



Life Detection Workshop

Scripps Institution of Oceanography

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Overview and Summary of Life Detection Protocol Update Workshop

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Development Strategy



Public **Conference** encouraged discussion of what it means to ‘detect life’ and develop a community consensus regarding what is required for a credible claim of life detection.

By-invitation **Workshop** addressed the potential for measurements that address broader scientific questions to be used also for planetary protection purposes to meet criteria for release of samples from containment, which could minimize use of scarce samples and duplication of effort.

Workshop Objectives:

- Evaluate current and possible scientific investigations that could identify signs of viable, extant life in samples returned from Mars
- Assess the state-of-the-art of available technologies and identify areas that require future work
- Discuss efficient phasing of planetary protection measurements in the context of proposed scientific analyses, to maximize efficient use of resources
- Identify needed improvements in sample preparation, detection technologies, and controls/blanks that would increase confidence in the results



Inputs from Conference



Assumptions: looking for life based on carbon chemistry that happens at Mars-surface temperature and pressure, on human-detectable timescales (i.e., water soluble).

Information addressing the properties of life as defined above might be found by measuring:

- 1) Structure and morphology of samples, at macro and micro scales
- 2) Chemical composition and heterogeneity of samples
- 3) Environmental and thermodynamic context of samples and interesting features within

Two competing hypothesis should be tested:

- 1) There is no life in the samples.
- 2) There is Mars life in the samples.

DATA will be collected: interpretation could provide 'strong biosignatures,' 'possible biosignatures,' 'indicators of abiotic processes,' or 'indicators of Earth contamination' – depending on which hypotheses the data support or refute.

PROPERTIES OF LIVING SYSTEMS (J. Farmer)

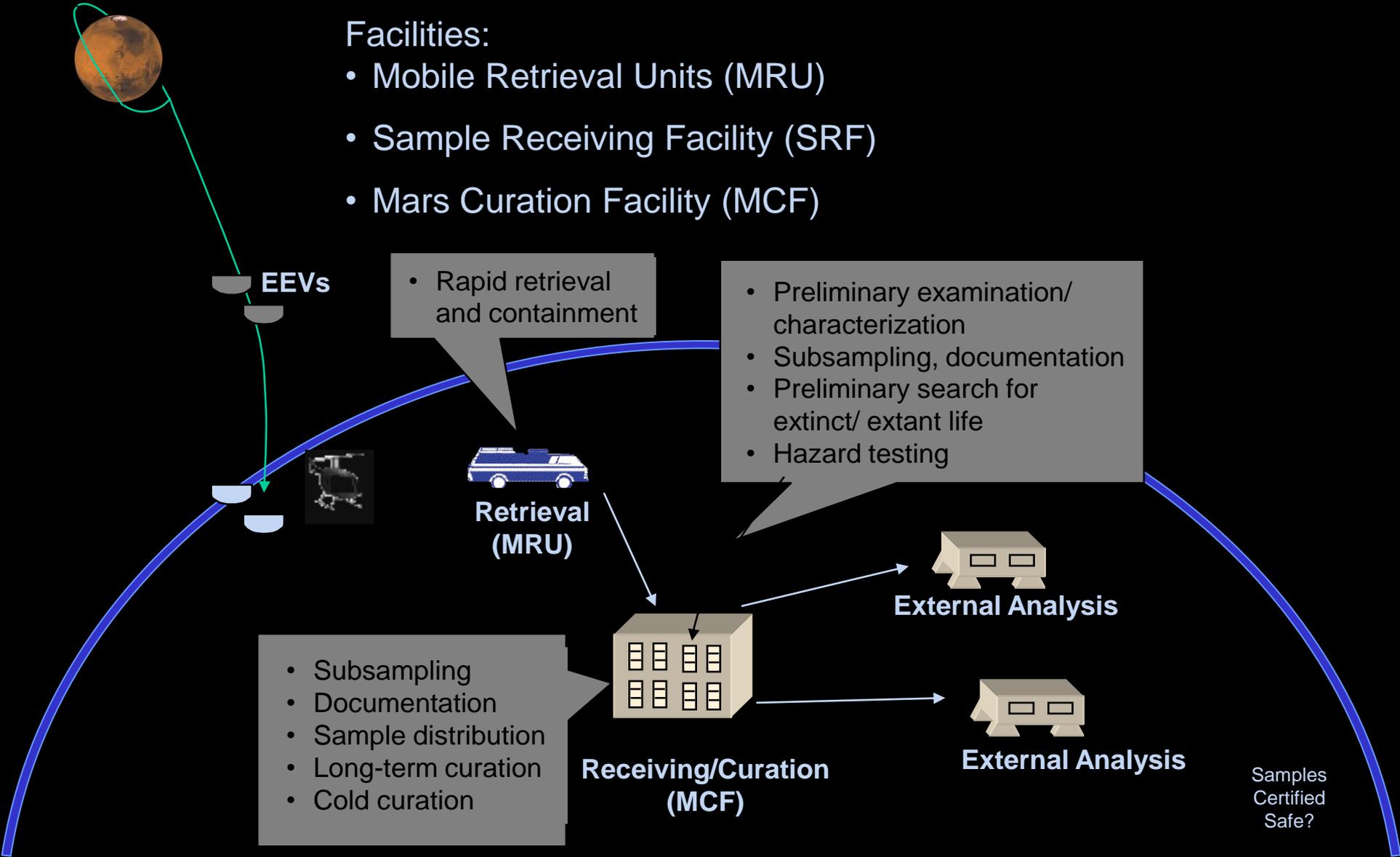
- **Order** - The structures and subsystems of living systems are highly ordered.
- **Replication** (reproduction) - Organisms replicate themselves through various methods of asexual, or sexual reproduction.
- **Growth and development** – In higher organisms there is a pattern of development controlled by regulatory genes.
- **Energy utilization** - Life utilizes a broad array of processes to extract energy from its environment.
- **Response to the environment** - Organisms interact with and respond to their environment.
- **Evolutionary adaptation** - Life adapts to environmental changes over time through mechanisms of Darwinian evolution.

