Refinement of Requirements for Category IVb Restricted Earth Return

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Category IVb Requirements for Mars (paraphrased)

Category IVb. For lander systems intended to investigate extant martian life, all of the requirements of Category IVa apply. In addition, one of the following conditions shall be met:

1. The total bioburden of the surface system is ≤ 30 bacterial spores on exposed internal and external surfaces, or at a contamination level driven by the nature and sensitivity of the particular life-detection investigations.

2. The average bioburden of the subsystems that are involved in the acquisition, delivery, and analysis of samples used for life-detection investigations is either:

(a) ≤ 0.03 bacterial spores/m2, or

(b) at a contamination level driven by the nature and sensitivity of the particular life-detection investigations,

and recontamination prevention of these subsystems and the samples to be analyzed is in place until the end of the life-detection investigations.

Refining Category IVb Requirements

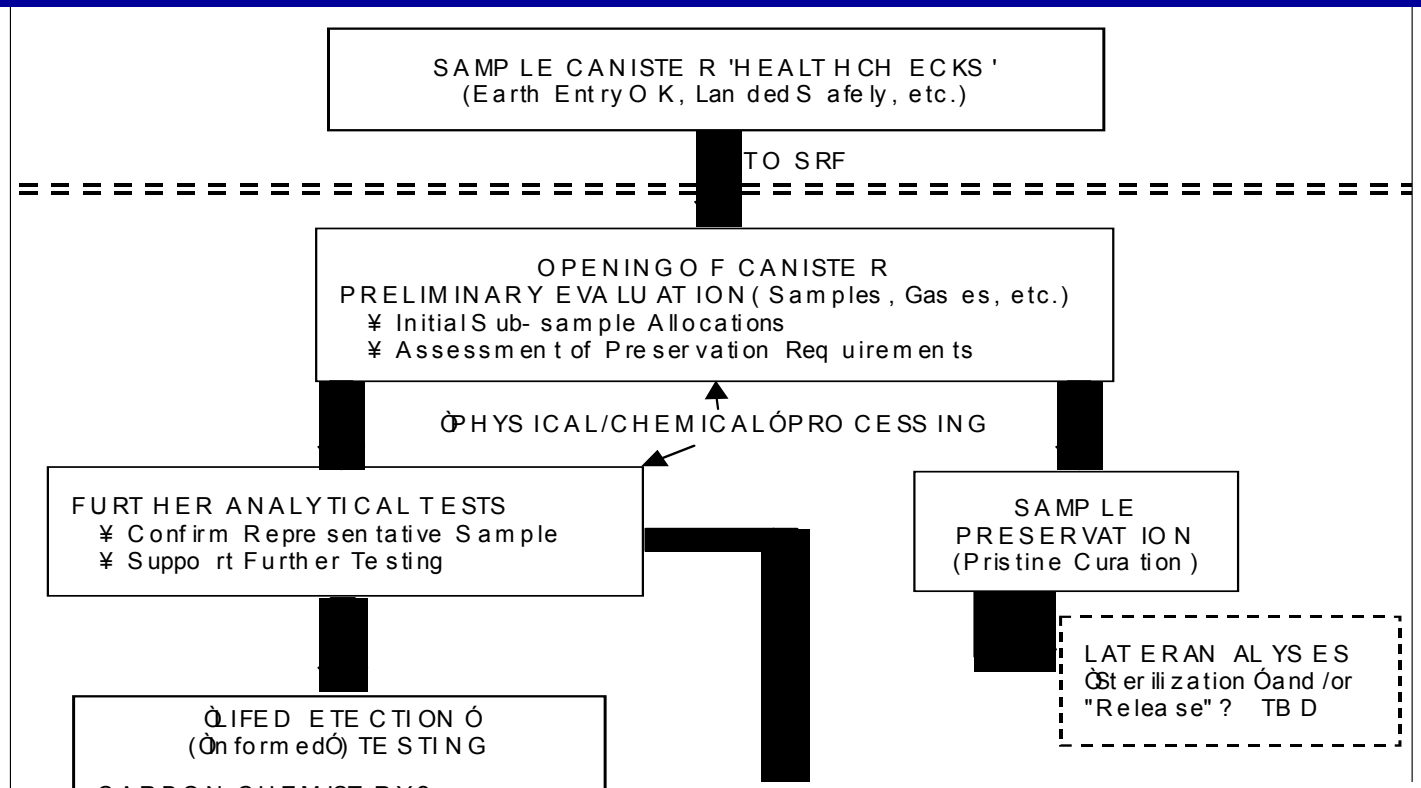
What does the requirement “driven by the nature and sensitivity of the particular life-detection experiments” really imply?

