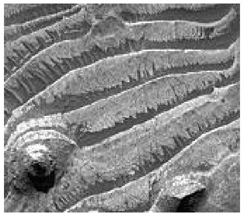
MEPAG
E2E-iSAG

On-Mars measurements and strategies, summary

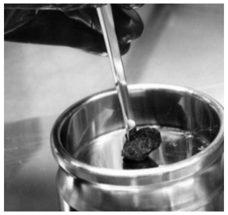
Lisbon, Portugal; June 16, 2011

Scott McLennan, on behalf of the E2E-iSAG committee

Pre-decisional: for discussion purposes only



Overview



Prioritized MSR science objectives

Derived implications

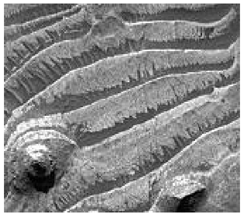
- Samples required/desired to meet objectives
- Measurements on Earth

Critical Science Planning Questions for 2018

- Variations of interest?
- # of samples?
- Types of landing sites that best support the objectives?
- Sample size?
- Measurements needed to interpret & document geology and select samples?
- On-Mars strategies?

Engineering implications

- Sampling hardware
- Instruments on sampling rover
- EDL & mobility parameters, lifetime, ops scenario
- Sample preservation



Objectives and samples required/desired

Scientific Objectives in Priority Order

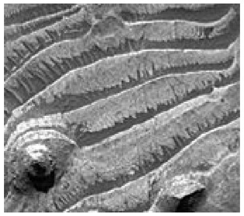
1	Critically assess any evidence for past life or its chemical precursors, and place detailed constraints on the past habitability and the potential for preservation of the signs of life
2	Quantitatively constrain the age, context and processes of accretion, early differentiation and magmatic and magnetic history of Mars.
3	Reconstruct the history of surface and near-surface processes involving water.
4	Constrain the magnitude, nature, timing, and origin of past planet-wide climate change.
5	Assess potential environmental hazards to future human exploration.
6	Assess the history and significance of surface modifying processes, including, but not limited to: impact, photochemical, volcanic, and aeolian.
7	Constrain the origin and evolution of the martian atmosphere, accounting for its elemental and isotopic composition with all inert species.
8	Evaluate potential critical resources for future human explorers.

Mandatory: Determine if the surface and near-surface materials contain evidence of extant life

Sample Types in Priority Order

- 1A. Subaqueous or hydrothermal sediments (EQUAL PRIORITY)
- 1B. Hydrothermally altered rocks or Low-T fluid-altered rocks
- 2. Unaltered Igneous rocks
- 3. Regolith
- 4. Atmosphere, rocks with trapped atmosphere

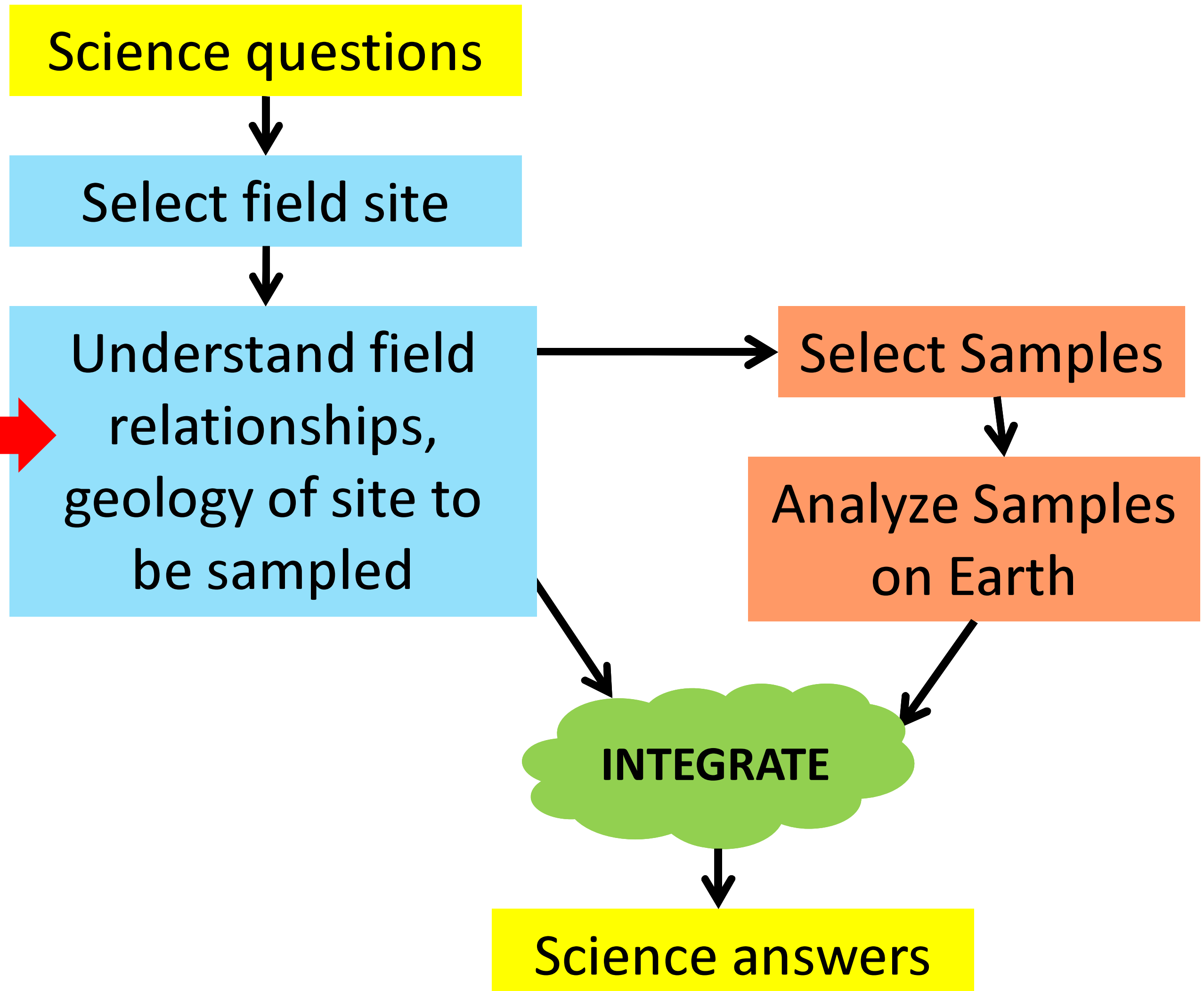
Pre-decisional: for discussion purposes only



Measurement capabilities

Revision - what determines the requirements?

The *in situ* scientific measurements must enable us to understand the geology of the site… sufficiently to enable sample selection AND interpretation of data from sample analyses on Earth.