Necessary versus sufficient...all are necessary,
but none sufficient.

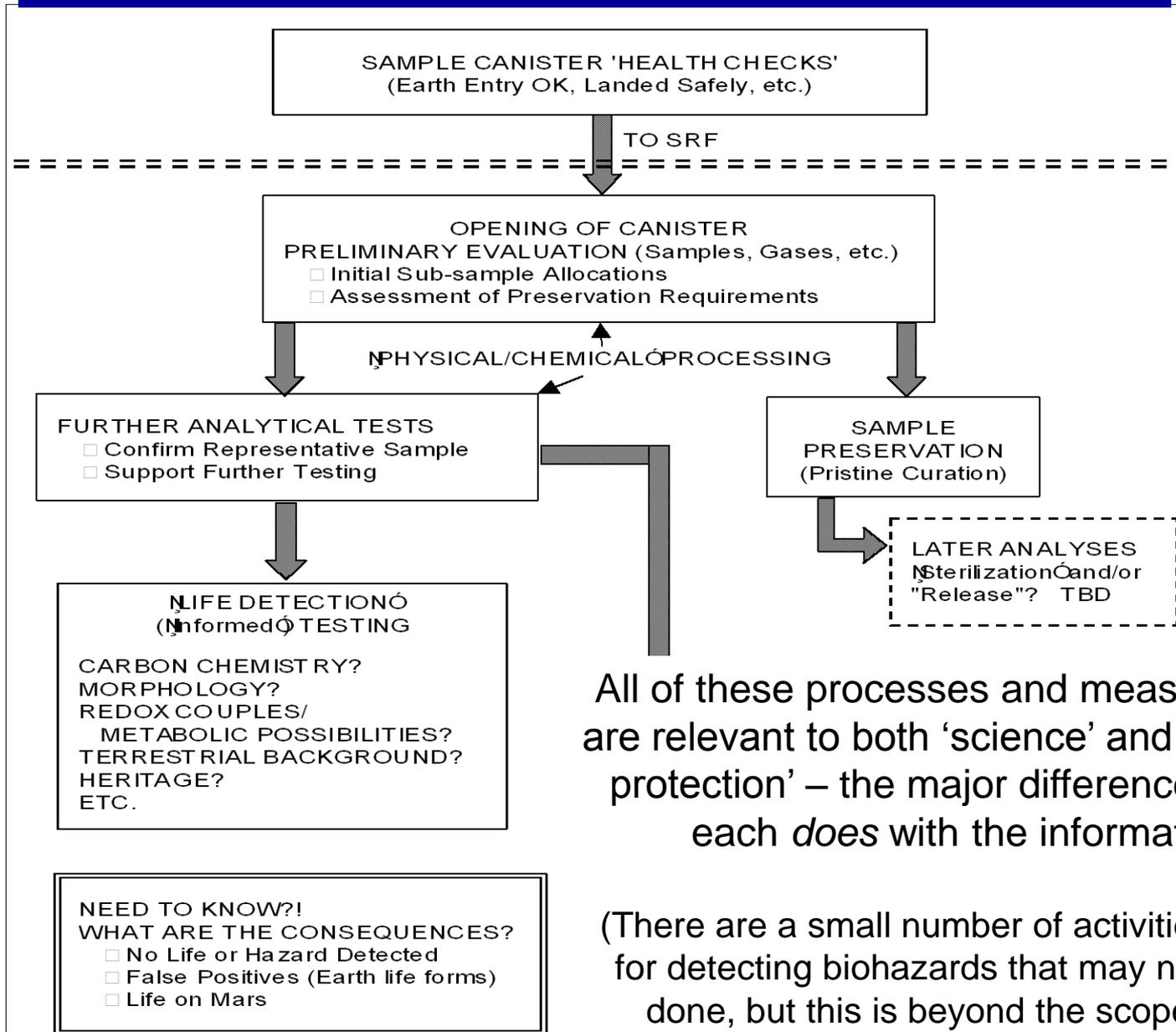
Back Contamination: A Candidate Mars Sample Handling Scenario

Facilities:

- Mobile Retrieval Units (MRU)
- Sample Receiving Facility (SRF)
- Mars Curation Facility (MCF)



Sample-Return Protocol Overview



All of these processes and measurements are relevant to both 'science' and 'planetary protection' – the major difference is what each *does* with the information.

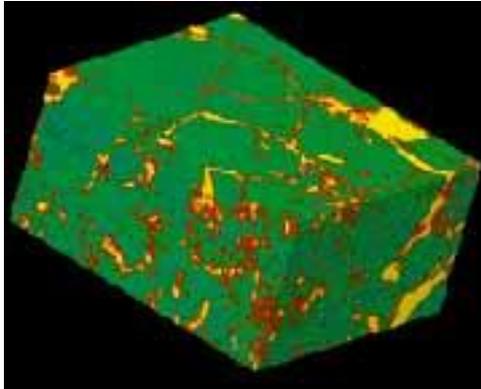
(There are a small number of activities specific for detecting biohazards that may need to be done, but this is beyond the scope here.)

Table 4: General Principles Guiding the Search for Life:

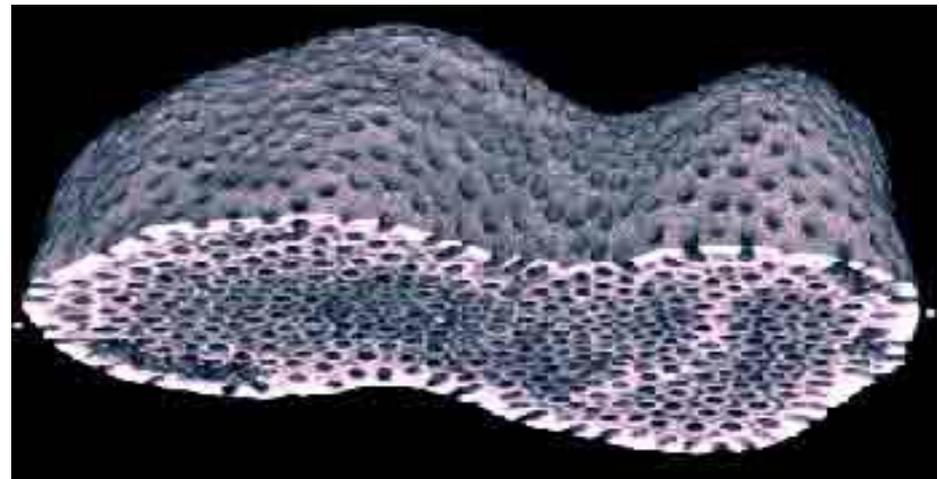
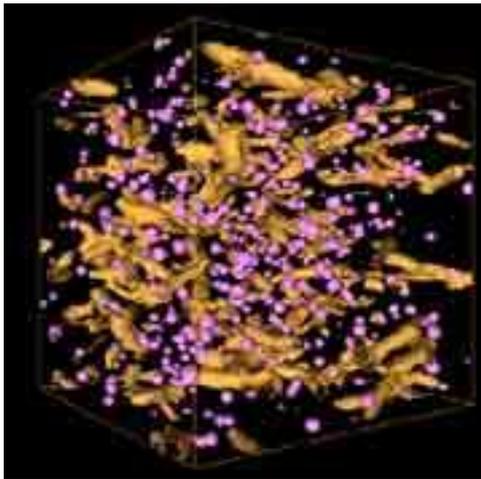
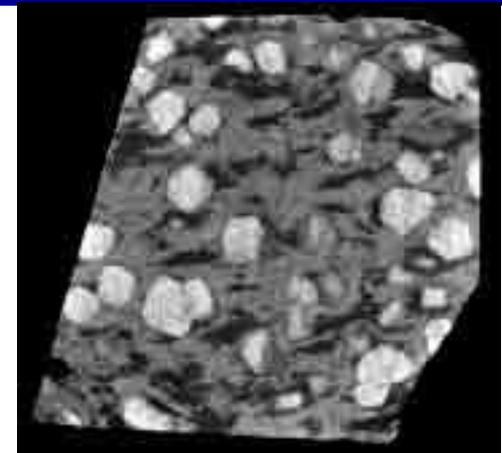
- Begin with a broad survey of a portion of different sample types for more general features suggestive of life, then turn to a higher resolution examination of sites with suggestive features for more complete characterization
- Emphasize structural signatures of life and other inhomogeneities that can be easily detected as a first order task
- Emphasize less destructive methods in the early stages of investigation, since they can guide the use of more definitive but destructive methods
- Start with samples which are the least likely to contain life (e.g., surface fines); if negative, use these as blanks and controls for spiking experiments
- Recognition of life will require the coincidence of multiple independent signatures
- Inactive or “past” life will be treated as potentially active life
- Generalize a carbon-centered methodology to other chemical species
- Use an iterative approach for the Life Detection protocol
- Invest significant time to the design of controls and blanks, as early in protocol development as possible



Initial Characterization



Computed Tomography
Elemental Imaging
Mineralogical Analysis



Stolen from UT Austin...