- Life detection experiments performed on Mars material returned to Earth will involve the best state-of-the-art instrumentation and capabilities available at the time

- Confidence in the conclusions of a life-detection protocol must be high to permit release of samples from containment

- Type of measurements and detection sensitivity will drive contamination limits on all elements of an MSR campaign, including initial sample caching missions

Returned Sample Handling 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.

NEED TO KNOW?!
WHAT ARE THE CONSEQUENCES?
¥ No Life or Hazard Detected
¥ False Positives (Earth life forms)
¥ Life on Mars

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

Draft Test Protocol Framework

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

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A DRAFT TEST PROTOCOL
FOR DETECTING POSSIBLE BIOHAZARDS IN
MARTIAN SAMPLES RETURNED TO EARTH

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.

Refining the Life Detection Protocol

The protocol addresses life based on carbon chemistry that happens at Mars/Earth near-subsurface temperatures and pressures, on human-detectable timescales.

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

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.

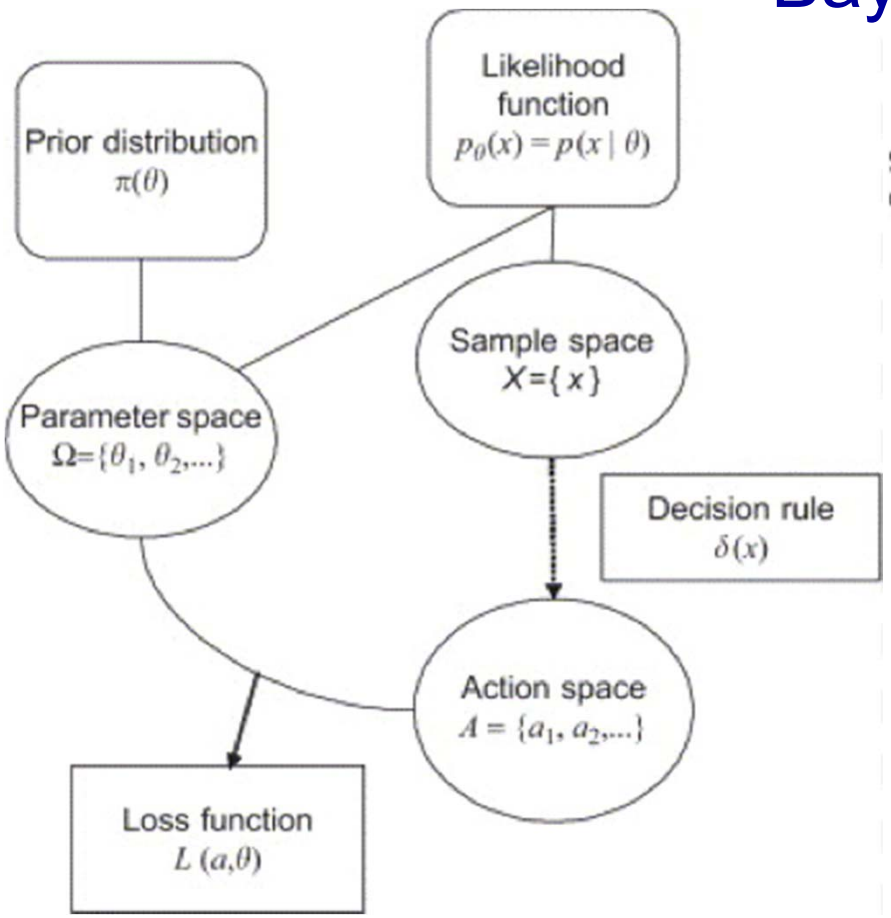
Data will be collected: these data may be equally relevant to ‘science’ and ‘planetary protection.’ ***Interpretation*** of collected data will guide policy decisions regarding sample safety and subsequent handling, as well as inform scientific research.