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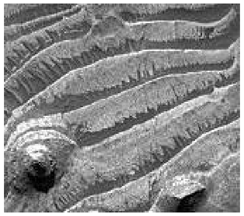
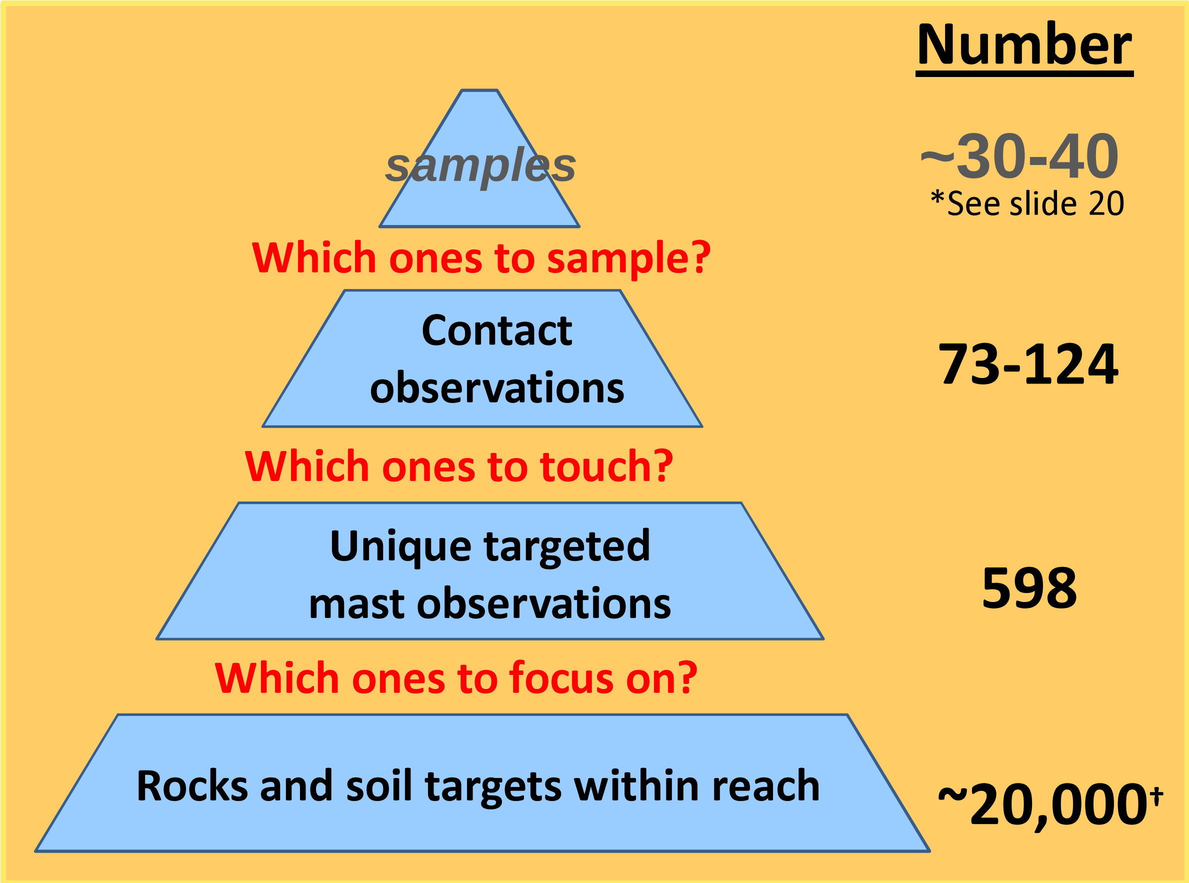


Sample Science General Principles: 2. Hierarchical Need for Information

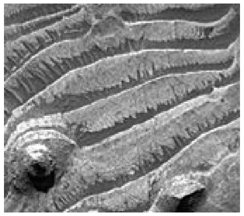
DRAFT FINDING #3. Putting together effective sample suites requires collecting information in the field on many more rock and soil candidates than the number eventually collected.

Example:
Counts from first Mars year of Spirit's exploration of Gusev Crater, 2004-2006.



†In first martian year, Spirit drove about 4000 m (lander to Haskin Ridge Seminole). Using a conservative visibility band of 15 m on either side of the traverse path (4000m x 30m = 120,000 sq m) times an average rock abundance of 15% comes out to 18,000 rocks

Pre-decisional: for discussion purposes only



Measurement capabilities

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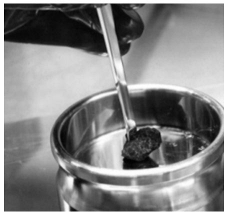


Objective 1,3,4: Subaqueous or hydrothermal sediments; Hydrothermally altered rocks or Low-T fluid-altered rocks

Natural Variation we may encounter:

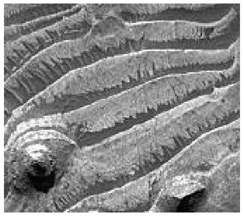
- Facies and microfacies in a sedimentary deposit
- Physical variations in a mineral phase: texture, crystal habit, or residence in veins/ layers/ cement/ clasts / concretions
- Inferred salinity gradient in a saline mineral assemblage
- Variations in organic matter: host mineralogy, concentration, spatial arrangement in relation to context
- Sedimentary structures and textures, associated mineralogical variations
- Mineral transition across a zone of alteration
- sequence of vein-fill deposits
- Proximal-distal trends at a hydrothermal vent

Objective 2:
Unaltered Igneous rocks

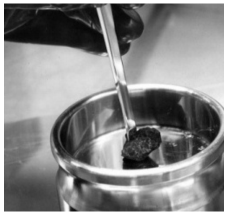
Natural Variation we may encounter:

- Petrologic character: ultramafic to granitic, mineralogic, trace element properties
- Age (although in the field this could only be hypothesized based on context)
- Type and intensity of aqueous alteration
- Type of occurrence: outcrop, “subcrop,” or float
- Igneous setting: intrusive, extrusive
- Grain size, chemical variation in minerals
- Degree of weathering
- Degree of impact shock metamorphism, including brecciation

NEED TO BE ABLE TO RECOGNIZE, MEASURE/DOCUMENT AND SAMPLE THESE

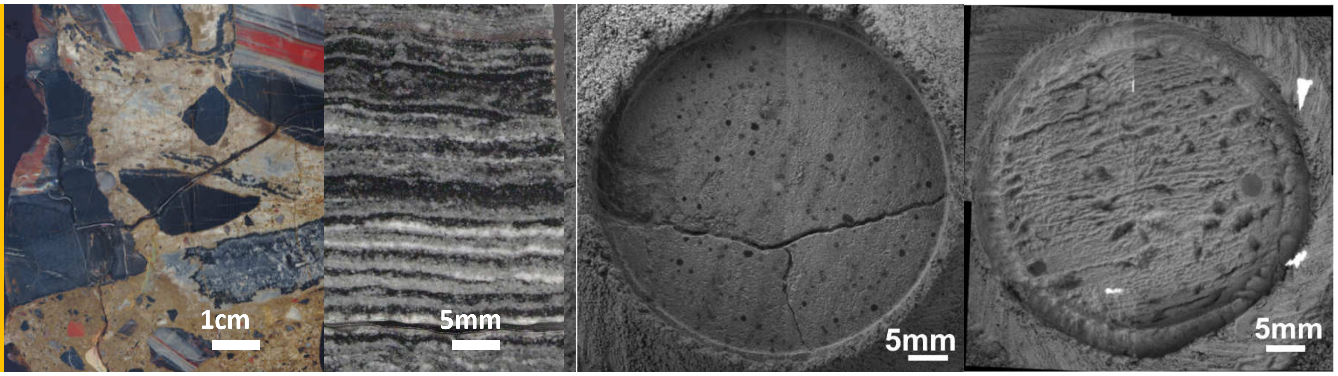


Scale of measurements



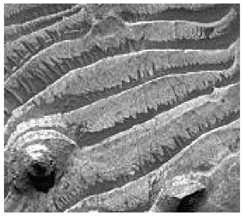
Essential evidence needed to make well-informed sample selection decisions lie in the composition of millimeter-scale features such as shown below.

