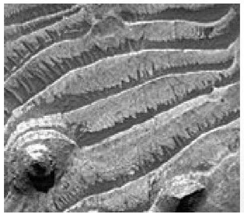
MEPAG
E2E-iSAG

Mars Sample Return (MSR) E2E-iSAG: Introduction and Initial Input

Scott McLennan and Mark Sephton, co-chairs

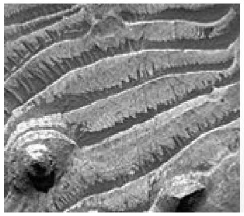
Sep 30, 2010

Pre-decisional: for discussion purposes only



Context

- NASA and ESA considering dual rover mission for 2018.
- In response to past recommendations and findings, it would be strategically important to include sample caching — this could be extremely valuable to a potential future effort to return samples.
  - Once cached properly, samples would be stable indefinitely
- NRC's Decadal Survey expected to release its recommendations about March 1, 2011; expected to comment on 2018 and MSR.
- Although DS report, and NASA's reaction to it, are pending, relationship of 2018 to returned sample science still needs to be thought through:
  - Key assets for 2018 landing site selection aging; time is of the essence
  - If we decide to proceed on 2018, timeline before requirements definition (e.g., SDT) is short



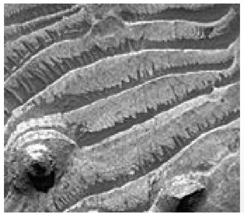
Introduction

Scientific objectives of the Mars Sample Return (MSR) Campaign can be thought of in two categories:

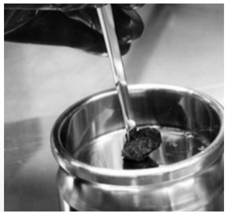
1. **Science that would be derived from the overall campaign, culminating in the study of the returned samples, and**

Focus of this study

2. Science that would be accomplished by each mission at Mars, in support of the campaign goals, by means of instruments that might be present on the individual flight elements.



The MSR End-to-End study (E2E)



1. Propose reference campaign-level MSR science objectives and priorities

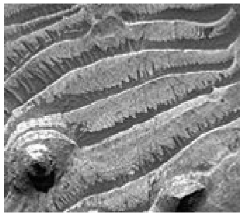
2. Understand derived implications of these objectives and priorities:

   a) Kinds of samples required/desired

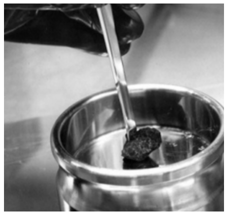
   b) Requirements for sample acquisition and handling

   c) Draft site selection criteria, and apply them to Mars to create some reference landing sites

   d) Capabilities required for adequate *in situ* characterization needed to support sample selection



The Team



Co-Chair	Mark Sephton	Imperial College, London, UK	Organics, ExoMars
	Scott McLennan	SUNY Stony Brook, NY	Sedimentology, geochemistry Co-I MER
Science Members	Carl Allen	JSC, Houston, TX	Petrology, sample curation, Mars surface
	Abby Allwood	JPL, Pasadena, CA	Field Astrobio., early life, liason MAX-C
	Roberto Barbieri	Univ. Bologna, IT	Astrobiology, paleontology, evaporites
	Penny Boston	NM Inst. Mining & Tech, NM	Cave geology/biology, member PSS
	Mike Carr	USGS (ret.), CA	Mars geology, water on Mars
	Monica Grady	Open Univ. UK	Mars meteorites, isotop., sample curation
	John Grant	Smithsonian, DC	Geophys., landing sites, MER, MRO
	Chris Herd	Univ. Alberta, CAN	Petrology, sample curation
	Beda Hofmann	Nat. Hist. Museum, Bern, CH	Geomicrobiology, ExoMars (Deputy CLUPI)
	Penny King	Univ. New Mexico	Petrology, geochemistry, MSL
	Nicolas Mangold	Univ. Nantes, FR	Geology, spetroscopy MEX, MSL
	Gian Gabriele Ori	IRSPS, Pescara, IT	Mars geology, sedimentology, MEX, MRO
	Angelo Pio Rossi	Jacobs Univ. Bremen, DH	Planetary geology, HRSC, SHARAD
	Jouko Raitala	Univ. Oulu, FI	Mars surface, tectonics, HRSC
	François Raulin	Univ. Paris 12, FR	Astrobio., extraterrestrial material, Deputy MOMA
	Steve Ruff	Arizona State Univ.	MER operations, spectral geology, MGS, MER
	Barb Sherwood-L.	Univ. Toronto, CAN	Astrobology, stable isotopes
	Steve Symes	Univ. Tennessee	REE, geocronology, member CAPTEM
	Mark Thiemens	UC San Diego	Gas geochemistry
Eng. Rep.	Peter Falkner	ESA	Advanced mission planning, MSR
	Mike Wilson	JPL	Advanced mission planning, MSR
Ex-officio	Dave Beaty	Mars Program Off., JPL	Liason to MEPAG, cat herder

Background:

MEPAG’s recent planning on MSR science

MEPAG’s Recent Thinking re: MSR

Scientific Objectives for MSR

11 candidate objectives identified.

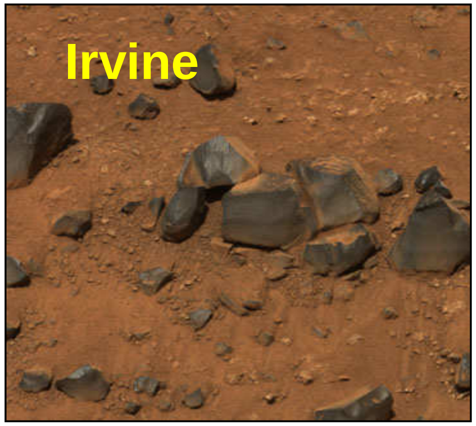
KEY OBSERVATION:

- ***No single site on Mars would support <u>all objectives</u>***
- ***<u>Every site</u> on Mars would support some***
- ***Dependency between objectives and landing site***

Ref.	Goal	Draft Objective	Nickname	Relative Priority
1	I	Characterize the reservoirs of carbon, nitrogen, sulfur, and other elements with which they have interacted, in chemical, mineralogical, isotopic and spatial detail down to the submicron level, in order to document any processes that can sustain habitable environments, both today and in the past.	Habita-bility	H
2	I	Assess the evidence for pre-biotic processes and/or life at one location by characterizing any signatures of these phenomena in the form of organic molecular structures, biominerals, isotopic compositions, morphology, and their geologic contexts.	Pre-biotic, life	H
3	III	Interpret the conditions of water/rock interactions through the study of their mineral products.	water/ rock	H
4	III	Constrain the absolute ages of martian geologic processes, including sedimentation, diagenesis, volcanism/plutonism, regolith formation, hydrothermal alteration, weathering, and cratering	Geochrono logy	H
5	III	Understand paleoclimates, paleoenvironments, and fluid histories by characterizing the clastic and chemical components, depositional processes, and post-depositional histories of sedimentary sequences.	Sedimenta ry record	H
6	III	Constrain the mechanisms and determine the characteristics of early planetary differentiation and the subsequent evolution of the core, mantle, and crust	Planetary evolution	M
7	III	Understand how the regolith is formed and modified and how it differs from place to place.	Regolith	M
8	IV	Substantiate and quantify the risks to future human explorers through characterization of biohazards, material toxicity, and dust/granular materials, as well as demonstrate the potential utilization of in-situ resources to aid in establishing a human presence.	Risks to human explorers	M
9	I	For the present-day Martian surface and accessible shallow subsurface environments, determine the state of oxidation as a function of depth, permeability, and other factors in order to interpret photochemical processes in the atmosphere, the rates and pathways of chemical weathering, and the potential to preserve chemical signatures of extant life and pre-biotic chemistry.	Oxidation	M
10	II	Utilize precise isotopic measurements of martian volatiles in both atmosphere and solids to interpret the atmosphere's starting composition, the rates and processes of atmospheric loss and atmospheric gain from interior degassing and/or late-stage accretion, and atmospheric exchange with surface condensed species.	Gas Chemistry	M
11	II	Determine the relationship between climate-modulated polar deposits, their age, geochemistry, conditions of formation and evolution through detailed examination of the composition of water, CO_2, and dust constituents, isotopic ratios, and detailed stratigraphy of the upper layers of the surface.	Polar	M

