



MEPAG  
E2E-iSAG

# Scientific objectives of the MSR campaign; kinds of samples, sampling priorities, number of samples

Lisbon, Portugal; June 16 2011

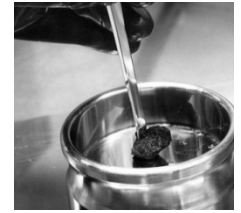
Mark Sephton, on behalf of the E2E-iSAG committee

*Pre-decisional: for discussion purposes only*

Package 2 of 5



THE MSR CAMPAIGN 1



# 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

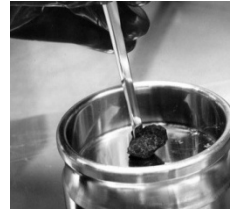
Instruments on sampling rover

EDL & mobility parameters, lifetime, ops scenario

Sample preservation



# MSR Science Objectives – Prioritization



The proposed science objectives were prioritized using the criteria below:

*Top-level Prioritization Criterion:*

✧ **The value of the incremental knowledge to be gained by returned sample analysis**

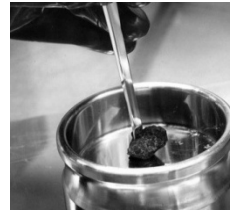
*Ways in which returned sample analysis would add value (sub-criteria):*

- 1. Would address science questions of high intrinsic priority (e.g. as judged by MEPAG, NRC, SSB, NASA & ESA Strategic Plans, etc.)**
- 2. Would address questions for which little meaningful progress can be made without sample return**
  - a) Instrumentation hard/impossible to miniaturize or make robust enough for interplanetary flight
  - b) Scale of investigation not amenable for in situ
  - c) Sample prep impossibly complex
- 3. Answers would have higher definitiveness**
  - a) Better accuracy, precision
  - b) Results confirmed by alternate methods
- 4. Would address questions for which there is an advantage if the analytical approach could be discovery-responsive (analysis pathway not limited by instrument payload).**





# Prioritized Scientific Objectives, MSR



*in Priority Order*

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

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

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# Extant Life objective



It would be mandatory to analyze the returned samples for extant life: (a) in order to meet Planetary Protection requirements and (b) because of the scientific importance of detecting extant life, if any is present.

However the search for extant life would be given low priority when it comes to sample and site selection because:

- There is an extremely low probability of extant life in any surface samples (low water activity, high UV, low temps, etc.)
- More hospitable environments that existed in the past, such as hydrothermal vents or lakes, are not active on Mars today.
- If organisms (resistant, dormant forms) are present near the surface, the criteria are unclear whereby sites and samples most likely to contain such forms could be identified.

In concurrence with MRR-SAG (2009), it is thought that the likelihood of life's existence in the past is much greater than the present on Mars, and that there would be ways to locate high priority targets in ancient terranes.

**DRAFT FINDING #1:** Analysis of the returned samples for extant life would be a high priority science objective, but we don't have a logical way to effectively incorporate this into sample selection on Mars.



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*Critical Science Planning Questions for 2018*

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Measurements needed to interpret & document geology and select samples?

On-Mars strategies?

*Engineering implications*

Sampling hardware

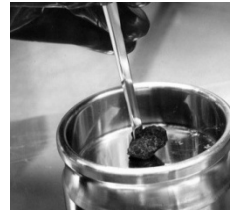
Instruments on sampling rover

EDL & mobility parameters, lifetime, ops scenario

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# Objectives and samples required/desired



## Scientific Objectives in Priority Order

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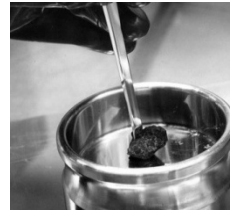
## Sample Types in Priority Order

- 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

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



# Explanation of sample types (Solid materials)



- Subaqueous or hydrothermal sediments
- Hydrothermally altered rocks or Low-T fluid-altered rocks

## DEFINITIONS

- Subaqueous sediments: sediments deposited in a standing body of water at the surface, such as a lake. Also includes playas, tufa style deposits.
- Hydrothermal sediments: sediments deposited at the surface from fluids derived from high temperature activity (e.g., magmatic or impact-driven). Includes sinter, travertine, or deeper water sediments like those at submarine vents.
- Altered rocks – of any category (igneous, sedimentary, metamorphic,) that have been secondarily altered by fluids passing through them

## EXPLANATION OF PRIORITIES

Priority reflects differences in potential for preservation of biological signatures.