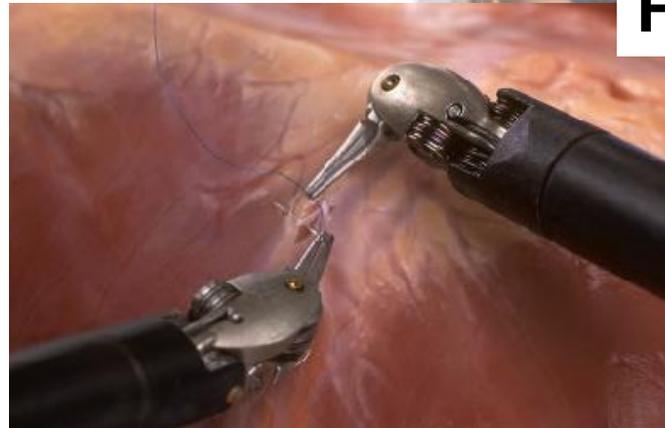
Subsample Processing



Past

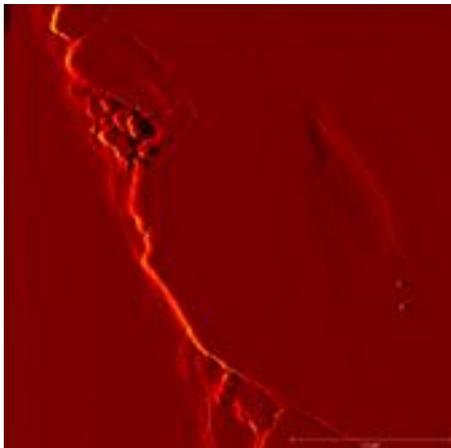
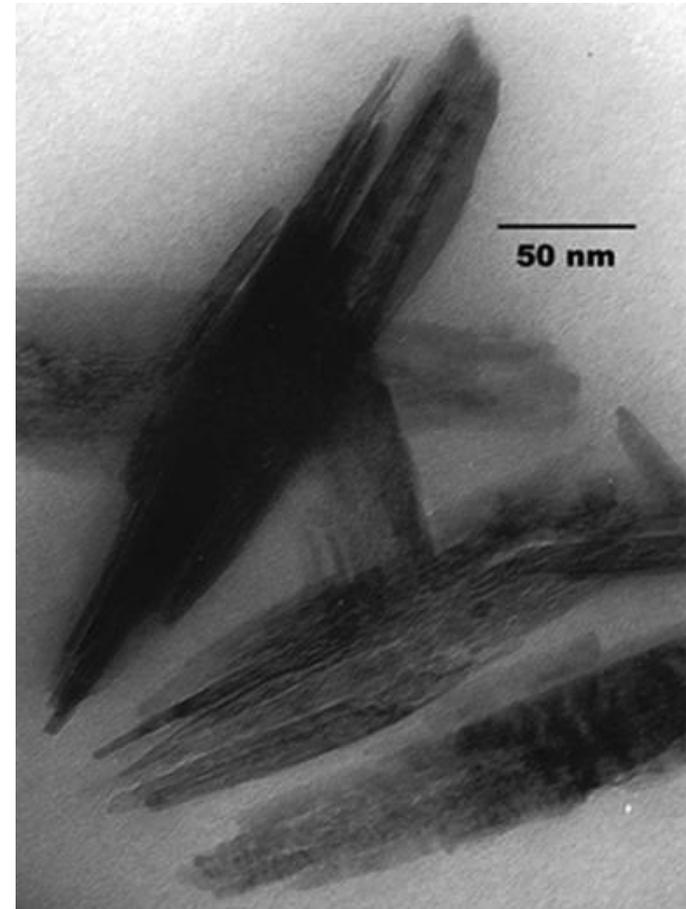
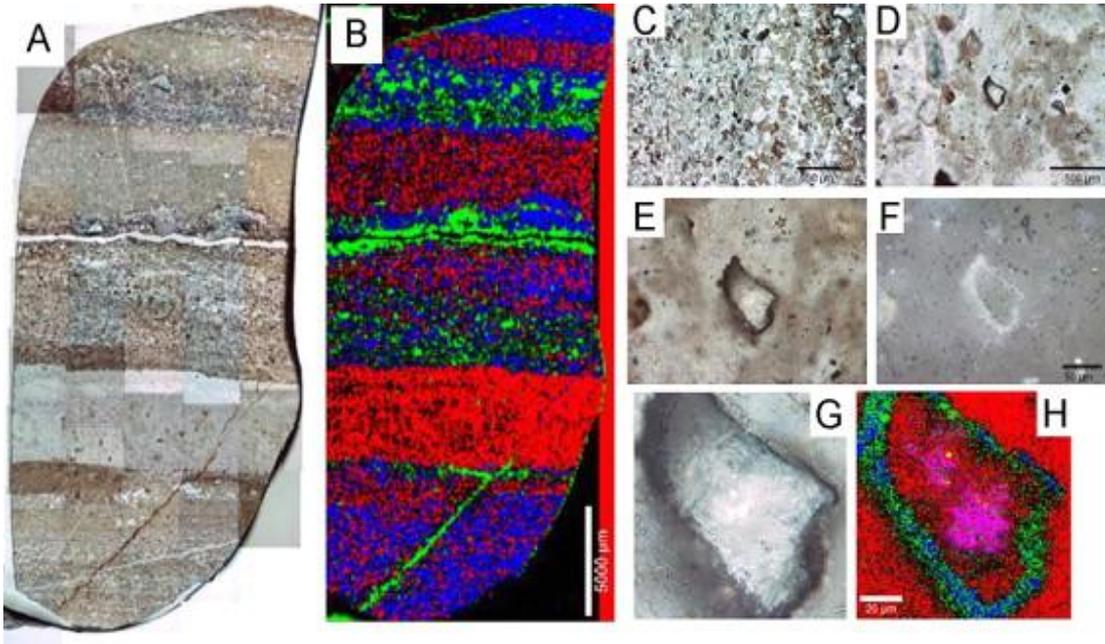