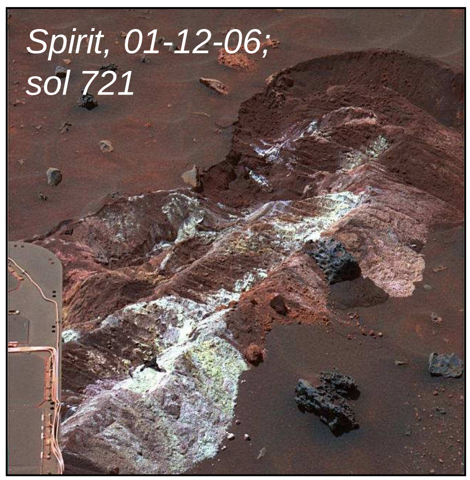
MSR: What Kinds of Samples?

ROCKS



By far most important, given the proposed objectives. Multiple diverse samples essential.

REGOLITH/ DUST



At least one relatively large sample, preferably also additional smaller samples.

ATMOSPHERIC GAS

One good sample.

The Concept of Sample Suites

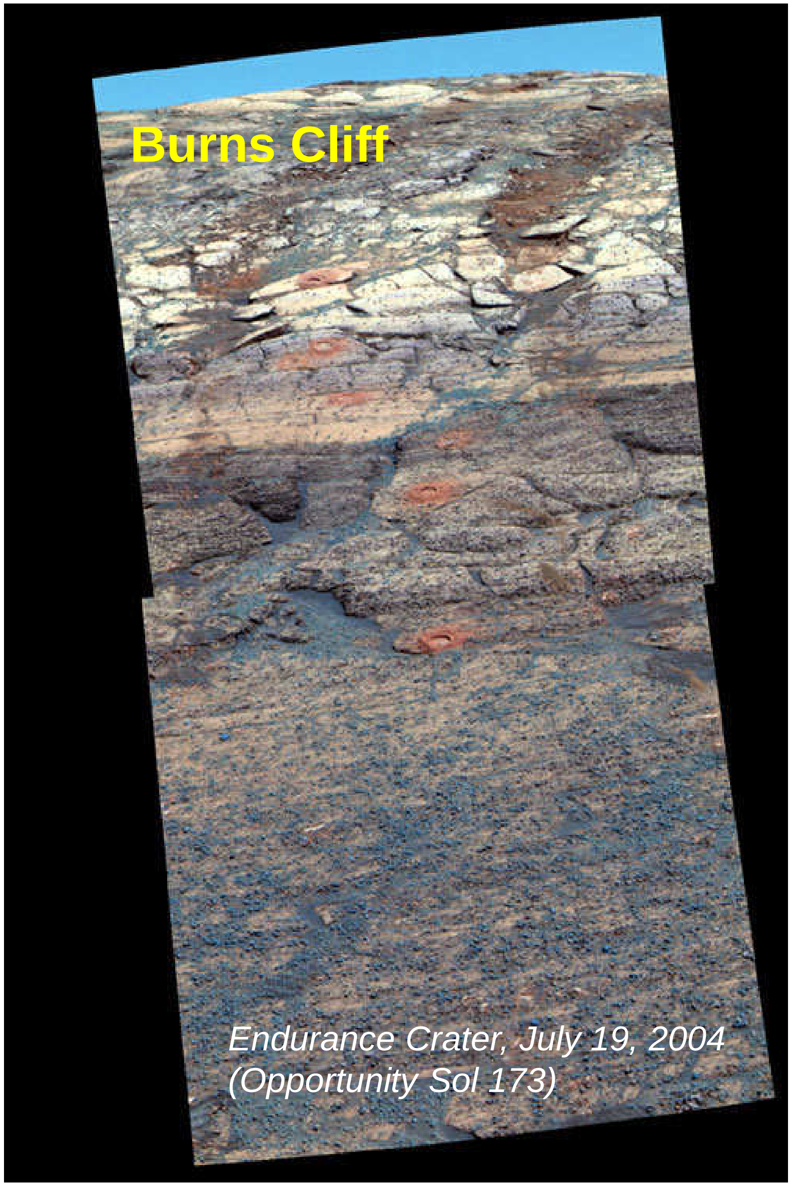
<u>ND-SAG FINDING.</u> MSR would have its greatest value if the samples were organized into suites of samples that represent the diversity of the products of various planetary processes.

- Similarities and differences between samples in a suite can be as important as the absolute characterization of a single sample
- The minimum number for a suite of samples is thought to be 5-8 samples.

- *Examples: Sampling several rock layers in a stratigraphic sequence, sampling along a hydrothermal alteration gradient, sampling both "ordinary" regolith and local variations (e.g., salts?) in an area.*

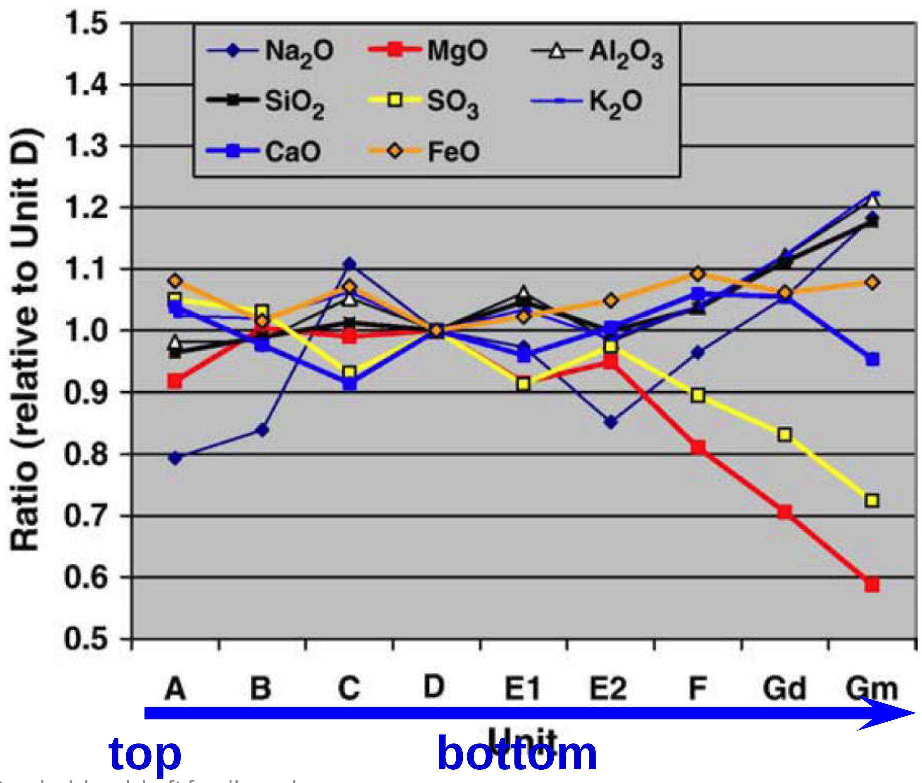
<u>ND-SAG FINDING.</u> The collection of suites of rocks requires mobility, the capability to assess the range of variation, and the ability to select samples that span the variation.

