AN ASSESSMENT OF THE ISSUES AND CONCERNS ASSOCIATED WITH THE ANALYSIS OF ICE-BEARING SAMPLES BY THE 2009 MARS SCIENCE LABORATORY. D.W. Beaty, (Mars Program Office, Jet Propulsion Laboratory, California Institute of Technology, dwbeaty@jpl.nasa.gov; 818-354-7968), S.L. Miller (JPL/Caltech), J.L. Bada (Univ. of Calif. San Diego), G.H. Bearman (JPL/Caltech), P.B. Black (CRREL, Picatinny Arsenal), R.J. Bruno (JPL/Caltech), F.D. Carsey (JPL/Caltech), P.G. Conrad (JPL/Caltech), M. Daly (MD Robotics), D. Fisher (Geological Survey of Canada), G. Hargreaves (USGS/National Ice Core Laboratory), R.J. Henninger (JPL/Caltech), T.L. Huntsberger (JPL/Caltech), B. Lyons (Byrd Polar Research Center), P.R. Mahaffy (NASA—GSFC), K. McNamara (NASA—JSC), M. Mellon (University of Colorado), D.A. Papanastassiou (JPL/Caltech), W. Pollard (McGill University), K. Righter (NASA—JSC), L. Rothschild (NASA—ARC), J.J. Simmonds (JPL/Caltech), J.G. Spray (University of New Brunswick), A. Steele (Carnegie Institute of Washington), A.P. Zent (NASA—ARC)

Introduction: In early 2003, the Mars Icy Sample Team (MIST) was formed to address several questions related to the acquisition and analysis of ice-bearing samples on the surface of Mars by a robotic mission. These questions were specifically framed in the context of planning for the 2009 Mars Science Laboratory (MSL) lander, but the answers will also also have value in planning other future landed investigations.

Questions:

- Which scientific investigations, in priority order (especially of relevance to an assumed mission theme of habitability), can be addressed using ice-bearing samples and the MSL landed system?
- Which measurements are needed on ice-bearing samples to support these investigations?
- What are the minimum sample collection hardware and processes needed to acquire the necessary ice-bearing samples?
- What are the minimum sample preparation steps required for ice-bearing samples?
- What are the issues associated with preservation of the scientific content of the samples between the time of their collection and the time of their analysis?
- Can common hardware be used to interact with both ice-free and ice-bearing samples? This would allow the decision of where to send the mission (i.e., in terms of a latitude band) to be deferred until very late in the mission development process.

Assumptions: For the purpose of this analysis, we have defined four model sample types: Weakly ice-cemented regolith, ice-saturated regolith, ice-supersaturated samples (up to 100% ice), and ice-bearing rocks. These sample types have different concentrations of ice, different texture, and different resistance to sampling devices.

Ice Science Priorities: The MIST team ranked the scientific objectives of studying an ice-bearing sample (using the potential capabilities of the MSL landed system). The following is a prioritized list, using the impact on astrobiology as the prioritization criterion.

1. Is ice present and in what abundance?
2. Are organic molecules present in the sample, and if so, what is their identity, and what is their relationship to the ice fraction of the sample?
3. Is some fraction of the water present in the sample in the liquid state (e.g., as fluid inclusions, or along grain boundaries)? If so, how much, and what is its composition?
4. How did the ice get into the ground? Was it trapped from the atmosphere? Is it buried surface ice? Did it percolate from surface standing water or from sheetwash?
5. How old is the ground ice?
6. Has the ground ice been processed, melted, or redistributed since deposition? If so, when and how?

In addition, the planetary scientists on the MIST team concluded that several additional high priority investigations (origin of the water, climate at the time the ice formed, exchange rates/processes, planetary modeling, etc.).could be supported by measuring the isotopic properties of the water.

Some assertions regarding ice sample science: Based on the collective experience of the MIST team, we pose the following assertions regarding deriving science value from an ice-bearing sample on the martian surface.

1. For the ice-related investigations described above, well-designed measurements on a small number of ice-bearing samples will be more useful than poorly designed measurements on a large number of samples.

2. None of the high-priority ice-related measurements require that ice-bearing samples be crushed.
3. It is not scientifically necessary to split a sample to make multiple ice-related measurements. Most of the logic for doing this for the refractory portions of geologic samples does not apply to the ice fraction. It is far more important that the samples are fresh than to have statistically equivalent splits.
4. Sample aging is always a problem with ice-bearing samples. An acceptable solution to minimizing these effects is to optimize the operational scenario (e.g., transfer ice samples at night, while it is cold). This will be far simpler than mechanical means of sample preservation (e.g. encapsulation, refrigeration).
5. It is impossible to design a simple sample preparation and distribution system in which dry and wet samples follow the same path. We never do this in Earth labs.
   - If the ice fraction of a sample melts in a system designed for dry samples, there is potential for serious damage (un-removable contaminants, and perhaps worse).
   - Note: It may be possible using thermodynamic arguments to show that the ice will sublimate rather than melt, and if so, an engineering solution is not required.

Discussion:

For the highest-priority astrobiology investigations, non-destructive measurements are essential. Textural relationships between ice crystals, any organic material present, liquid/salt inclusions, and any associated mineral material need to be observed. Microscopy, probably with different kinds of illumination, will be key. For the highest priority planetary science investigations, subliming the ice and running the vapor through a mass spectrometer is essential. Given the priorities of the Mars program, we do not see a good scientific reason to subject an ice-bearing sample to mechanical sample preparation steps such as crushing and splitting. Thus, the mechanical process of interacting with an ice-bearing sample is in some ways simpler than interacting with rocks, which need to be crushed and split for many types of measurements.

The most useful kinds of ice-bearing samples for the scientific objectives described above are ice-saturated regolith and ice-supersatured material. These two sample types cannot be effectively sampled without a drill. We do not have a good way of calculating the depth of penetration necessary to acquire these sample types, but in our judgement a subsurface access capability of 0.3-0.5 m is a minimum.

When a cold ice-bearing sample is moved from its natural state to the warmer environment of the rover, it will progressively degrade, first by addition (freezing of water vapor onto the sample), then by subtraction (sublimation). We were unable to model the rate of this degradation process in the time available to us, but it will be dependent on the integrated exposure to higher temperature over time and air circulation. How much time-temperature is acceptable?--Preliminary calculations suggest that several hours should be acceptable if ΔT is modest.

Recommendations:

1. We recommend including a means of determining whether or not ice is present in the acquired sample either at the site of sample collection, or at the front end of the lab.
2. Minimize the effects of sample degradation by:
   - Placing ice-critical instruments in a cold part of the rover.
   - Collecting and processing samples for ice-related measurements at night.
   - Processing and analyzing ice samples quickly. We recommend that instruments needing to receive raw ice-bearing samples have a “by-pass” port, which would allow raw material to be introduced without passing through the sample preparation systems.
3. To protect the principal (dry) sample prep and analysis systems which are at the heart of MSL’s scientific objectives, we recommend that samples be dried prior to introduction into crushing, splitting, or sieving operations.
   - The combination of time and temperature necessary to achieve the minimum necessary state of dryness needs more analysis and discussion. A part of this analysis needs to include assessment of the temperature at which one starts to lose information on hydrated phases.

Conclusion:

Our summary conclusion is that it is possible to design a single overall surface system that can interact with both ice-bearing and ice-free samples. However, this system will need to have more complexity than a system designed to interact only with ice-free samples. Such a system could be designed now, and we would be able to send it to a location selected years from now in response to future discoveries (possibly either ice-free or ice-bearing).