Future?





Targeted Characterization



**Prepared Surface
Imaging**

Micro-scale Probes

Particle Analysis



Breakout 1 Questions



Test two competing hypotheses:

- 1) The samples contain no life.
- 2) The samples contain local life.

Breakout 1:

How would you detect signs of life in samples from an environment, assuming no prior knowledge of local life?

- What measurements (structure, composition, context) would you make?
- How do you deal with sample heterogeneity?
- What commonalities of life could inform the detection process?
- What are the significant challenges? (few organics, uneven distribution, absence of structures, ??)



Breakout 2 Questions



Design a life-detection protocol:

- What kinds of macro-scale measurements could be most informative, and why?
 - 3D Non-Destructive (Tomography) Approaches
 - Surface Analysis/Imaging Approaches
 - Others?
- What kinds of micro-scale measurements could be most informative, and why?
 - Micro-scale Non-destructive Approaches
 - Localized Probe-type/Destructive Approaches
 - Others?
- Do aspects of the sample (composition, structure, context) deviate from what abiotic conditions would predict, and how?
- What could be done to improve confidence on the measurements? (controls, blanks, signal/noise issues, etc)
- How might you distinguish between Earth contamination and Mars life?
- How could a life detection protocol be tested/validated?



Full Discussion Questions



- Are there measurement outcomes that would confirm a 'Mars life-detection event'?
- Are there essential steps missing from our ability to perform an effective life detection protocol?
- What research/development activities would improve our ability to accomplish life detection successfully? (e.g., sample handling and storage conditions, working in containment, remote (robotic arm) manipulation, analytical capabilities, other?)



Conclusions/ Future Directions



Testing competing 'null' hypotheses is an effective strategy to address both scientific and planetary protection interests. Hypotheses are:

- 1) There is no life in the samples.
- 2) There is Mars life in the samples.

Data will be collected: these data may be equally relevant to 'science' and 'planetary protection.' **Interpretation** of collected data will guide policy decisions regarding sample safety and subsequent handling, as well as inform scientific research.