- •Laminae
- •Clasts (vs. matrix)
- •Crystals
- •Void fills
- •Concretions
- •Veins

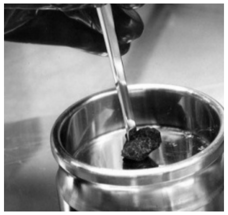


Measurements would be needed that resolve composition (mineralogy, elements, organics) of these millimeter-scale features. These measurements should be able to be integrated with their larger scale context.

DRAFT FINDING #21. Integration of observations from macroscopic (outcrop, regional) scales down to microscopic (sub-millimeter) scales is essential for robust geological interpretation in support of sample selection and provision of context for sample analyses on Earth.



Summary of required Field Capabilities implied by science priorities



The capabilities <u>required</u> to assess the geology and select the sample suites are:

1. Ability to detect variations in mineralogy, chemical composition, textures/structures (micro-, meso-, and macro-scale) <u>in outcrops</u>
2. Sufficient number of interrogations by the instruments of the outcrops to fully understand the geologic context.
3. Ability to "see" the rocks below their coverings of dust and weathering products.
4. Mobility range and lifetime sufficient to conduct exploration outside of the landing ellipse (see discussion later in this package)

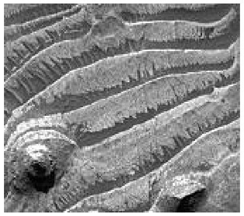
****this is not a priority order—all would be required****

SLIDES #18-19; FINDING #3, 4

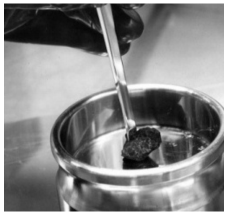
FINDING #2, 3

SLIDES #18-19

SLIDE #41; FINDING #15



Measurements: NASA/ESA Collaboration and the Mars 2018 Mission

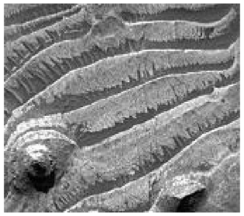


Current (May, 2011) relevant assumptions about the 2018 rover

1. Single joint rover delivered by MSL skycrane system
2. The mission will support both proposed Mars Sample Return science (based on science priorities updated via the E2E analysis) AND *in situ* science derived from prior ExoMars priorities.
3. Inclusion of Pasteur payload previously selected. ***Whether additional instruments for sample selection/caching would be required is analyzed by E2E***; selection via future joint AO assumed.

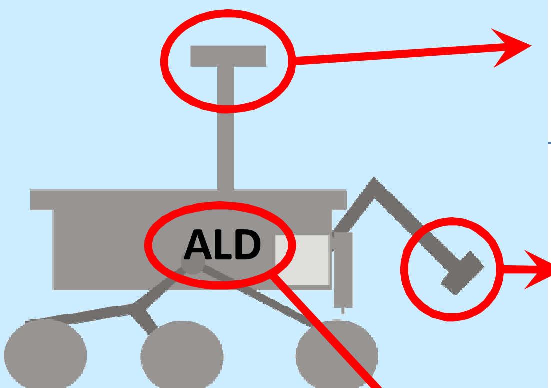
CURRENTLY APPROVED PASTEUR PAYLOAD		
INSTRUMENT NAME	**DESCRIPTION**	**COMMENT**
PanCam (WAC + HRC)	Panoramic camera system	Mast-mounted
MOMA	LD-MS + Pyr GC-MS organic molecule characterization	**Analytical Laboratory Drawer (ALD)** Instruments**:** Rover-body; internal analytical instrument suite.
MicrOmega IR	IR imaging spectrometer	
Mars-XRD	X-ray diffractometer + X-ray fluorescence	
Raman	Raman spectrometer	
Life Marker Chip	Biomarker detection; immunoassay	
CLUPI	Close-up imager	Drill-mounted
WISDOM	Shallow ground-penetrating radar	Rover-body; internal electronics, external antennas
Ma_Miss included in 2.0-m drill	IR borehole spectrometer	Drill-mounted

Pre-decisional: for discussion purposes only



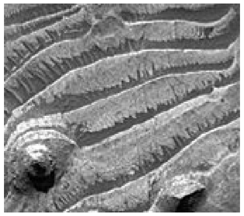
On-Mars measurements

<u>DRAFT FINDING #22</u>. Mast, arm and on-board lab instruments would *all* be of value for achieving the proposed MSR science objectives. However, each would play a different tactical role in sample selection and establishment of geological context.



Measurements can be grouped by position on rover

Value to returned sample objectives	# of potential targets	Operations Speed	*Decision flow*
Survey geology and acquire/prioritize IDD targets	>10^3 rocks in view, ~10^3 targeted	FAST: some done concurrent with driving	Use IDD? Continue remote survey?
Confirm/prioritize specific sample targets, analyze geologic setting	~ 10^2	MEDIUM: Stop, arm deployment, 1-3 sols	Cache sample? Continue survey? ALD sample?
added detail & verification of arm/mast measurements	~ 10^1	SLOW: sample acquisition, processing 10-20 sols	