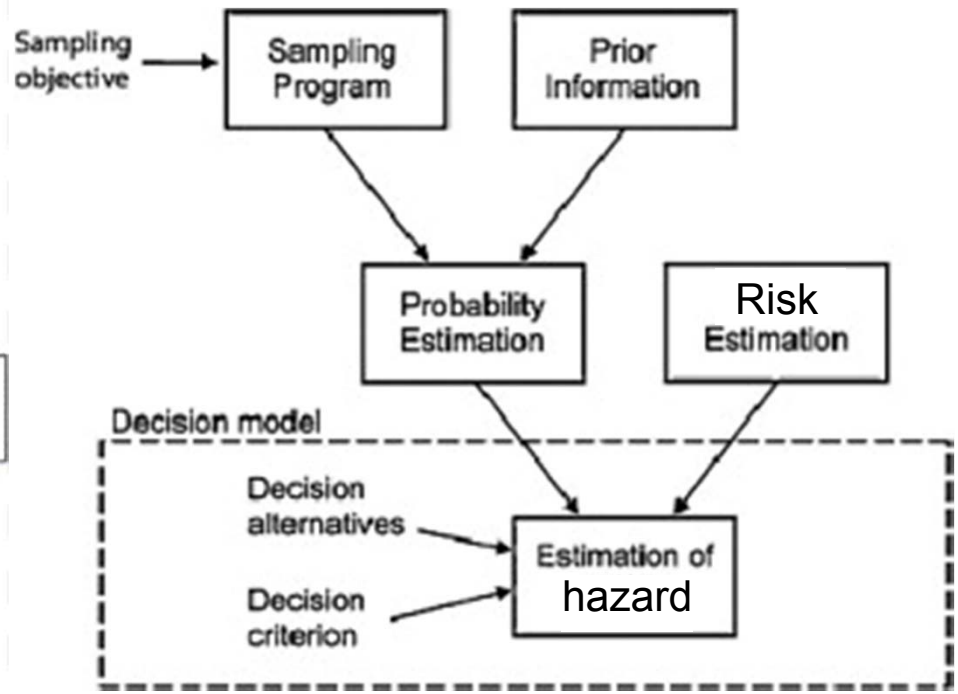
Characterization of measurements as 'strong biosignatures,' 'possible biosignatures,' 'indicators of abiotic processes,' or 'indicators of Earth contamination' could be useful