## Unaltered igneous rocks

Priority is on **ancient mafic volcanic rock**, preferably rapidly cooled (glassy). Of secondary priority are **xenolithic, ultramafic or felsic** rocks.

## DEFINITIONS

Volcanic: a rock that solidified from a magma after reaching the surface via lava extrusion/effusion or explosive eruption

Mafic: igneous rock with Fe-Mg silicates, and feldspars, feldspathoids, and/or glass

Xenolithic: pertaining to rock fragments that are foreign to the igneous rock in which they occur

Ultramafic: igneous rock dominated by Fe-Mg silicates

Felsic: igneous rock dominated by feldspars, feldspathoids, quartz, and/or glass

*Pre-decisional: for discussion purposes only*

## Regolith

## DEFINITIONS

Regolith: The entire layer of fragmental and loose, incoherent, or unconsolidated rock material of any origin, that mantles more coherent bedrock and includes the following:

***Air fall dust***: fine-grained material that has settled from the atmosphere

***Soil***: any loose, unconsolidated material that can be distinguished from rocks, bedrock, or strongly cohesive sediments but has no singular origin

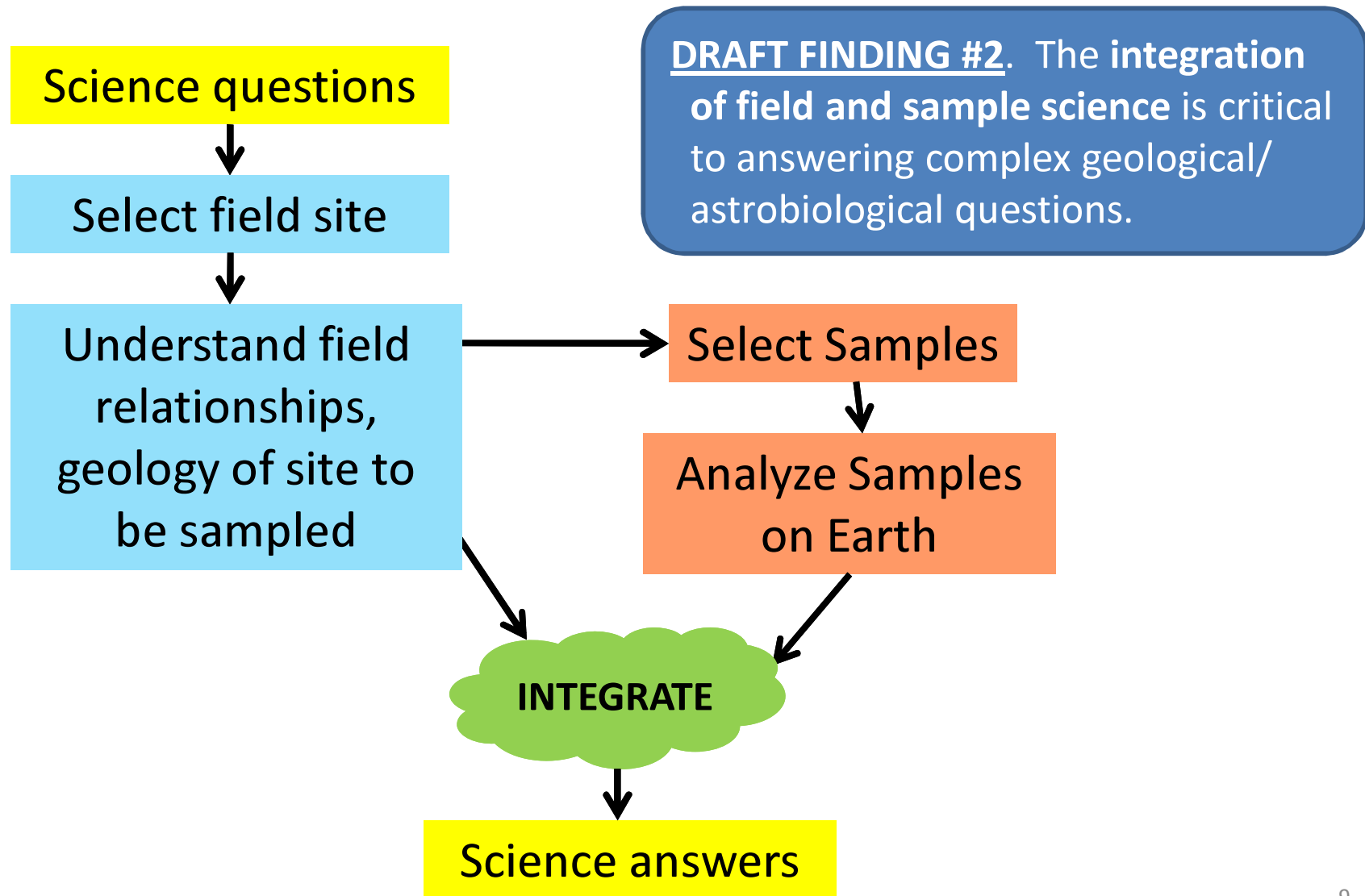
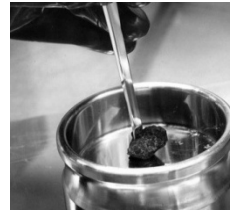
***Aeolian deposits***: any accumulation of windblown sediment that occurs in recognizable bedforms or sand sheets