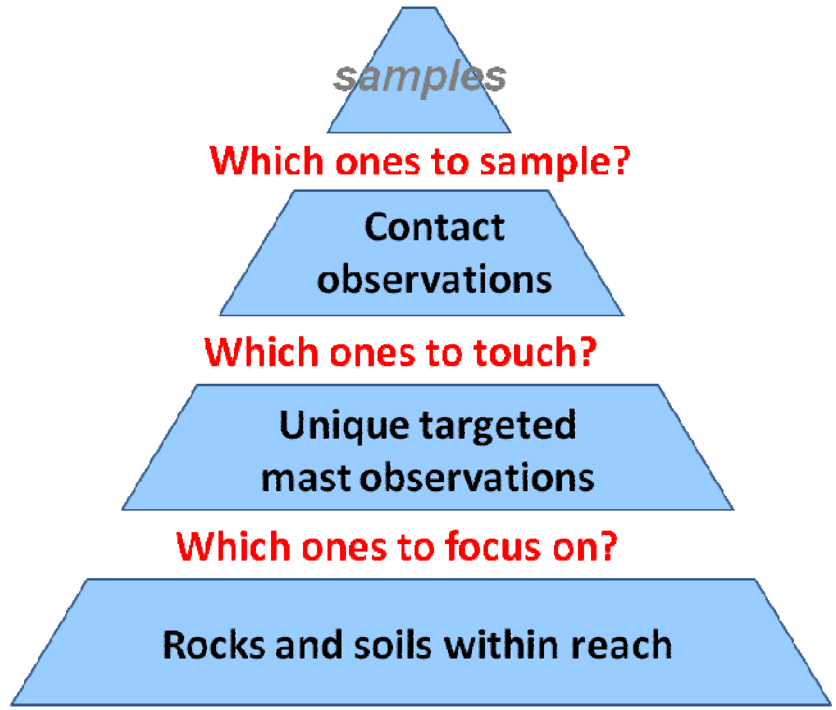


On-Mars measurements

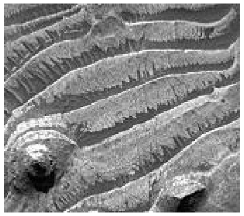
Is the ExoMars Pasteur payload sufficient on its own to meet MSR science objectives?

Sample selection decisions would be based on a foundation of numerous (100's to 1000's) observations and measurements of the local geology. These would be most efficiently done with mast- and arm-mounted instruments.

DRAFT FINDING #9. MAST/ARM INSTRUMENTS: The majority of the information for deciding which samples to return to Earth must be based on relatively fast, efficient mast- and arm-mounted instruments, in order to keep the mission within plausible lifetime and resource constraints (reaffirms a key finding of MRR-SAG).



Pre-decisional: for discussion purposes only



SUMMARY: On-Mars measurements required/desired to support MSR

DRAFT FINDING #26. In order to recognize the geological characteristics of interest and to provide a proper basis for sample selections, two measurement types would be required from the mast, and 3-4 more from the arm, as identified in the figure below. On-board laboratory measurements such as provided by the ExoMars ALD are highly desirable.

Required contact measurements* on ARM:

- Microscopic imagery
- Elemental chemistry
- Mineralogy

Highly Desired measurement* on ARM:

- Organic C detection

Additional capability required on ARM:

- ability to remove rock weathering layer

Sub-mm measurement scale highly desirable for all contact measurements; required for imaging and mineralogy

"Selecting high quality samples is essential to the success of the sample return effort"—NRC (2011)

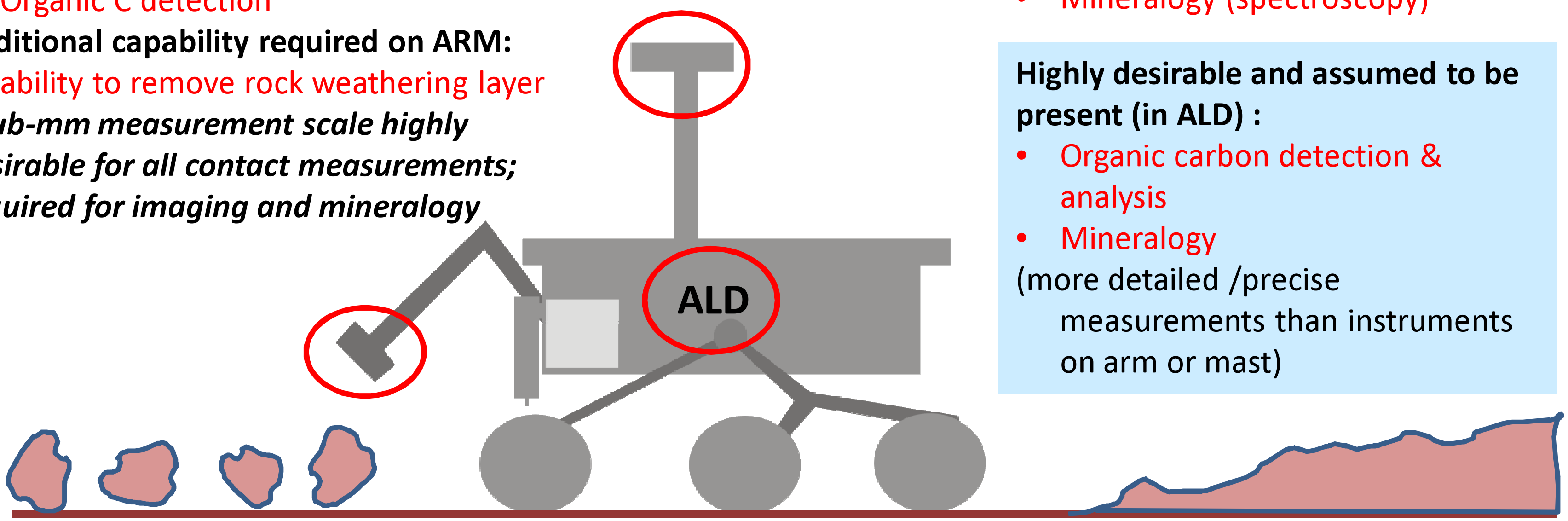
Required on MAST:

- Macroscopic imagery
- Mineralogy (spectroscopy)

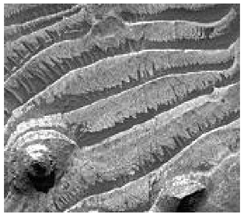
Highly desirable and assumed to be present (in ALD) :

- Organic carbon detection & analysis
- Mineralogy

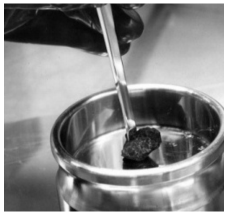
(more detailed /precise measurements than instruments on arm or mast)



Reinforces key findings of MRR-SAG (2009) and NRC Decadal Survey (2011)



Sample Transfer Opportunity #1:
Passing samples from arm to ALD

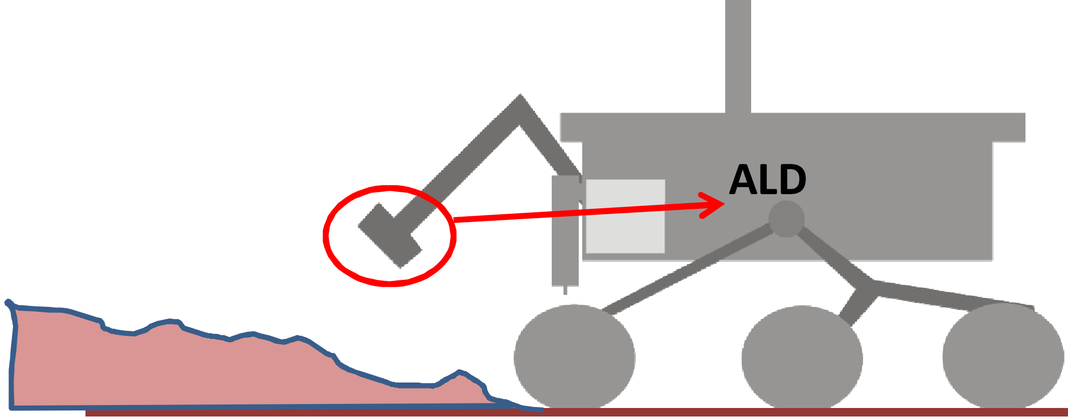


Maximizing the value of the ALD to MSR

ONBOARD LAB INSTRUMENTS provide detailed, highly sensitive analysis of a select number of high priority targets

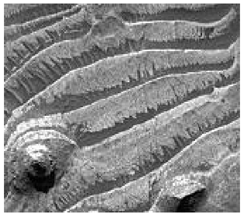
The value of the ExoMars ALD for meeting proposed MSR science objectives depends on how much of the range of encountered materials it can be supplied with. If *any* materials accessible by the arm could be passed to the ALD, the value of the ALD would be high.