Rock Sample Suites: Sedimentary



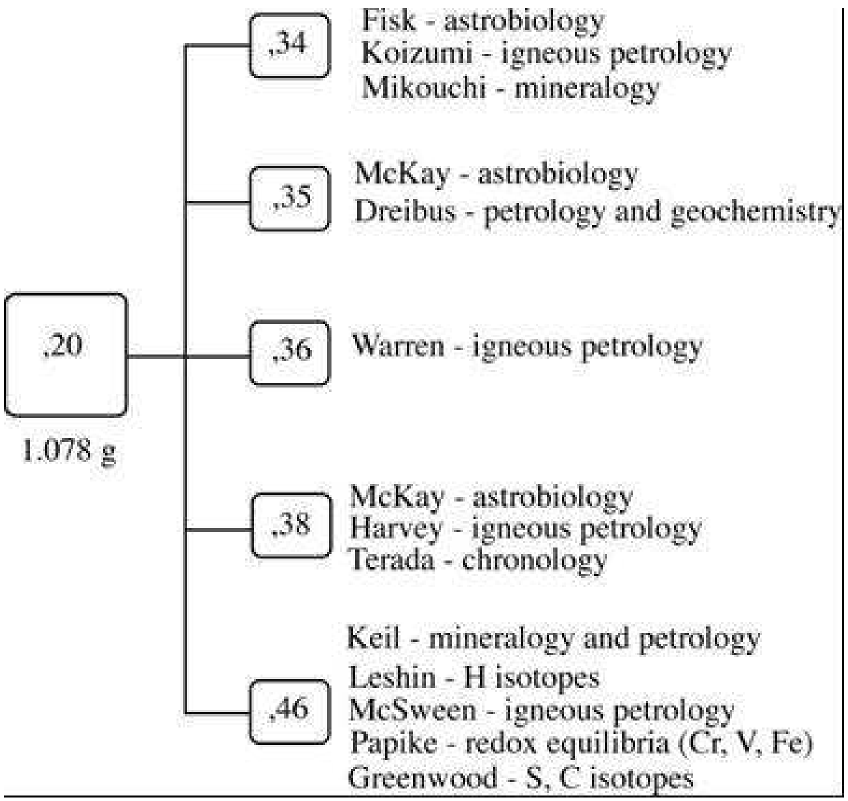
Stratigraphic geochemical variation interpreted as diagenetic redistribution of salts and is central to the water question.

Could not be recognized with 1-2 samples.



Clark et al., 2005 (EPSL)

Sample Size: Rock Samples



Example: meteorite
QUE-94201 (mass = 12.02 g)

Image courtesy Kevin Righter

Subdivided into over 60 individual samples of some kind or another.

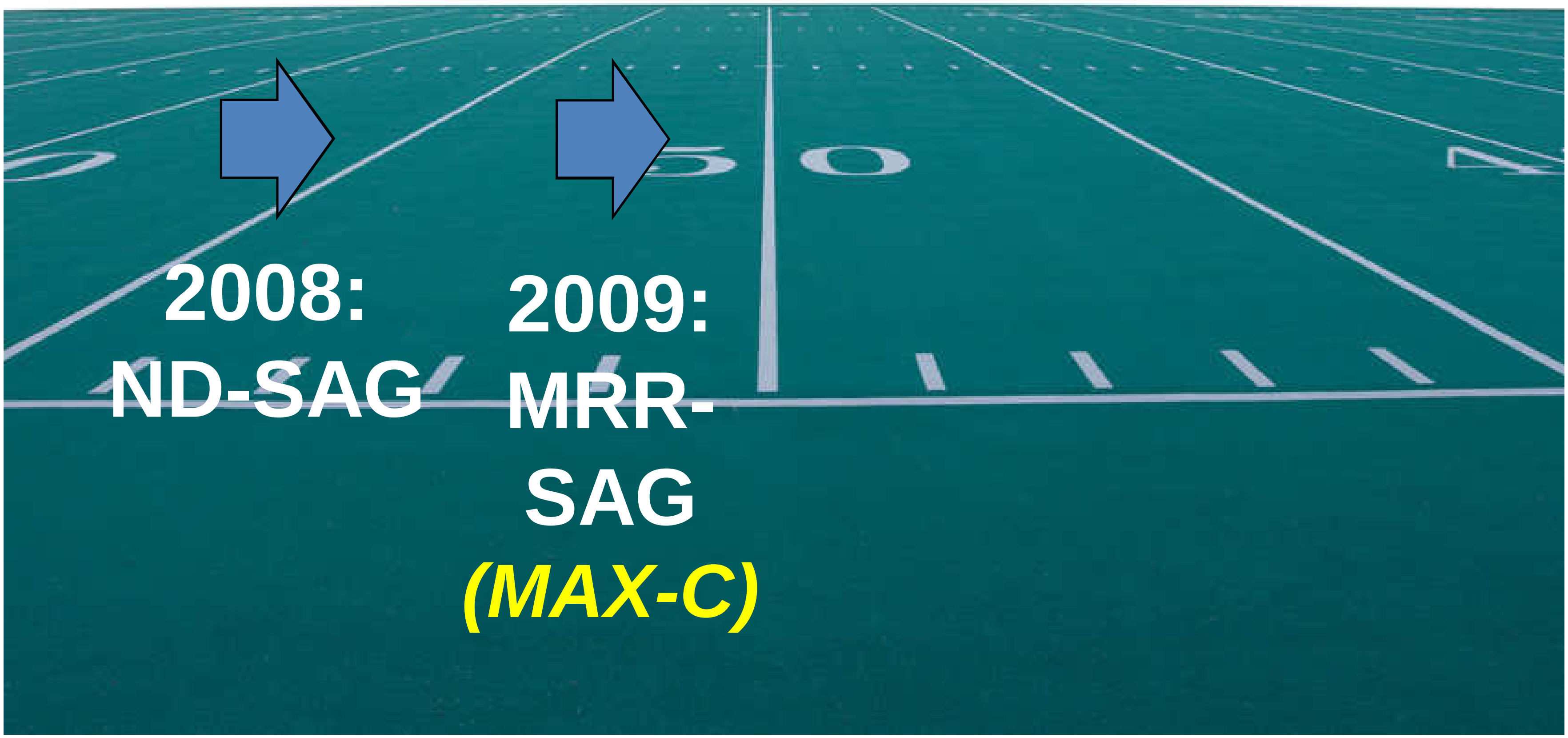
EXAMPLE: 1 gram chip made 5 thin sections used by by 14 investigators.

Sample Packaging & Labeling

1. **Airtight encapsulation for samples with hydrated minerals and/or volatile organics (~2/3 of total)**
2. **Regolith/dust samples must not commingle**
3. **Samples must be uniquely identifiable for field relationships**

Impact test, June 8, 2000 (max. dynamic load ~ 3400 g, avg. ~2290 g). 10 samples of basalt and chalk in separate sample cache tubes with tight-fitting Teflon caps. Many of the teflon caps came off as a result of the impact

MEPAG's Recent Thinking re: MSR



Findings Related to Potential Sample Return

MEASUREMENTS NEEDED FOR SAMPLE SELECTION: REVISIT VS. NEW SITE

FINDING: The capabilities needed to do scientific sample selection, acquisition, and documentation for potential return to Earth would be the same whether the rover would be sent to an area that has been previously visited, or to a new unexplored site.

