EVOLVING TECHNOLOGIES FOR IN-SITU STUDIES OF MARS ICE F. D. Carsey[1] and M. H. Hecht[2], [1]MS 300-323, Jet Propulsion Laboratory California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA 91109, USA, fcarsey@jpl.nasa.gov, [2]MS 264-255, Jet Propulsion Laboratory California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA 91109, USA, mhecht@jpl.nasa.gov.

Introduction: Icy sites on Mars continue to be of high scientific importance. These sites include the polar caps, the southern mid-latitude subsurface permafrost, and the seasonal frost. These sites have interest due to their roles in climate processes, past climates, surface and near-surface water, astrobiology, geomorphology, and other topics. As is the case for many planetary features, remote sensing, while of great value, cannot answer all questions; in-situ examination is essential, and the motivation for in-situ observations generally leads to the subsurface, which, fortunately, is accessible on Mars. It is clear in fact that a Mars polar cap subsurface mission is both scientifically compelling and practical.

Recent data from orbiting platforms has provided a remarkable level of information about the Mars ice caps; we know, for example, the size, shape and annual cycle of the cap topography as well as we know that of Earth, and we have more information on stratification that we have of, for example, the ice of East Antarctica. To understand the roles that the Mars polar caps play, it is necessary to gather information on the ice cap surface, strata, composition and bed.

In this talk the status of in-situ operations and observations will be summarized, and, since we have conveniently at hand another planet with polar caps, permafrost and ice, the role of testing and validation of experimental procedures on Earth will be addressed.

Exploration Science: The usual Mars scientific topics, life, climate, geophysics and water, are all well connected to Mars ice, and in situ examinations are necessary to obtain the composition, stratification, surface processes, or basal conditions. The primary emphasis for these studies are climate history and processes, on Mars as on Earth. More speculative, but not less interesting, is the prospect that the basal environments of the Mars polar caps, in a climate scenario warmer than the present, would be an excellent habitat, supplied with nutrients and protected from Surficial unpleasantness.

Technologies: In short, Mars polar ice subsurface in-situ missions call for transport to Mars, soft-landing on the polar cap, operations on the surface, power, communication, conduct of surface and near-surface science, access to the subsurface, observing and/or sampling of the subsurface ice cap material, sample management of this material for instrumentation, and planetary protection. It is worth emphasizing that in several of these areas polar science can be accomplished more easily that at other sites. We will proceed here assuming availability of transport to Mars.

Soft landing on a polar cap. The polar caps are characterized by springtime CO_2+H_2O frosts of unknown mechanical properties; we need better information on the response of this frost to landing processes.

Surface operations. The polar caps are benign places in summer with steady temperatures and constant or near-constant sunlight; however, overwintering calls for dedicated development for survival of infrastructure, and this can be accomplished, especially with a nuclear power source. In addition, a mission that lands while the frost is present must accommodate to some decimeters of the landing surface burning off, possibly in nonuniform ways, early in the mission.

Power. A summer mission with low power needs, i.e., one that does not involve deep drilling, has access to ample solar power, although degradation of solar cells in the environment must be examined. Nuclear power from a reactor would solve a host of problems related to high power requirements, as for deep drilling, and to multiyear missions, due to the long life and abundant thermal power produced. This thermal output is also an engineering challenge, since it can both melt away its floor and provide heat that will influence local environmental conditions. Finally, the radiation field of a reactor becomes an engineering issue for electronics. Non-reactor nuclear power occupies a middle ground, with modest power, heat and multiyear capability with fewer difficulties, other than acquiring the radioactive salts.

Communication. Communication from the poles is not challenging. Linkage to orbiters is enhanced by frequent overpasses, and direct communication to Earth is quite simple in the Martian summer.

Surface and near-surface science. Ice cap surface properties and fluxes are likely to be required for any polar cap mission, and the conduct of the measuring programs can be demanding. Key complications are the small variations and fluxes that must be measured accurately, the influence of the spacecraft as an obstacle to windflow and sunlight, operations at the triple point of water, the non-steady surface conditions, and the unknown properties of the surface material.

Access to the subsurface. Drilling even a meter into ice-rich material in the temperature range near –100°C cannot be taken lightly; this material is hard.