If *only* the materials accessible by the ExoMars drill (those directly below the rover) could be passed into the ALD, the application of the ALD to MSR science is more restricted.



DRAFT FINDING #27. The value of on board lab instruments would be greatly increased if samples can be passed from the arm corer to the lab.

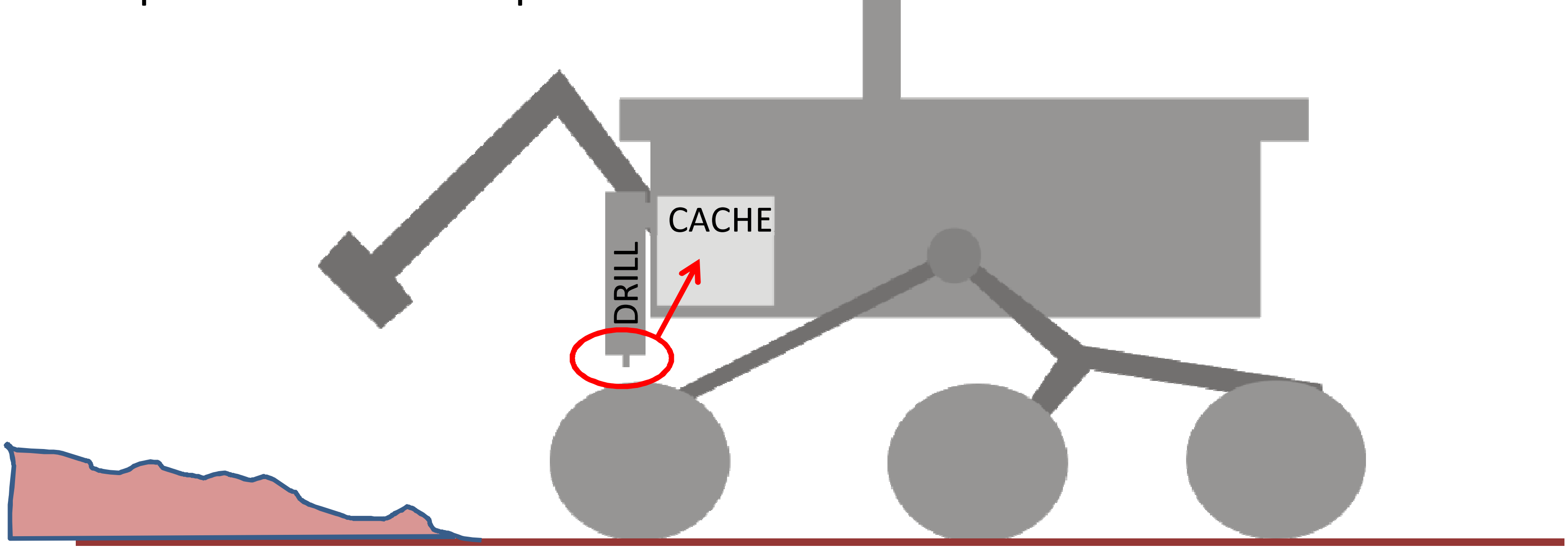
Pre-decisional: for discussion purposes only



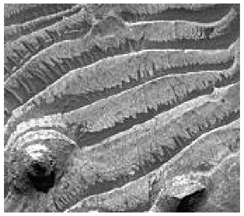
Sample Transfer Opportunity #2:
Getting a subsurface sample into the cache

<u>Maximizing the value of the drill to MSR</u>

- The <u>capability</u> to cache and return one or more rock samples from ~2m depth would be <u>extremely valuable</u>
- This would require an ability to pass a drill sample into the cache
- Such a capability is considered more important than the capability to pass arm-corer samples into the ALD