		MRR-SAG	
What would be needed	Measurement	New site	Prev site
Ability to locate samples	Color stereo imagery	YES	YES
Ability to determine fine rock textures (grain size, crystal morphology), detailed context	Microscopic imagery	YES	YES
Ability to differentiate rock types, effects of different natural processes	Mineralogy	YES	YES
	Bulk elemental abundance	YES	YES
Ability to detect organic carbon	Organic carbon detection	YES	YES
Ability to remove weathered or dust-coated surface and see unweathered rock	Abrasion tool	YES	YES

From MRR-SAG: *Reducing payload would limit the ability to select or document samples during collection and greatly increase science risk.*

Findings Related to Potential Sample Return

LANDING SITES

FINDING: There are many candidate sites of high potential interest for a future sample return beyond those previously visited or to be visited by MSL.

Using MSR prioritization criteria, additional sites of high potential priority have been recognized

- **NRC: Astrobiology Strategy for Mars**: Several additional kinds of sites of high interest to astrobiology for a potential future return of samples were noted by the NRC (2007).
- **Community-generated.** At recent Mars-related conferences (LPSC, EPSC, AGU, EGU, AbSciCon, GSA, etc.), the global Mars science community has presented many additional sites and site-related astrobiology hypotheses.

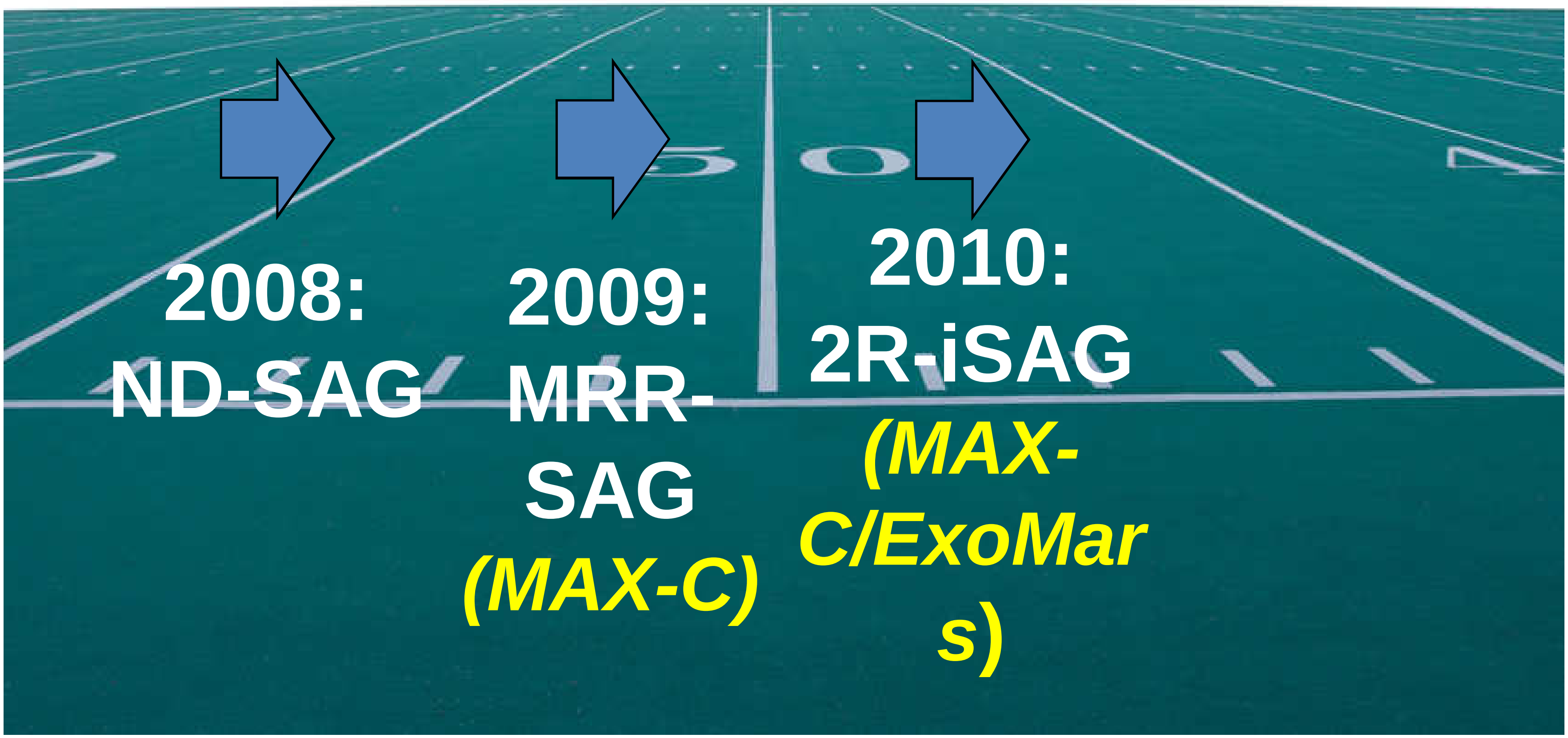
Findings Related to Potential Sample Return

RELATIONSHIP BETWEEN IN SITU *SCIENCE AND SAMPLE RETURN*

Kinds of rocks that would need to be interrogated to achieve proposed *in situ* objectives are a class of samples that would also be of crucial interest for potential sample return. Therefore:

MAJOR FINDING: The instruments needed to achieve the proposed *in situ* objectives are the same instruments needed to select samples for potential return to Earth, and to document their context. Because of these compelling commonalities, it makes sense to merge these two purposes into one mission.

MEPAG's recent thinking re: MSR



2RiSAG-Proposed PRIMARY SCIENTIFIC OBJECTIVES, 2018 DUAL-ROVER MISSION

Proposed Common Scientific Objectives

1. At a site interpreted to represent an environment with high habitability potential, and with high preservation potential for physical and chemical biosignatures
   a) Evaluate paleoenvironmental conditions;
   b) Search for possible signs of past life
2. Collect, document, and package in a suitable manner a set of samples sufficient to achieve the proposed scientific objectives of the potential future sample return mission.