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

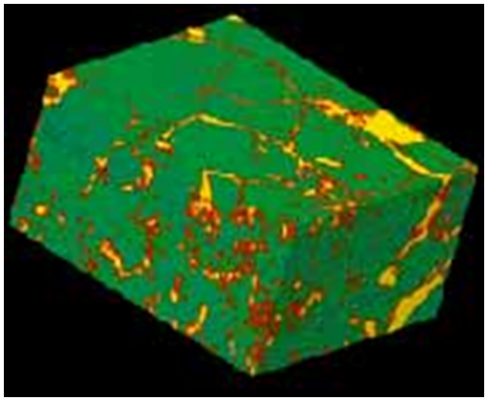
Science Informs Policy

Bayesian Decision Analysis





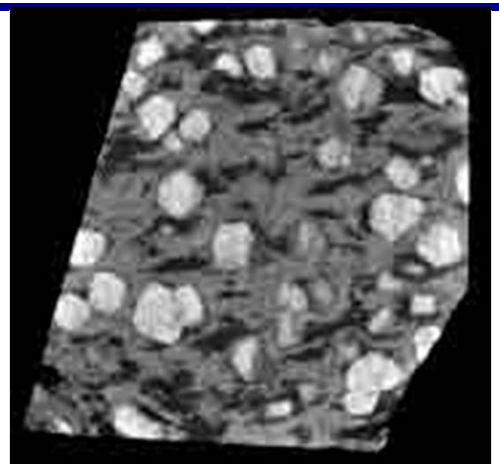
Initial Characterization

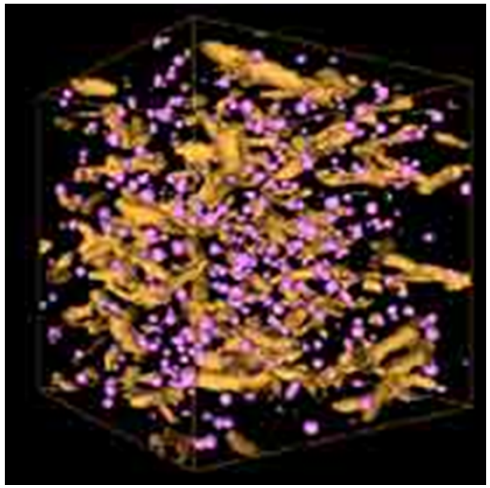


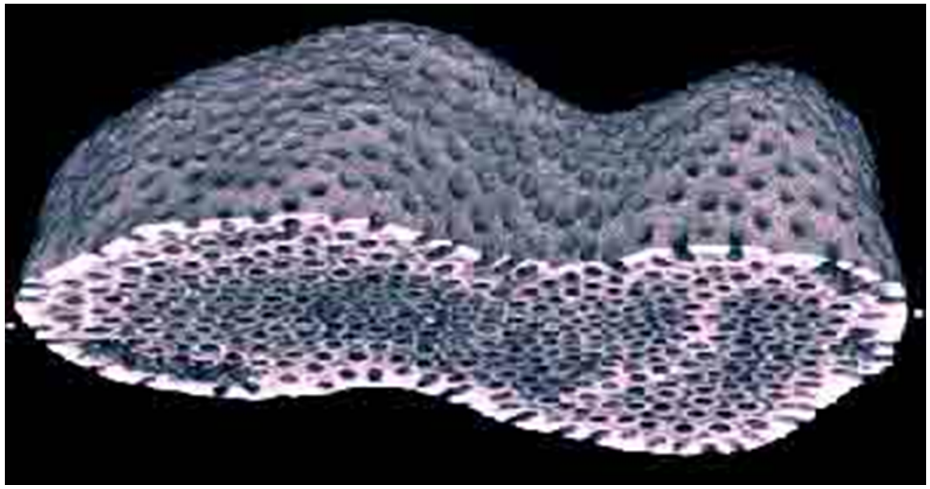
Computed Tomography

Elemental Imaging

Mineralogical Analysis





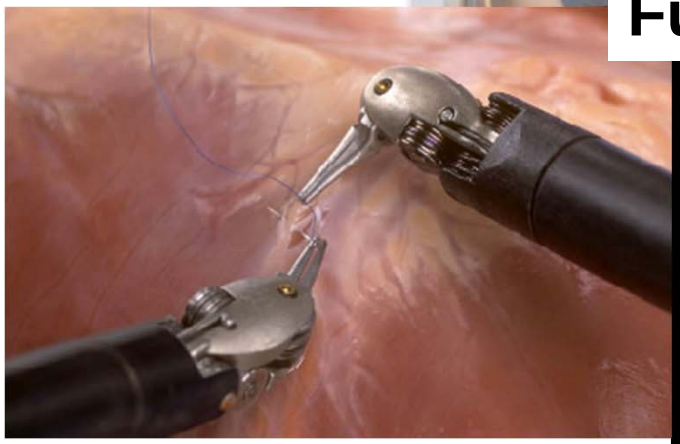


Stolen from UT Austin...