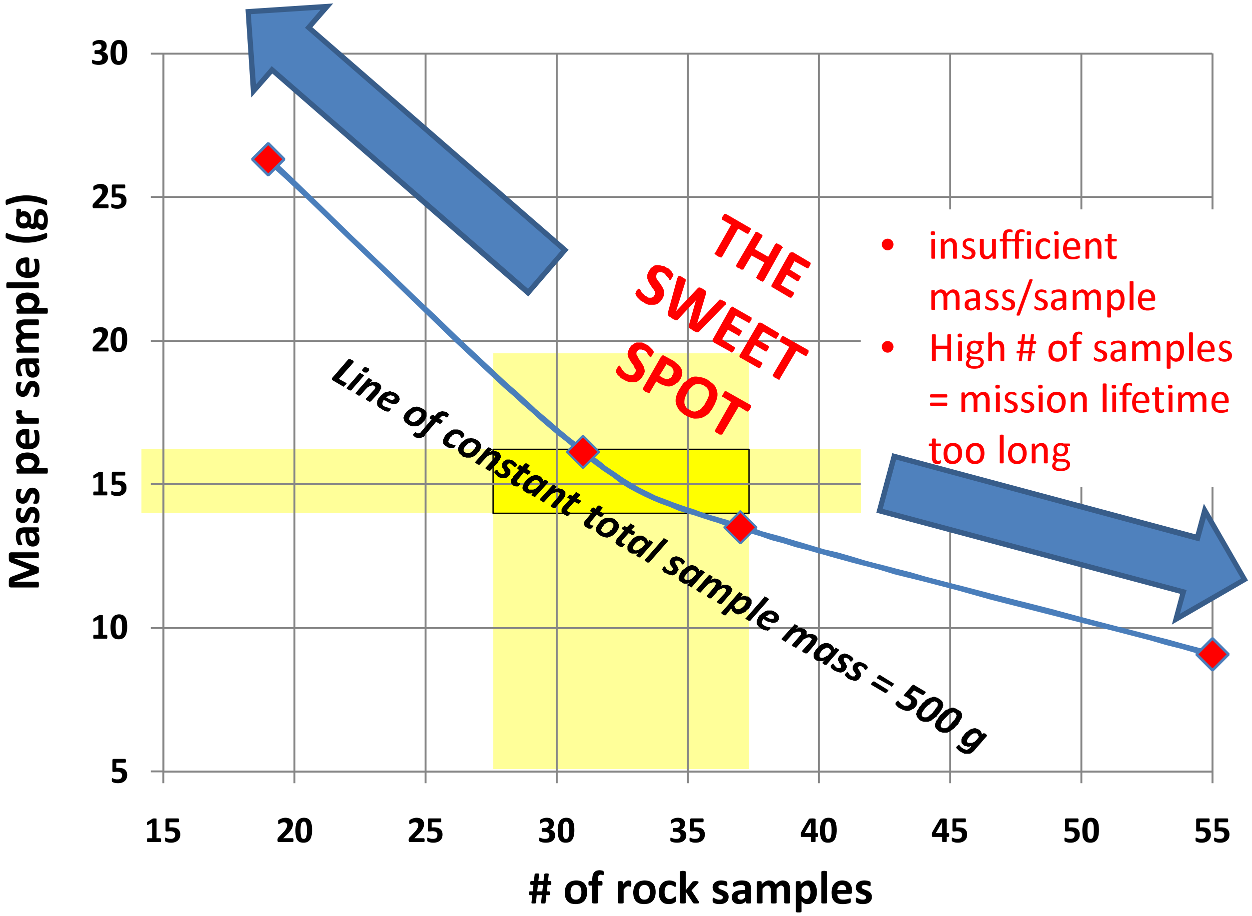


Pre-decisional: for discussion purposes only

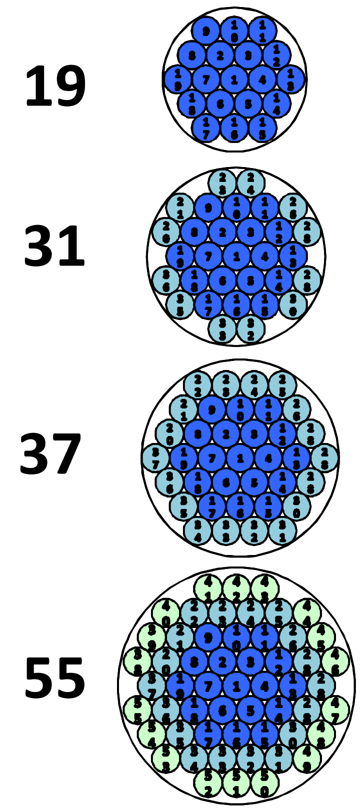


Sizing the sample collection system: Relationship between #samples and mass

- mass/sample higher than needed
- # of samples too small if field site is “target-rich”

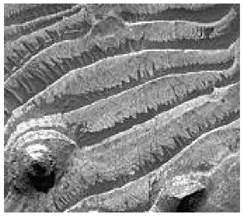


- Diamonds occur where # rock samples would have a very efficient packing geometry. Other geometries are possible



Canister packing

Pre-decisional: for discussion purposes only



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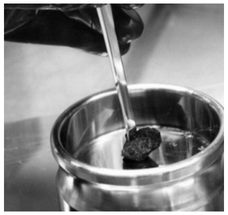
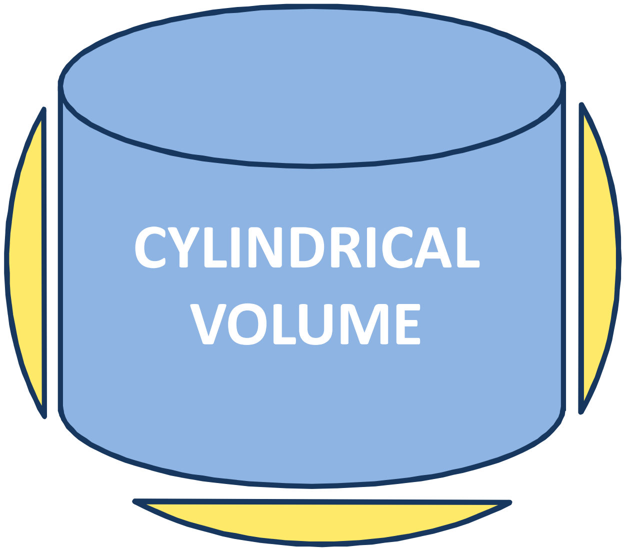
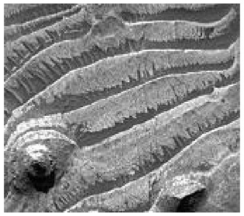


- The rock and regolith samples would be collected into a cylindrical sample canister by the 2018 rover caching system.
- The proposed MSR-L mission would place the cylinder into a spherical container for return to Earth
- The gas sample could be collected into the volume around the cylinder inside the sphere, as shown:

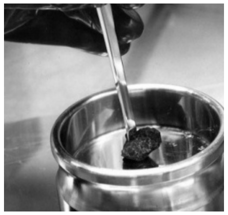


Rock and regolith samples are packed in the cylindrical volume

Gas sample is in the non-cylindrical volume



Sample Collection Mass Inventory



Assumptions: a cylindrical canister with 31 slots

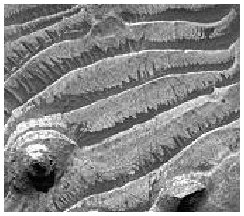
- Some of the 31 sample slots need to be used for blanks and standards
- All slots in cylindrical volume would be identical size
- Relative number of sedimentary, igneous, and granular samples to be decided by future science team.

	# samples	# samples	Mean mass/ sample	Total Sample Mass
Aqueous sedimentary / aqueous altered rocks	31	28	~16g	460g
Unaltered Igneous				
Granular Materials				
Blanks and standards		*Must be planned for*		
Atmospheric Gas	2	2	0.0001	0.0002g
TOTAL				**~500g**

UPDATE TO TABLE 5 OF ND-SAG REPORT (2008)

<u>DRAFT FINDING #26</u>. The collection should be sized to a total sample mass of about 500 g.