Use of thermal methods can be energy intensive and will generate vapor. Thermal methods have received extensive attention and have interesting aspects in their favor at depth, but for shallow penetration with limited power a mechanical approach is favored. Working at depth calls for thermal methods, and both closed-hole (or cryobot) and open-hole strategies have been examined. Power levels become crucial for moderate (10's of meters) and deep (100's of meters) access. It is astonishing to consider that it is within our capability to access essentially any depth of the Mars polar caps.

Scientific observations, sampling and sample management at depth. Once the subsurface has been accessed, sampling must be addressed. Cold ice-rich material is hard and brittle; once a sample is removed and exposed it begins to sublimate if warmed, and if it contains a mix of granular material and salts it may crumble or become mushy or wet; if introduced into instruments, it may adhere to surfaces. Clearly, any observations that can be accomplished non-invasively, e.g., APXS, light scattering, fluorescence, Raman, NMR, etc, are desirable, and some are capable of acquiring data from material within the ice, material not effected by the presence of the drill. On the whole an excellent array of non-invasive scientific instrumentation suitable to subsurface science is in development and requires only adaptation to the specific environment. Sample acquisition and management approaches, of clear value to any in-situ mission, are also in development but have more problems to confront.

Planetary protection. Soon planetary protection requirements for a Mars polar cap mission will be formulated as category IVc, a new (not yet fully documented) category for "special regions" which includes the polar caps. While the specifics of the standards are still in study by the National Research Council, it is clear that rigorous standards of cleanliness will be in force, and these requirements should be integrated into planning early in mission thinking, if possible.

Earth Opportunities for Advancing Mars Polar Exploration Technologies: The high latitudes of Earth contain ice sheets, glaciers, periglacial terrain, permafrost, seasonal snow, rock glaciers and related icy sites in which strong Mars analogs can be developed, as is well known. In the context of climate change, it is of interest to address sites that have changed through cooling, and these are not obvious since Earth seems to be warming now. Some sites worthy of mention:

West Antarctica. The ice streams of West Antarctica (and possibly other locations) are now seen as exhibiting periodic behavior, so called "binge and purge" cycling, in which the bed cools immediately after rapid movement and warms during stagnation.

South Pole "lake". Near South Pole a subglacial flat spot has been observed on airborne radar and identified as a subglacial lake or frozen paleolake or perhaps just a curiously flat spot. Should it be the site where liquid water was present during a previous interglacial, it would today be a fascinating case study in frozen biota, possibly not unlike sites on Mars.

Subglacial volcanoes. At least one active subglacial volcano discovery has been claimed in West Antarctica, and other active volcanoes, with permanent ice and snow covers, can be found in Antarctica and Alaska. Such sites may be highly valuable for comparison with sites in the north polar region of Mars.

Greenland and Antarctica. Substantial regions of both Greenland and Antarctica are at the pressure melting point, and a zone of obvious interest is the transition region between wet and frozen bed areas; these zones can make clear the matter of how this subglacial water alters bed chemistry and biology.

Permafrost. Terrestrial permafrost has long been compared to Mars, and recent Odyssey results certainly encourage this thinking. In the western Arctic, permafrost has been warming, drying, and collapsing, while in Scandinavia there are reports of cooling permafrost. Comparisons of these changes could be useful for Mars thinking. DNA from permafrost has been shown to be well preserved over a few millennia; specific chemical changes to biochemicals over longer time intervals and environments would be interesting for Mars mission planning.

Basal and bed science. For a number of reasons terrestrial glaciology today is strongly interested in bed processes. This is good news for Mars polar science as these projects directly support future Mars polar science in the development of instruments and insights.

Conclusion: Mars polar cap science has received much attention at this, as well as other, scientific meetings, and its high value is well understood among the participants here. An examination of exploration technologies shows us that many of the tools we need to conduct comprehensive scientific studies of the Mars polar caps are available or are in active development. Moreover current work in Earth science is addressing analogous questions in analogous sites; there are effective means to develop, test, validate and assess relevant tools and approaches. In short the scientific questions are mature and the means to address them are maturing quickly. The time is essentially here for significant missions to the polar caps of Mars, and the possibilities are very exciting to contemplate. It is up to us to make these missions happen.