Proposed Separate Scientific Objectives

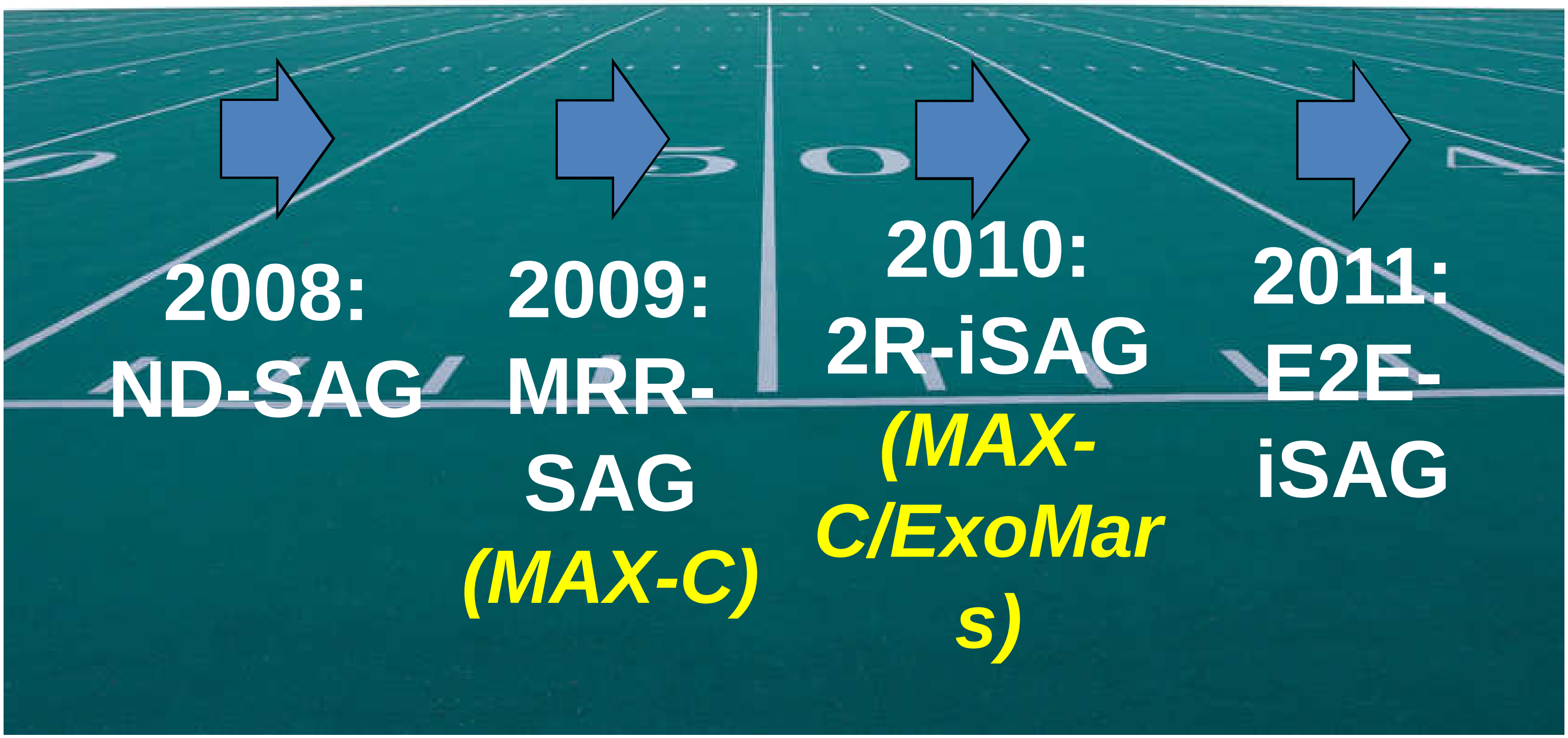
ExoMars Rover

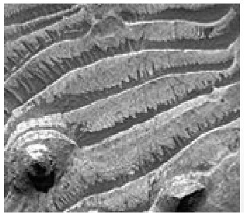
3. Characterize the water /geochemical environment as a function of depth in the shallow subsurface (0-2 m depth)
4. Search for signs of present life

MAX-C Rover

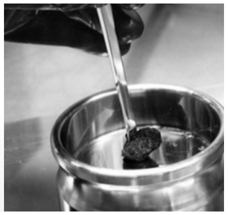
5. Characterize potential for preservation of biotic/ prebiotic signatures
6. Determine the geological variability (incl. lithology, mineralogy, texture) of the landing site at scales from kms to 10 μm, interpret the genetic processes.

The E2E Study





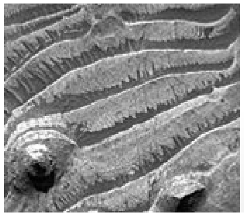
Starting Assumptions



1. MSR Campaign Science Objectives. Build from past reports of NRC and MEPAG.

2. MSR campaign would consist of three flight elements, each of which must have a "controlled appetite" in areas such as mission instrumentation and sample preservation.

3. Following sample acquisition functionality available to MSR campaign (note that these are planning assumptions, not decisions):
   - At least 20 encapsulated surface or subsurface samples of ~10 grams each, to be collected from a mobile platform,
   - At least 1 regolith sample collected from the immediate vicinity of the MSR lander by a deck- or body-mounted sampling system.
   - One atmospheric gas sample collected into a valved, pressurized container. The combination of volume and pressure is TBD.



Requested Tasks -1

TASK 1. MSR Campaign Science Objectives.

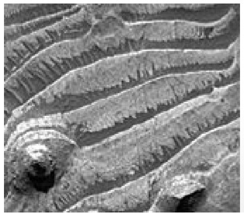
Consolidate and prioritize previously proposed “campaign-level” science objectives. Particular detail is required in areas that would affect proposed 2018 sampling mission.

TASK 2. Derived Criteria.

Map MSR campaign science objectives to specific requirements regarding: 1) sample acquisition and handling and 2) site selection criteria. Specific points to consider are:

a) Samples:

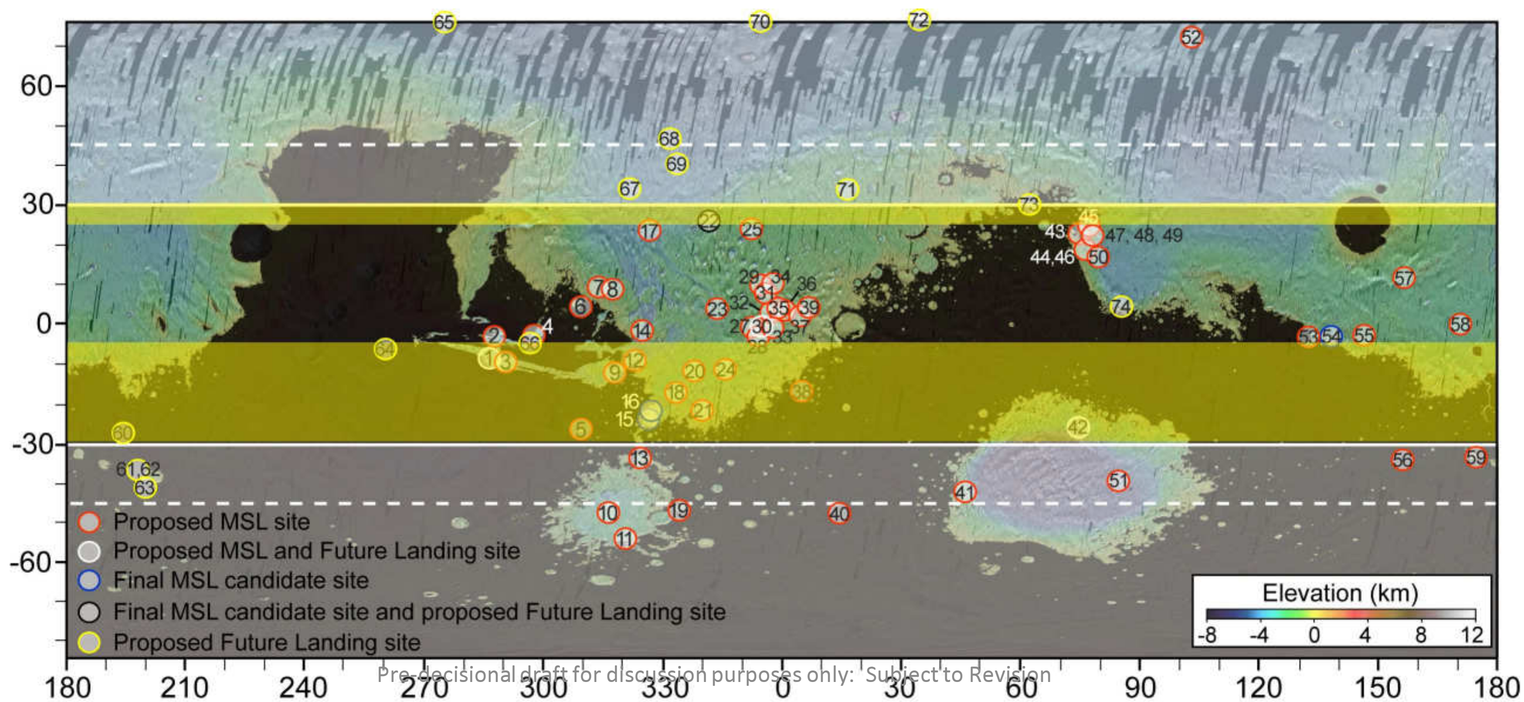
i. Priorities for sampling different rock types
ii. Value of ExoMars subsurface sample for inclusion in sample cache
iii. Nature and priority of regolith samples
iv. Nature and priority of gas samples