# Sample Science General Principles:

## 1. Field and sample science





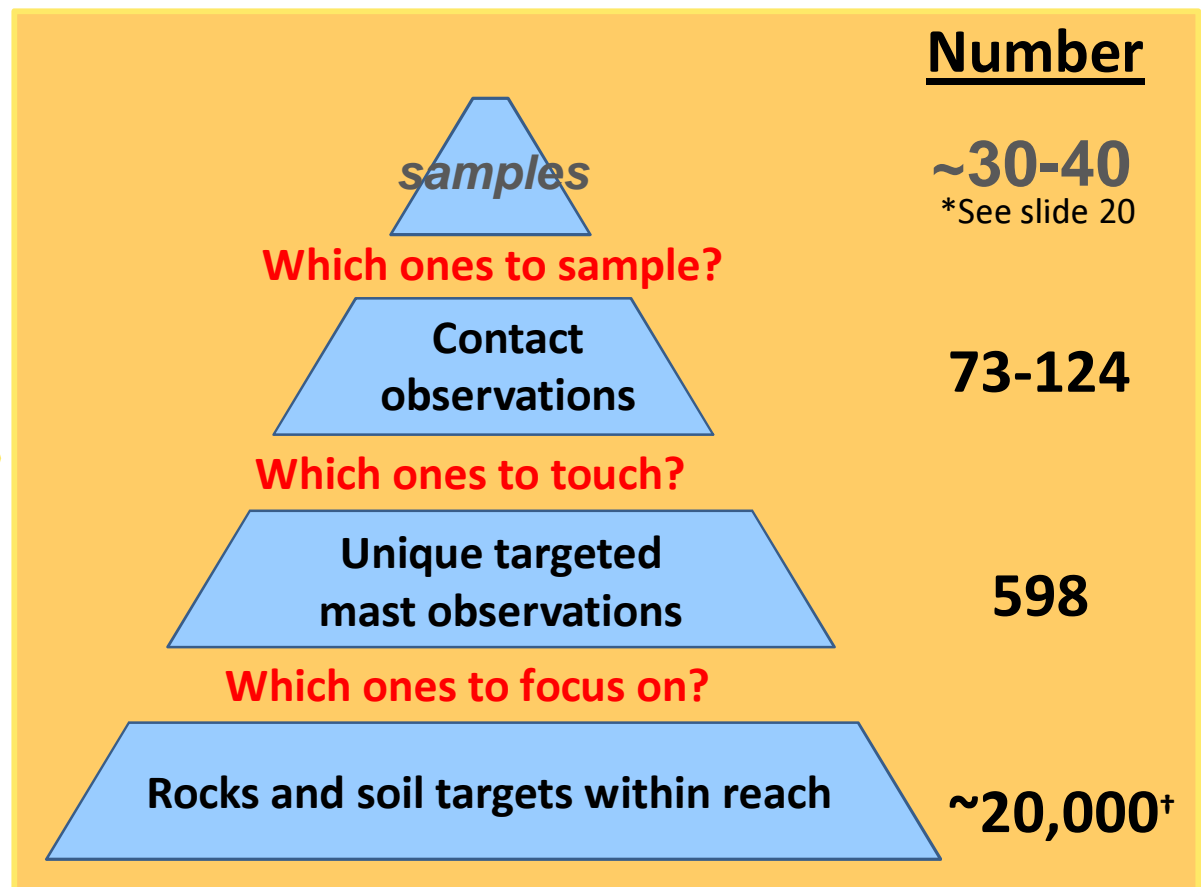
# Sample Science General Principles:

## 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.

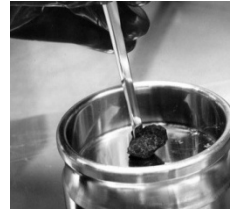


<sup>†</sup>In first martian year, Spirit drove about 4000 m (lander to Haskin Ridge Seminole). Using a conservative visibility band of 15 m on either side of the traverse path (4000m x 30m = 120,000 sq m) times an average rock abundance of 15% comes out to 18,000 rocks



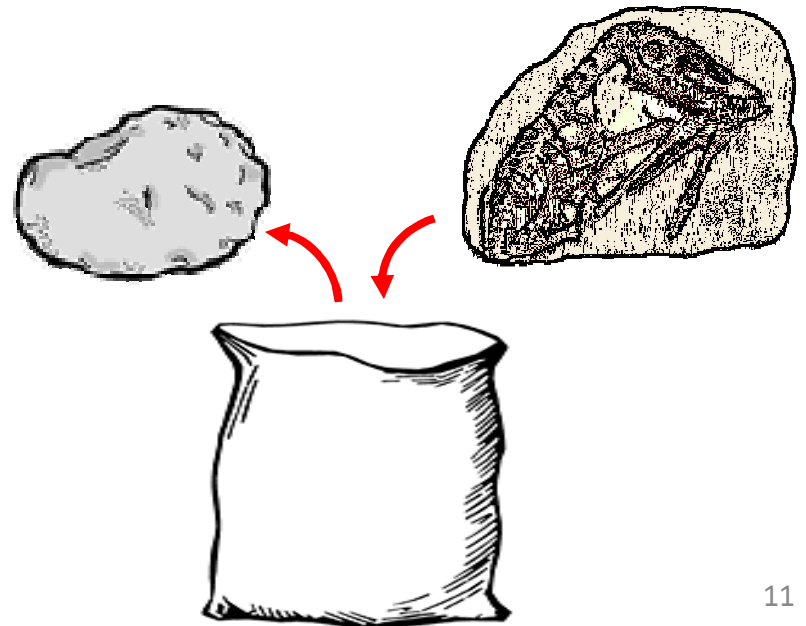
# Sample Science General Principles:

## 3. Collect early, exchange later



- Sampling could be optimized if the geology were fully understood before sample collection commenced, but **when time is constrained they would have to be done concurrently.**
- This entails some risk that the cache might already be full when highly desirable samples are identified later in the mission when the geology is better understood .
- This risk would be reduced if it possible to exchange samples in the cache for new samples as operations proceed.
- E2E estimates that this excess capability should be  $\geq 25\%$  of the number of samples in the returned collection.

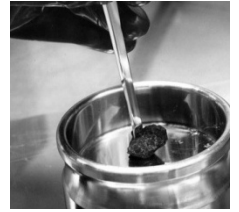
**DRAFT FINDING #4**: The scientific value of the collection could be improved significantly if the sampling rover had the capability and lifetime needed to replace earlier-collected samples in the cache with later-collected samples.