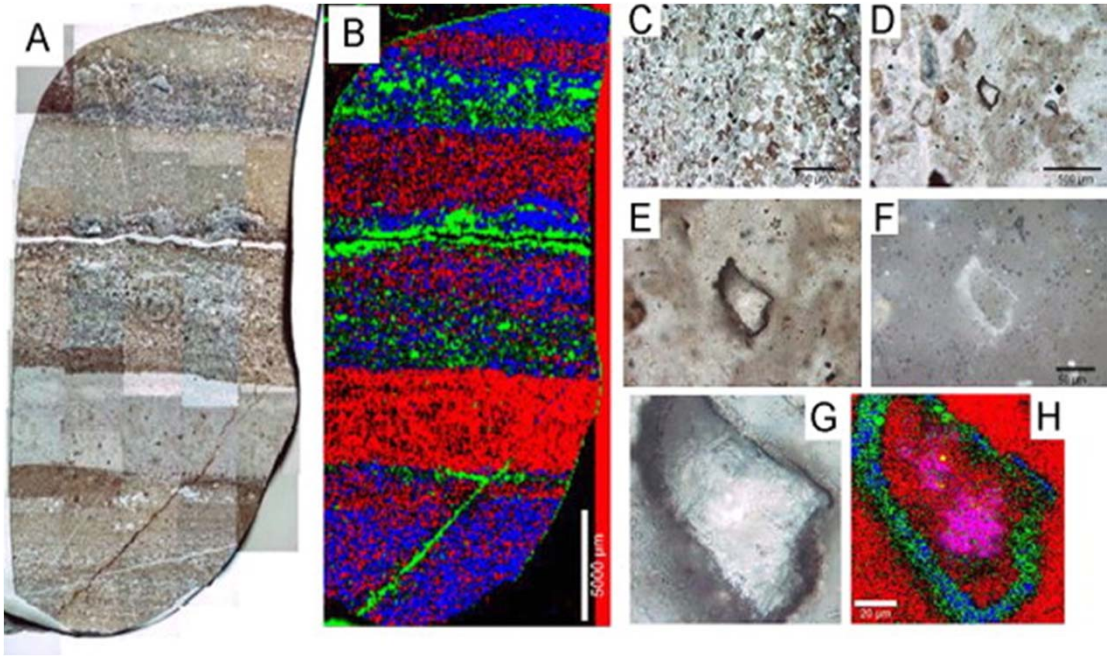
Subsample Processing

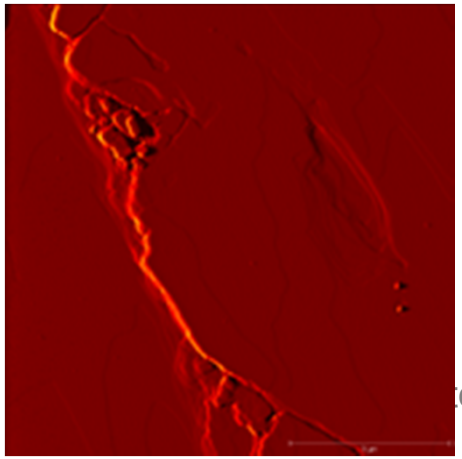
Past

Future?