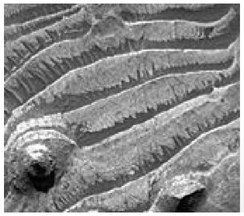


Requested Tasks - 2

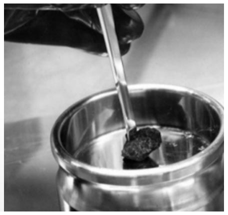
- **b) Instrumentation:** Minimum requirements for *in situ* characterization needed to support sample selection.

- **c) Landing Site Criteria:** Threshold landing site science attributes (required for any site to be considered) and qualifying science attributes (making candidate sites more attractive from point of view of MSR-campaign science objectives.
  - i. Are there suitable candidate sites for MSR in the 5S to 25N latitude band at elevations less than -1 km?
  - ii. What is the value of going to sites outside of this latitude band?





Requested Tasks - 3

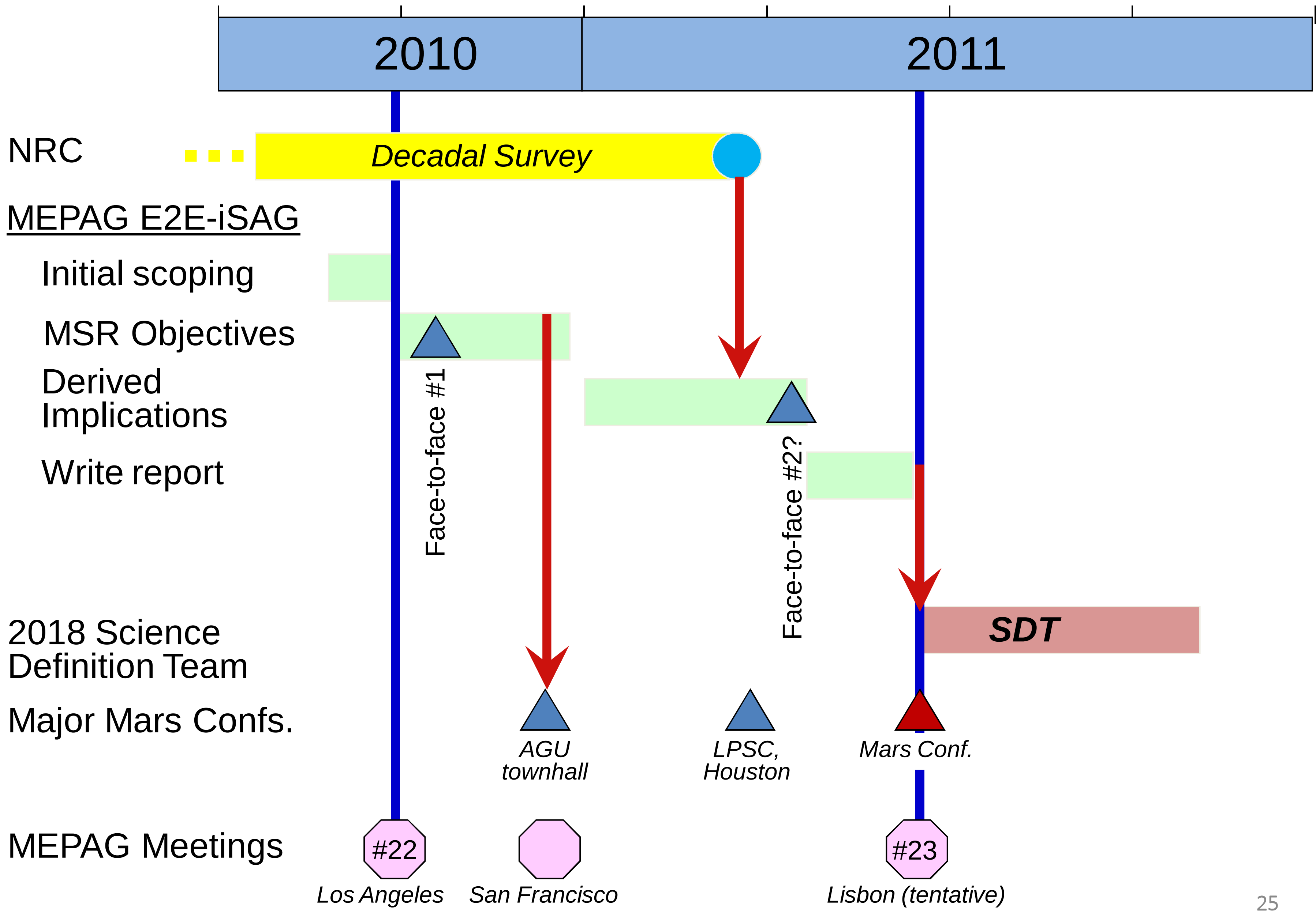


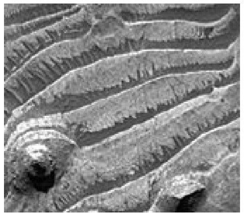
<u>TASK 3. Reference landing sites</u>.

To assist in planning the engineering of the landed elements of the MSR campaign, identify several reference landing sites of interest that contain proposed attributes. Purpose of these sites would be to help engineers design the mission elements so that at least some sites of interest could be accessed.

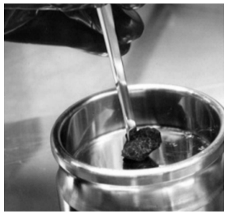
Note that these reference sites would not carry any formal status; there would be an independent landing site competition.

E2E-iSAG Schedule



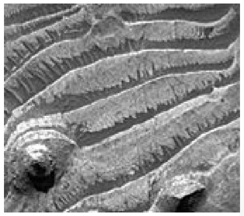


Discussion Topic #1

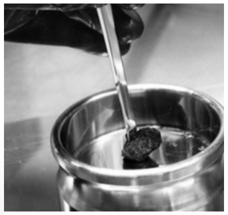


Landing Sites:

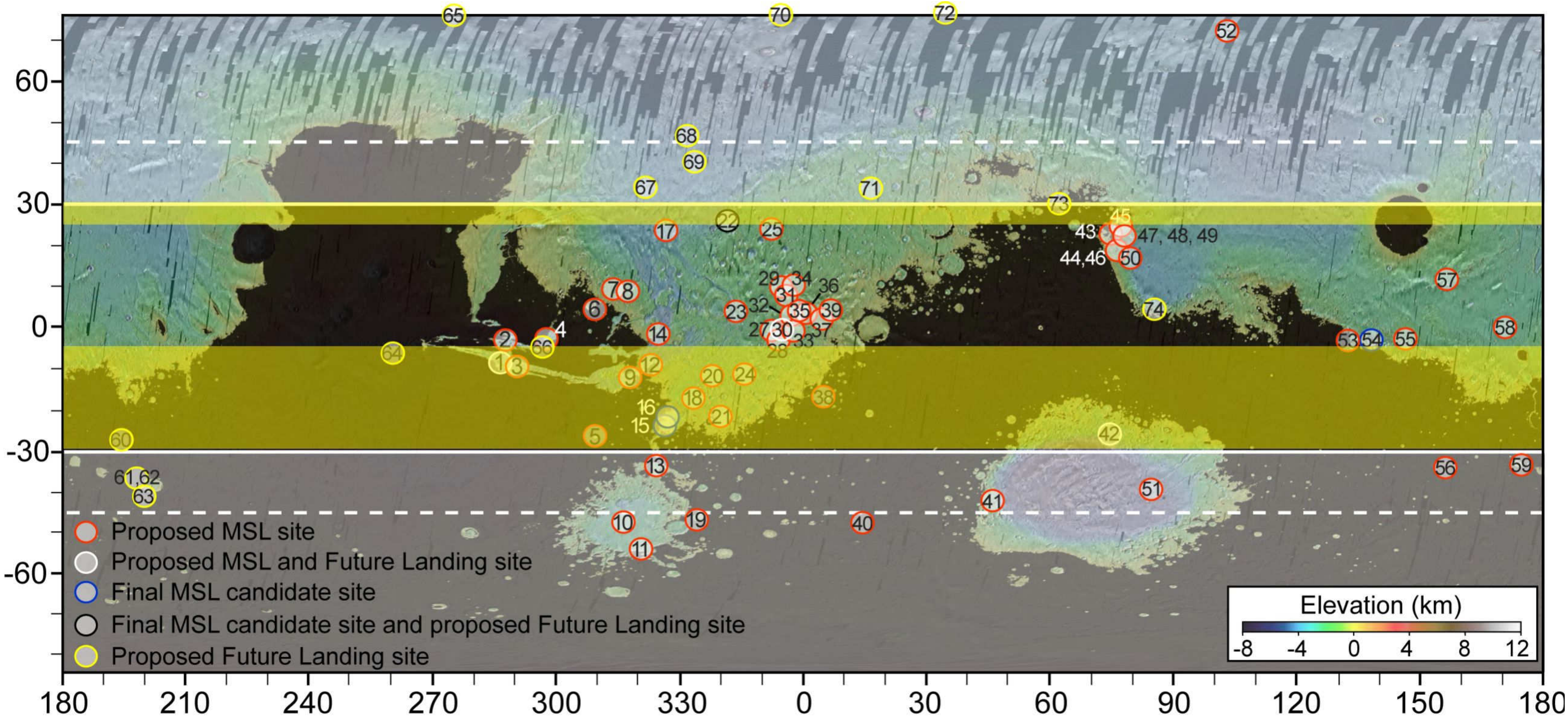
1. What scientific considerations should go into choosing the dual rover mission landing site ?
2. Are the current scientific objectives (i.e., ND-SAG objectives) too constraining in choosing the environments and lithologies of the selected landing site ?
3. What are the prospects for finding scientifically important landing site candidates within the latitude and elevation restrictions ?
4. What is the value of going to sites outside of this latitude band?



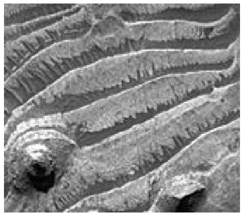
PROPOSED LANDING SITE CRITERIA



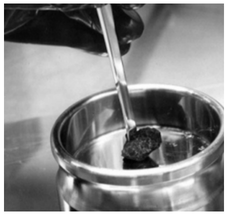
5S to 25N latitude at elevations less than -1 km



Pre-decisional draft for discussion purposes only: Subject to Revision



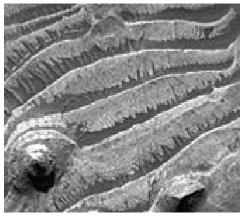
Discussion Topic #2



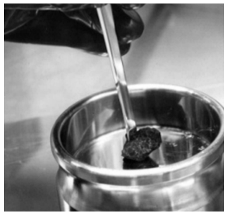
Investigations:

1. What types of investigations would be needed to achieve the objectives of MSR ?

2. Are there investigations that have not been discussed to date ?



Further Discussion

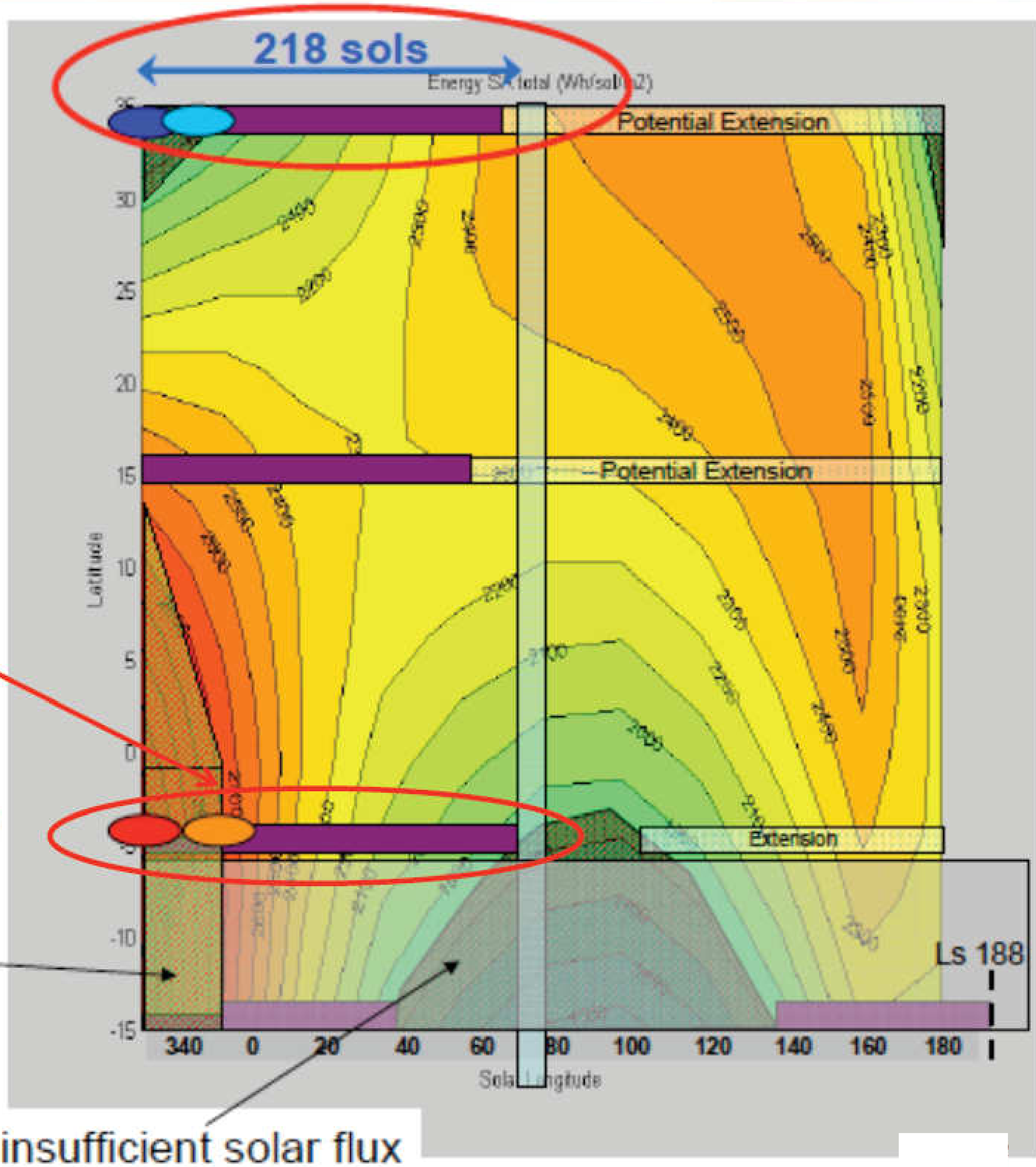


Additional ideas ?