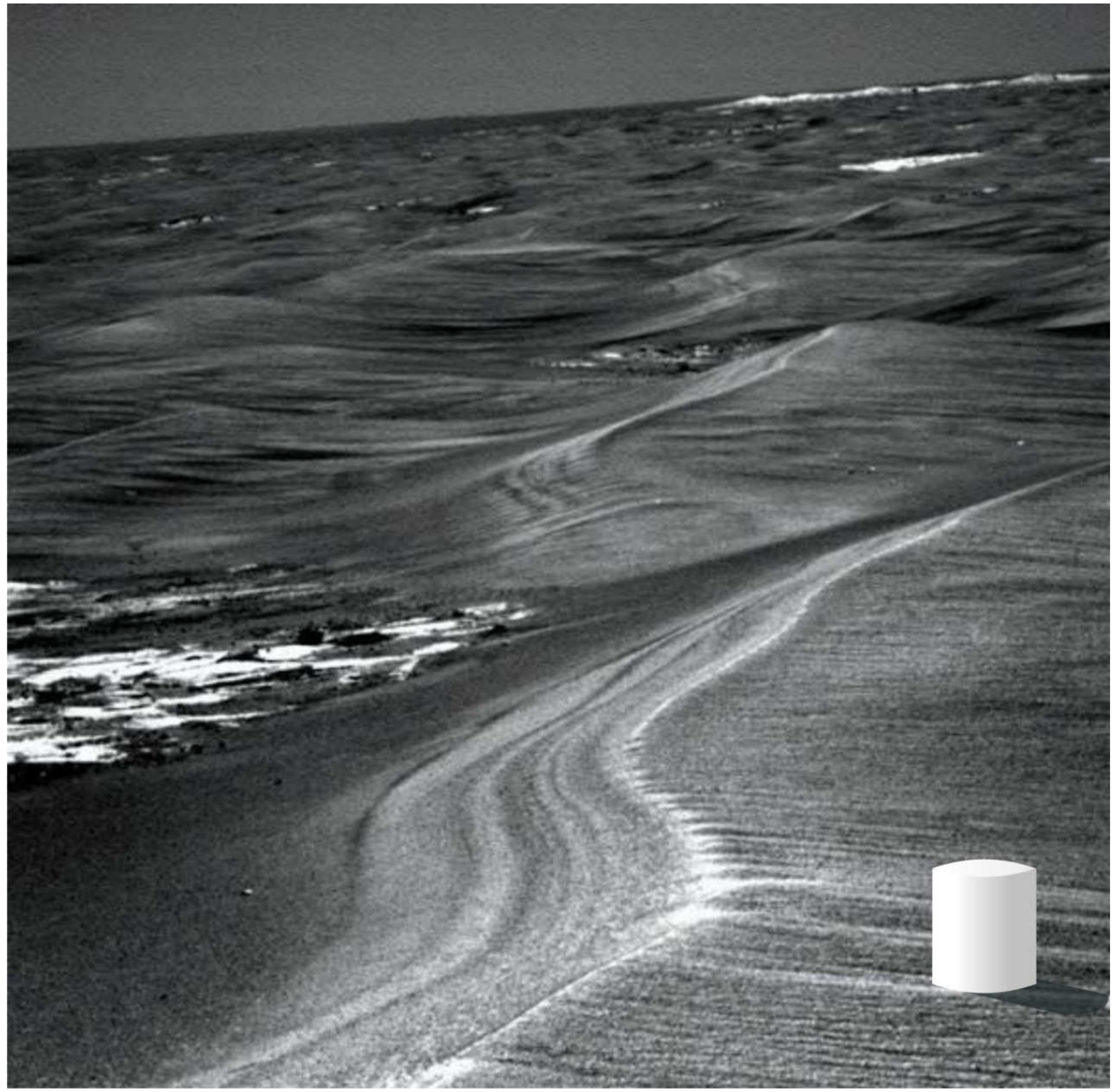
Pre-decisional: for discussion purposes only



Sample Preservation: Sealing

<u>DRAF T FINDING 27</u>: To ensure the science objectives could be met, the samples must maintain their scientific integrity while cached on the martian surface (potentially for several years) and while being transferred from Mars to Earth. Adequate sealing of the **<u>sample tubes</u>** and the **<u>sample canister</u>** are a key part of achieving this.

<u>DRAFT FINDING #28</u>. The volatile species for which limiting mass transfer (in/out of the sample tubes) would be most valuable is water.



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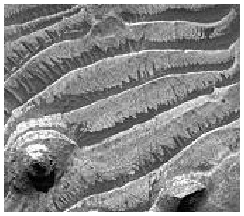


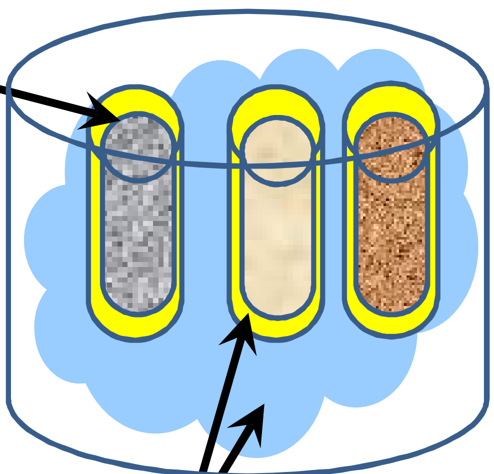
Sample tube seals

DRAFT FINDING #29a. Sample tubes should be sealed as they are acquired. The seals should restrict the loss of particles and volatiles from the samples.

DRAFT FINDING #29b. Prior to leaving the martian surface, it would be extremely desirable to seal the canister sufficiently to avoid a significant pressure differential across the sample tube seals during transit. This would mean that mass transfer in/out of the sample tubes would be by diffusion only, which is a relatively slow process.

PHASE I. ON MARS

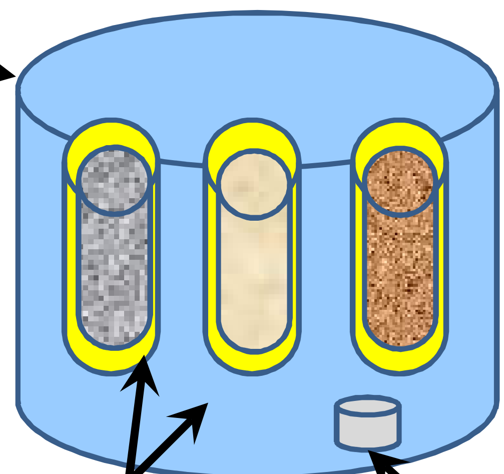
Sample tube seal



Mars atmosphere

PHASE II. IN TRANSIT

Canister seal

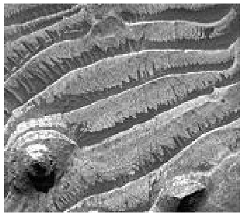


P = 1 Mars atm. *if canister sealed before MAV launch*

Possible water getter?

