

Our group at JPL demonstrated an early prototype version of such a drill on the Athabasca Glacier in 2003 (in conjunction with the Mars Polar Conference) and descended to 20 meters [2]. We have since developed a prototype drill for a landed mission to the martian north polar cap, incorporating most of the technology required for such a drill. This technology will be demonstrated by descending to 100 meters in terrestrial ice sheets. The drill is capable of operation in -50°C terrestrial ice, and incorporates features that will be necessary for operation in the extreme environment of the martian north pole.

The main components of the drill consist of the “nose” or the heating/melting element, the pumping system, down-hole electronics, the tether, and the deployment system. Surface control and instrumentation is based on commercially available components. The nose of the drill is designed to maximize the efficiency of heat transfer to the melting surface while simultaneously rapidly scavenging the meltwater as it is generated. Minimizing the amount of water present in the hole minimizes the amount of heat lost through conduction to the ice and enhances spatial sampling resolution by minimizing mixing in the hole.

The pumping system is designed using a pre-pump to collect the meltwater from the bottom of the hole with the suction available from Martian atmospheric pressure. The pre-pump feeds a reservoir for the exclusion of atmospheric gases to prevent bubble formation in the tether tubing and the analysis system. Gravity feed from the reservoir feeds the high-pressure pump which is required to move the meltwater to the surface. At the surface, a sampling system is used to distribute the meltwater to the various analysis systems.

The down-hole electronics support a number of engineering sensors designed for health monitoring and flow control, including thermocouples, an ultrasonic water level sensor for the reservoir, and a load cell and tilt sensors for maintaining a constant tension in the tether so the drill does not lean against the ice. In addition, the electronics control various internal heaters to prevent freezing of critical components such as the pump itself, and the water lines within the probe. The heaters used for melting are also controlled and switched by the drill electronics. The drill carries...
a digital camera with a lighting system for imaging the bore-hole wall during descent.

The prototype, 100-meter tether consists of several power and data lines, the tube for pumping water to the surface, and a tether heater to prevent freezing of the water in the tube. Power is delivered down the hole at high voltage (200—375 V) to control losses in the tether, and is converted to lower voltages for operating internal and nose heaters. The tether is insulated with flexible aerogel and jacketed with a rugged silicon rubber coating. The drill power system can produce up to 600 watts for melting and for internal power needs, including thermal management, pumping, and sensors. For this prototype, data is transferred between the surface and the drill using an RS-422 interface over twisted pair incorporated into the tether.

The deployment system is a motor-driven reel controlled by a computer, and includes a magnetic brake for maintaining tension in the tether, and an encoder for depth determination. Tether tension is controlled through a feedback loop using load-cell data transmitted to the surface from the drill.

The surface instrument package for the prototype is made up of discrete commercial instruments, and includes a water isotope analyzer, several chemical sensors, and a laser-based particle counter.

This prototype system will be deployed to several terrestrial field sites, including Summit Camp, Greenland.