Please contact   Mark Sephton, Scott McLennan, or Dave Beaty

Backup

Solar energy & thermal environment



: Operational sols

: Superior conjunction

5°S Latitude: Limit

: Cold operational case

: Hot operational case

: Cold non-operational case

: Hot non-operational case

Excluded, too hot

Excluded, too cold & insufficient solar flux

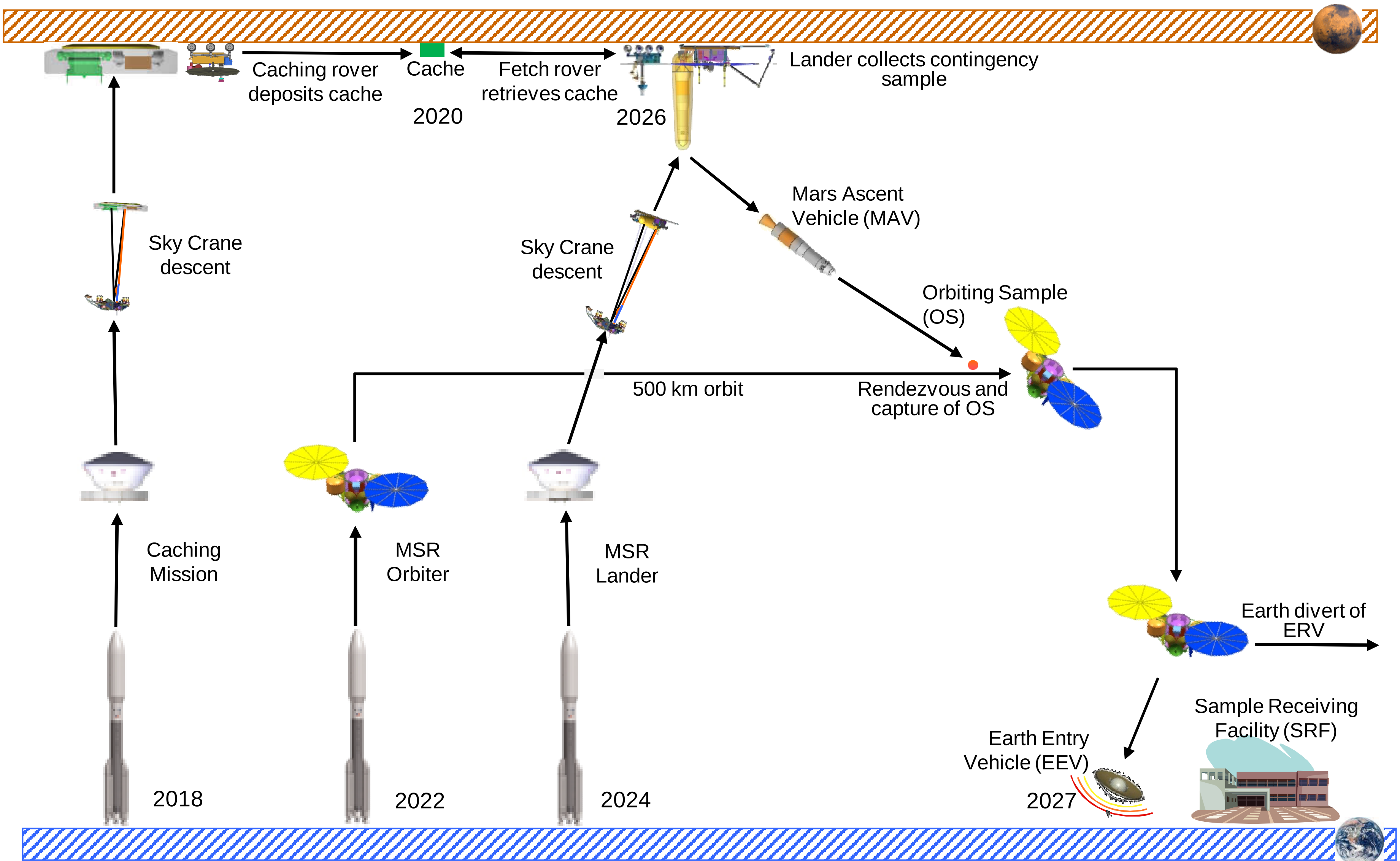
Findings Related to Potential Sample Return

LANDING SITES

FINDING: The best way to evaluate the multiple candidate sites from which to consider returning samples is via **an open landing site selection competition with sample return selection criteria**. A mission such as the proposed MAX-C presents the first opportunity to evaluate new high-potential sites via such a competition.

Conceptual MSR Campaign

A System with **Multiple Mission Elements** Launched in a Sequence of Mars Opportunities (***one landing site for multiple missions***)



Draft Sample Size: Rock Samples

Mass (g)	Goal	Specific purpose	Methods
EXAMPLE MASS ALLOCATIONS: ROCK SAMPLE			
Sample examination within SRF			
0.5	get enough info. to make decisions about what to do with sample	Preliminary examination	Non-destructive or minimally destructive PE observations on thin sections; optical microscopy, SEM, EMPA
	LD-BH*	Life detection and biohazard non-destructive tests	raman, confocal raman, FTIR, XRF, LD-MS, 3D tomography
2	LD-BH*	Destructive tests associated with characterizing sample, including C chemistry	GC-MS, LC-MS, PCR, LAL, TOF-SIMS
Research Requests from Principal Investigators			
1.0	Thin section science	Develop at least 5 thin sections to support multiple investigations	SIMS, LA-ICP-MS, XANES, SEM, EMPA, FTIR, raman
3.0	General research	Allocations within first year to 12-15 PIs for destructive and non-destructive investigations	geochronology (TIMS, MC-ICP-MS), stable isotopes, Mossbauer, GCMS, LCMS
3.5	Future research	Stored for future analyses (beyond 1st year)	
10	**Total sample mass**		

*Life Detection/Biohazard testing

Draft Composition of the Collection

		Number of Samples			Returned Mass				
Sample Type	Mechanical Properties	Min.	Pref.	Proposed science floor, 1st MSR	Mass/ sample (gm)	Total Sample Mass	Vial mass/ sample (gm)	Total Vial mass (gm)	Total mass (gm)
Cache from a previous mission is NOT returned									
Sedimentary suite	rock	5	15						560
Hydrothermal suite	rock	5	10						0
Low-T W/R suite	rock	5	10	28	10	280	10	280	0
Igneous Suite	rock	5	10						0
Other	rock	1	2						0
Depth-Resolved Suite	rock or reg.	5	10	0					
Regolith	granular	1	5	4	10	40	10	40	80
Dust	granular	1	1	1	5	5	5	5	10
Ice	ice or liquid	5	10	0					
Atmospheric Gas	gas	1	2	2	0.001		10	20	20
Cache from previous mission	rocks	0	0			0	50	0	0
TOTAL				**35**		**325**		**345**	**670**

NOTE: Consensus not yet reached