Characterization of measurements as 'strong biosignatures,' 'possible biosignatures,' 'indicators of abiotic processes,' or 'indicators of Earth contamination' could be useful

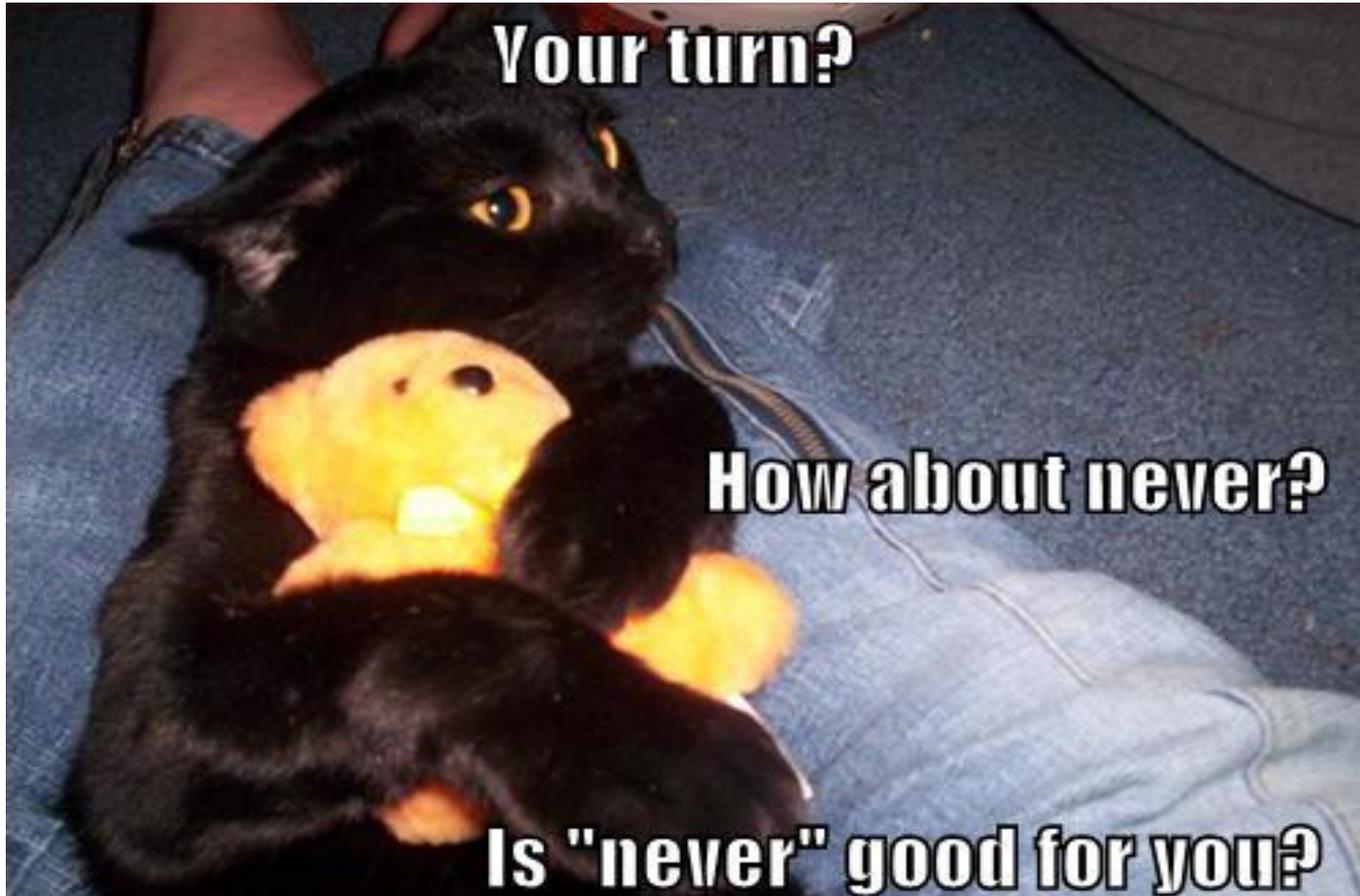
A decision analysis strategy based on Bayesian statistics could be used to direct sequences of investigations to increase confidence in conclusions as input to policy

Sample handling and containment are key technology needs:

- 1) Non-destructive imaging should be used to identify subsamples for further analysis
- 2) Significant improvements in clean subsampling capabilities are needed
- 3) Remote micromanipulation could greatly facilitate clean sample handling



Criteria for 'Release'?



Not very much sample there!