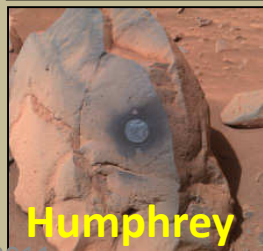
# Sample Science General Principles:

## 4. Sample Suites



1. Rock outcrops/geologic terrane have multiple properties that vary.
2. Not all natural variation is equally important.
3. The variation that matters depends on the question.
4. Complex questions typically require sets of samples having specific differences (**SAMPLE SUITE**).
5. The differences between samples in a suite can be more important than their absolute values.

*EXAMPLE: This suite is defined by variations in bulk chemistry*



**DRAFT FINDING #5.** Sample collections designed around one or more sample suites maximize their potential for answering scientific questions.

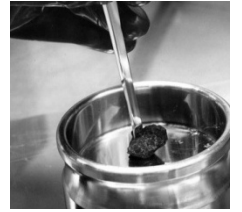
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*Extended from ND-SAG (2008); NRC Decadal Survey (2011)*

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# Sample Suites: Implications of the objectives (1 of 2)



Desired sample types: 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

## Some example sampling priorities

- Rocks that have high potential to preserve organic molecules, including biological remains;
- Rocks that enable interpretation of paleoenvironmental conditions;
- Rocks from different stratigraphic positions that span potential changes in past climate
- Rocks that exhibit mineralogical or textural characteristics that may be microbially influenced
- Rocks whose composition are likely to provide constraints on the composition of ancient surface or subsurface waters

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

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*Extends key findings of NRC Decadal Survey (2011)*

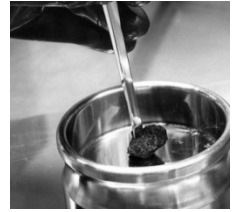
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*Pre-decisional: for discussion purposes only*





# Sample Suites: Implications of the objectives (2 of 2)



Desired sample type: 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

## Some example sampling priorities

- Rocks of probable Noachian age having known stratigraphic context
- Rocks that best preserve primary igneous character: least affected by alteration, weathering, or impact shock metamorphism
- Rocks that span potential variations in bulk composition
- Rocks that contain xenolithic clasts
- Rocks that exhibit mineralogical or textural characteristics that suggest rapid cooling from a melt (e.g., quenched flow margin)

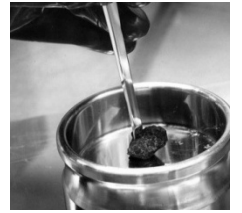
**NEED TO BE ABLE TO RECOGNIZE, MEASURE/DOCUMENT AND SAMPLE THESE**

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# Number of Samples— Insight from the Gusev Experience



- Spirit operated >6 yrs in target-rich environment - >75 rocks studied *in situ*
- however, several ‘campaigns’, each lasting on the order of weeks to months, would provide insight into MSR sample requirements - **suggests ~30-40 samples**

## A Hydrothermal System

- In Eastern Valley, exposures of opaline silica-bearing rocks and soils
- e.g., Fuzzy Smith; Kenosha Comets
- Hydrothermal system
- $n \approx 10$  (4 Si-rich rocks; 4 Si-rich soils;  $\approx 2$  unaltered rocks)

## An Alkaline Igneous Province

- Gusev Plains - Columbia Hills magmatic rocks - e.g., Adirondack, Wishstone, Backstay, Irvine classes
- Long-lived alkaline igneous province – similar mantle sources
- $n = 7$

## Home Plate Campaign

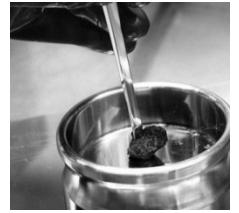
- 2 meter section of altered pyroclastics reworked by eolian processes at top
- e.g., Barnhill, Posey, Chanute, Pesapallo
- $n = 7$

## Variability & Targets of Opportunity

- During Husband Hill ascent numerous distinctive rock classes encountered
- e.g., Clovis, Peace, Watchtower classes
- $n \approx 8-10$  ( $>15$  on Husband Hill)



# Number of Rock Samples



- The number of samples needed to characterize a given field site is dependent on the geology of the site, and the range of materials available to sample.
- Since the actual site will not be known for many years, it is important to set sampling capacity to allow flexibility down the track (choosing landing sites and assembling sample cache).