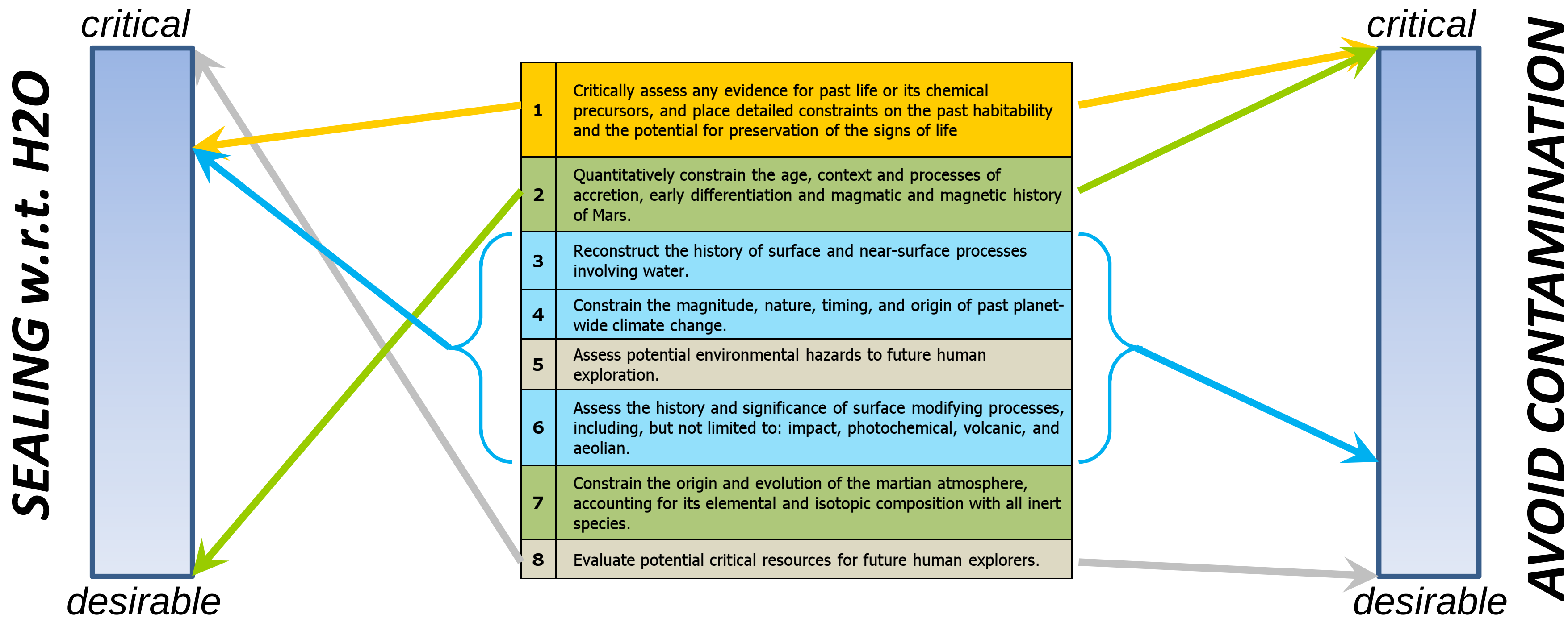
SAMPLES REMAIN IN MARS ATMOSPHERE

Pre-decisional: for discussion purposes only



Science Priorities Regarding Encapsulation

A number of sample tube sealing options are possible. However, there is a trade-off between degree of sealing and introduction of contaminants. The relative importance of sealing vs. contamination depends on the science objective.



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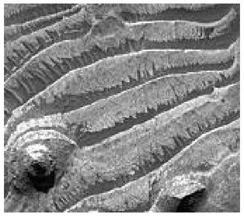
5	Assess potential environmental hazards to future human exploration.
6	Assess the history and significance of surface modifying processes, including, but not limited to: impact, photochemical, volcanic, and aeolian.
7	Constrain the origin and evolution of the martian atmosphere, accounting for its elemental and isotopic composition with all inert species.
8	Evaluate potential critical resources for future human explorers.

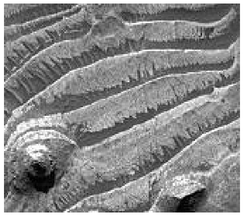


Sample Tube Sealing

Discussion

- Teflon is a good choice for seal material: because of its high chemical inertness and thermal stability, the chance of chemical interaction / degradation / contamination is very low. Moreover, the potential (although unlikely) contaminants induced by Teflon, will be fluorinated organics, easy to discriminate from Martian organics.
- Teflon is one of the very few materials routinely used in the curation of extraterrestrial samples.
- Metals, especially copper which may be easily oxidized, and - more important - may play catalytic role once in contact with the martian samples, could induce chemical changes in the samples.
- Indium is undesirable because of interference with trace element geochemical studies.

DRAFT FINDING #34. Materials used in the sealing process need to be compatible with the planned measurement objectives. Seals made of Teflon are an example of such a material.



E2E: Summary of Really **BIG MESSAGES**

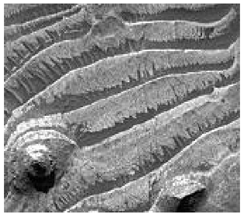
1. MSR should address 8 major, community-developed science objectives. The most important objective by far relates to determining whether evidence of past life or prebiotic chemistry exists in the examined materials.

2. To answer the complex questions associated with the highest priority objectives (1-4) would require sample suites that are carefully selected through a process of comprehensive *in situ* science that also provides critical context for sample analyses back on Earth.

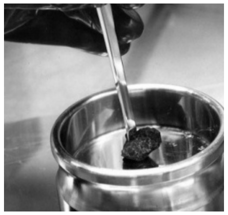
3. The total number of samples that would be needed to address the objectives is 30-40. The approximate mass per rock sample needed for analyses on Earth would be 14-16 g.

4. There are multiple potential landing sites on Mars where it appears possible to meet the proposed MSR science objectives. To access these sites and sample the desired rocks, the proposed mission may need to be able to tolerate some hazards in the landing ellipse (OR have an ellipse small enough to avoid the hazards) AND be able to traverse beyond the ellipse.

5. In order to achieve the *in situ* science and assemble the necessary sample suites, the 2018 rover should have the field exploration capabilities defined by the E2E-iSAG



Recommendations for Future Work
(1 of 2)



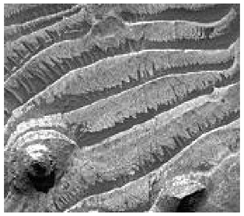
Potential MEPAG-related Tasks

1. Considering the prioritized MSR objectives, determine the sample contamination issues that would affect the scientific measurements to be made on Earth (parts of this should be worked jointly with PP, CAPTEM, NAI, other).
    - *a. Determine contamination control standards for the sample contact chain, including both the part in the flight system and the part in MRSH.*
    - *b. Determine positive and negative control standards, and where they need to be introduced into the sample chain, in order to defend the discoveries we are seeking to make.*
2. Evaluate and develop life detection investigation & measurement strategies to be carried out on the returned samples (worked jointly with PP).

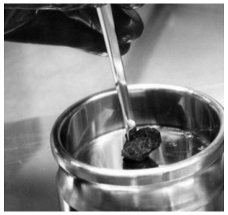
Program-level issues (NASA and ESA)

3. As aggressively as possible, conduct a landing site qualification and prioritization process. This is crucially important while MRO is still in service!

4. Determine the approximate depth of regolith sampling required to plan for an eventual human mission to the martian surface.



Recommendations for Future Work
(2 of 2)



Research & Development

R&A Program Work (NASA and ESA)

5. General research on reduction of sample mass including:
   - *a. Increased instrument sensitivity*
   - *b. More efficient sample preparation, specifically including polished section manufacture*
   - *c. Use of same material in sequential analyses*
6. Compare ancient hydrothermal/Low-T fluid alteration environments vs. ancient sedimentary environments for prospects of finding signs of ancient life
7. Determine thermal limits for the sample cache and evaluate Mars surface scenarios.

Engineering Development (NASA and ESA)

8. Develop improvements in hazard avoidance capabilities & improved landing accuracy.
9. Enhance rover operations efficiency (e.g. increased autonomy), to optimize productivity within a constrained lifetime.
10. Develop and test drilling capabilities using a library of relevant sample analogues, to ensure adequate drill bit lifetime and sample quality.
11. Optimize end-to-end sample handling to ensure mechanical core integrity until analysis
12. Research, development and testing of sample sealing mechanisms, gaseous transmission rates across seals of different types, and evaluations of seal longevity.