Targeted Characterization

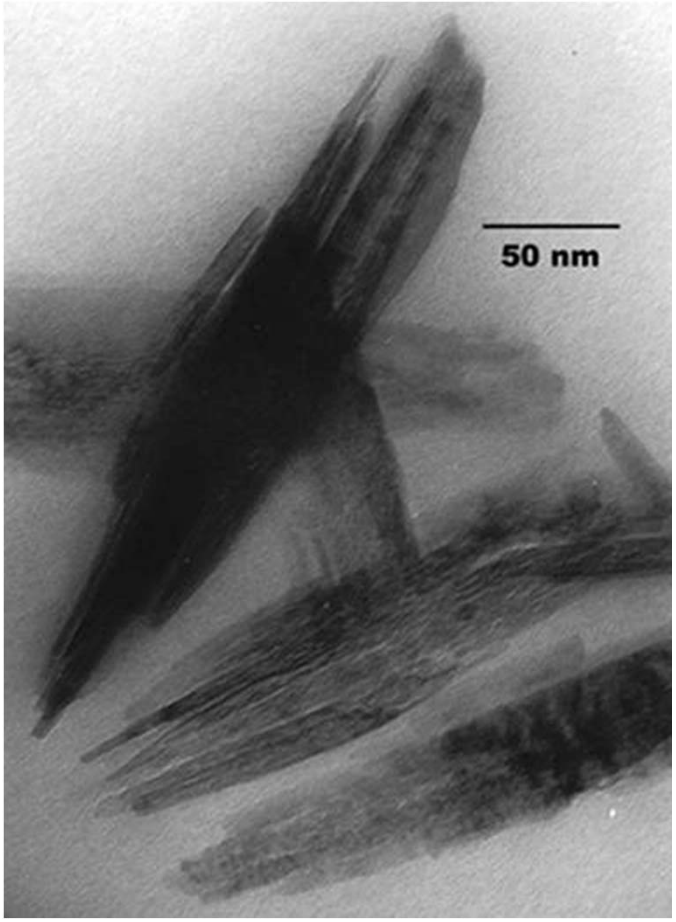




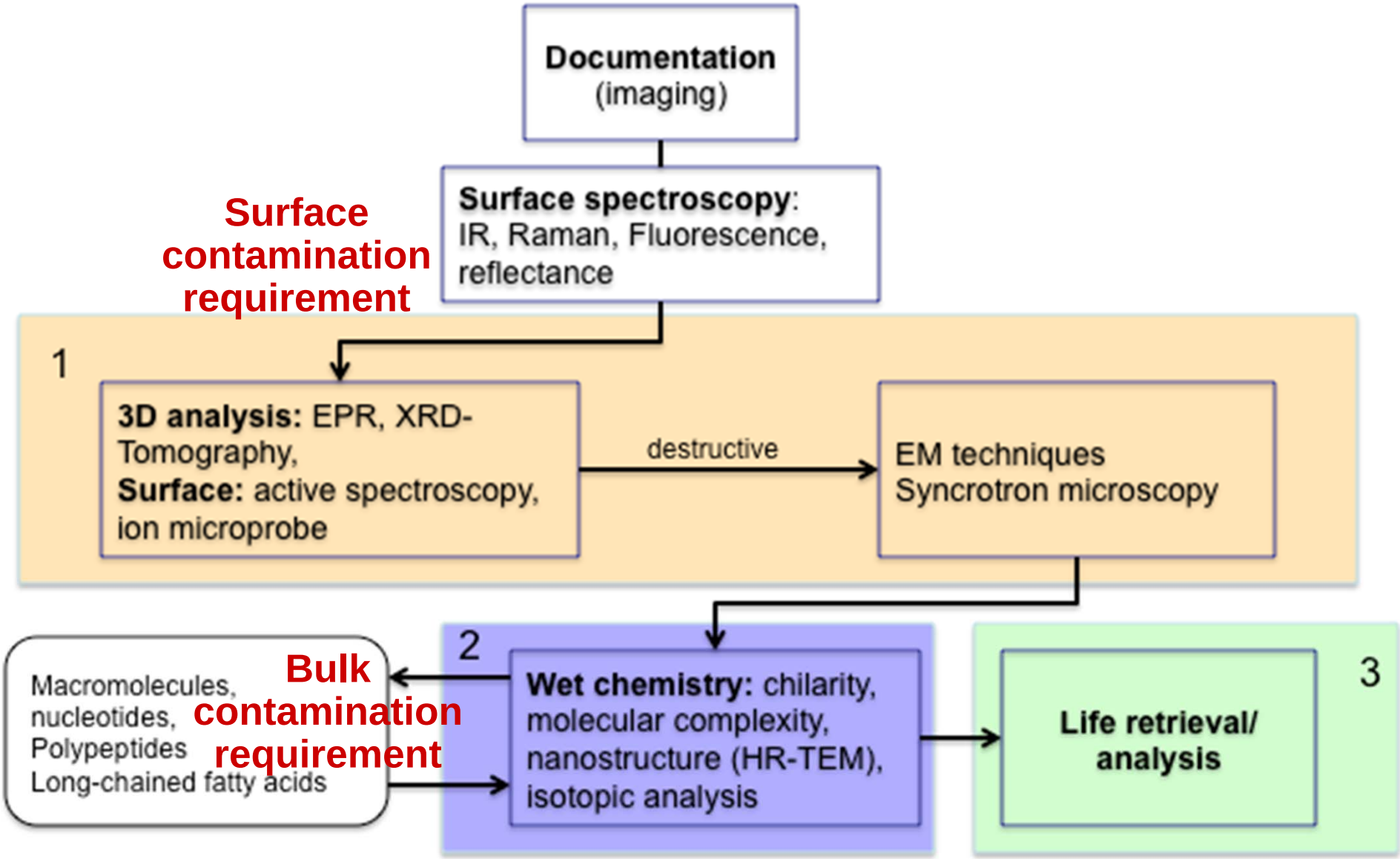
Prepared Surface Imaging

Micro-scale Probes

Particle Analysis



Example Scheme



Define Requirements Today for Analyses Tomorrow...

- Instrumentation used on returned Mars samples will be at least as sensitive as today's instrumentation
- Detection of organic material on surfaces can attain femptomolar/attomolar sensitivity over micron-scale spots (e.g., LDMS; other desorption techniques)
- Detection of organic material in bulk samples can attain parts-per-billion sensitivity (ng/g)
- Capabilities to verify pre-launch organic/biological cleanliness may constrain requirements in practice
- Provisional guidance can be derived from past and current life detection missions, but additional work is necessary to assess current capabilities and extrapolate future needs

Clean Sample Handling...