- ND-SAG (2008; Table 5) previous recommendation:
- Gusev case history: Est. 30-40 rock samples

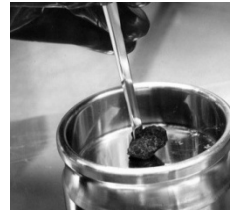


From ND-SAG (2008)		
	Minimum # of samples	Preferred # of samples
Rocks	28	47
Granular Materials	5	6
Atmospheric Gas	1	1

**DRAFT FINDING #6.** For the kinds of landing sites of interest to the proposed MSR campaign, the number of high-priority rock samples is estimated to be ~30-40. This reaffirms a key finding of ND-SAG.



## The scientific value of a subsurface sample (e.g. 2m depth) in the returned collection



- The capability to return one or more rock samples from ~2m depth would be extremely valuable.
  - Subsurface rock encountered by a drill will have been protected by overlying regolith for at least some of its history. Organic matter therefore has a greater chance of being preserved in these deeper materials.
  - He, Ne, Ar isotopes in a subsurface rock (e.g. in fluid inclusions) will have been protected from cosmogenic contributions and are valuable for studying Mars degassing history .
- Subsurface exploration with a drill expands the potential to understand the geology of the site and its astrobiology potential.
- However, the E2E team concludes that the proposed MSR campaign is scientifically viable even without the return of deep samples, although there would be a risk of missing out on significant scientific value.



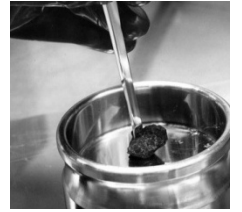
*Give your best apple  
to your friend to take  
to town  
(from 2R-iSAG)*

*Without this capability,  
there would be a risk  
that we cannot bring  
back our best sample!*

**DRAFT FINDING #7.** While the MSR Campaign can be justified using near-surface samples alone, the capability to return subsurface samples from a depth of up to 2 m would be scientifically valuable because of the possibility of enhanced preservation of organics.



# Regolith: Why returning at least one regolith sample is critical



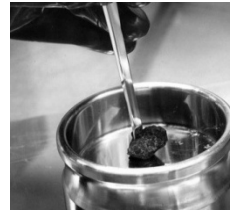
1. Possible Biohazard. For a *human* mission to the martian surface, it is considered impossible to break the chain of contact with Mars—this means that uncontained martian material would be transported to Earth via the astronauts and their equipment. Planning for such a mission is therefore critically dependent on prior information about potential biohazards in the soil/dust. (See MSR Objective #5)
2. Future Resources. The single thing that has the greatest potential to change the planning basis of a future human mission to Mars for the better is the definition of recoverable hydrogen resources. Resources contained within the shallow regolith would be of greatest interest, because they would be most compatible with extraterrestrial mining and processing technology. (See MSR Objective #8)
3. Surface Processes. The regolith represents the integration of a number of processes associated with the decomposition of rocks, and the redistribution of their products. Correctly interpreting these processes will require multiple analytic methods, and grain-by-grain investigation. (See MSR Objectives #3, #6)
4. Exotic Fragments. The regolith may contain exotic lithic fragments, which can be important in understanding the petrologic diversity of Mars.

**DRAFT FINDING #8.** The return of at least one regolith sample is required to support future human missions and to address critical questions in martian geology.





# Regolith: Objectives and Priorities



## ***PRIORITY ORDER***

### **Goal IV sub-objectives (MEPAG Goals Document, 2010)**

1. Determine if **extant life** is widely present in the martian near-surface regolith, and if the air-borne dust is a mechanism for its transport.
2. Assess the potential of regolith to be a **resource for hydrogen**.
3. Determine the possible **toxic effects of martian dust** on humans
  - a) Assay for **chemicals** with known toxic effect on humans (e.g., Cr<sup>6+</sup>).
  - b) Characterize **soluble ion distributions and reactions**
  - c) Analyze the **shapes of martian dust grains** to assess their possible impact on human soft tissue (especially eyes and lungs).
4. Characterize the particulates that could be **transported to hardware** through the air that could affect engineering performance (esp. seals, electrical properties, corrosion, bearings, and lifetime).

## ***OTHER***

### **Goal III sub-objectives (MEPAG Goals Document, 2010)**

- Characterize the spectral properties of the regolith, since it is a filter through which we view most of the Martian surface by remote sensing.
- Interpret the history of surface conditions and processes.



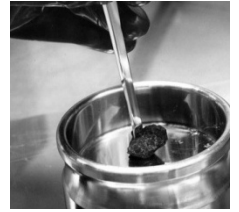
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Source: ***MEPAG Goals Document***

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# Regolith Sampling Implications



## To support human precursor objectives

At one location: Sampling of regolith from the surface down to the depth that might be affected by human surface operations (perhaps 0.25-0.5 m, though this has not been analyzed in detail)

- presence or absence of biological activity is most important

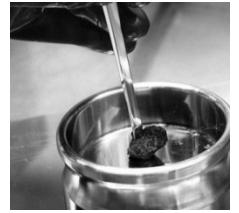
## To support geological objectives

In addition to depth sampling at one location (above), lateral sampling of surface regolith that shows different spectral, compositional, or other geologic properties.

Sample Collection Considerations	
Biologically clean	<b>REQUIRED</b>
Mobile platform	<b>HIGHLY DESIRED</b>
No hydrazine	<b>HIGHLY DESIRED</b>
Sample from depth (0.25-.5 m?)	<b>REQUIRED</b>



# Regolith: Type and number of samples of interest



**OF PRIMARY RELEVANCE TO:  
OBJECTIVE #6 OBJECTIVE #5**

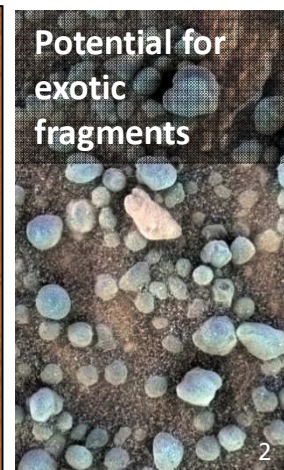
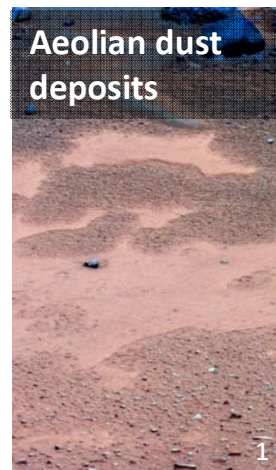
'generic' soil sample that contains a significant fraction of air-fall dust

1-3 additional mobility-enabled samples of opportunity



Minimum of two samples:

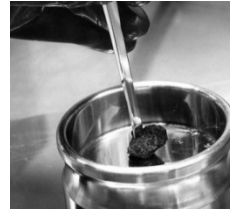
1. From surface
2. From max. depth of disturbance by human mission



Images are from: <sup>1</sup>Spirit's exploration of Gusev Crater, <sup>2</sup>Opportunity's exploration of Meridiani Planum



## Findings related to Regolith

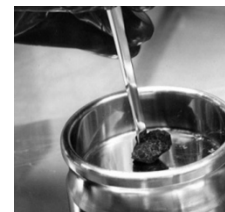


**DRAFT FINDING #9.** For several reasons, multiple regolith samples collected from the proposed 2018 mobile platform would be significantly more valuable than 1 or more regolith samples collected from the proposed immobile MSR-Lander (MSR-L).

**DRAFT FINDING #10.** No measurement capability in addition to that required to select and document the rock samples is needed for regolith samples.



## Gas Sample



**A GAS SAMPLE WOULD BE  
REQUIRED BUT IS NOT  
DISCUSSED HERE**



# Transition to John



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