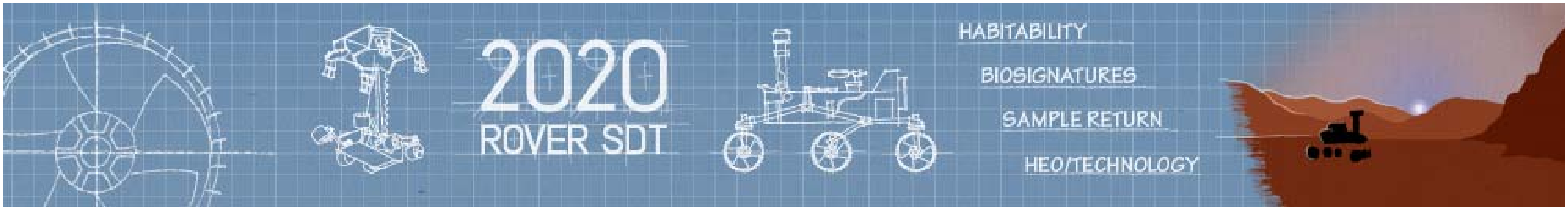

Mars 2020 Science Definition Team Report: **Presentation to CAPS**

Sept. 4, 2013

Jack Mustard, David Des Marais, John Grant

On behalf of the

2020 Mars Rover Science Definition Team

<u>NOTE</u>: The content of this presentation is drawn from the SDT's text report, and for further information, the interested reader is referred there (http://mepag.jpl.nasa.gov/reports/mep_report.html).

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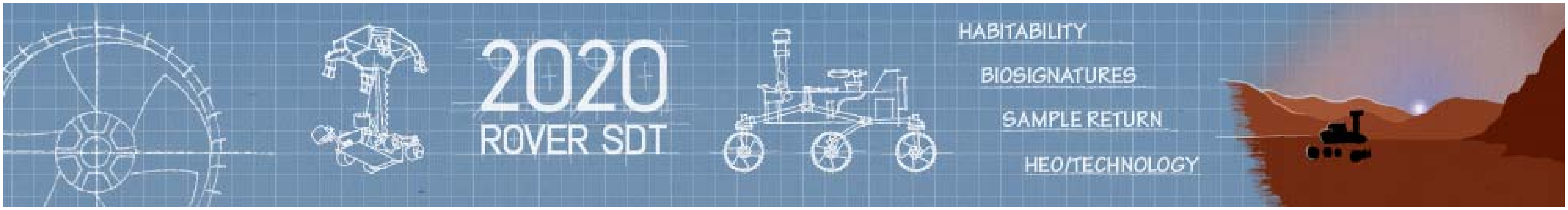

Mars 2020 Science Definition Team Report:

Part 1. Introduction, Context, Constraints, Assumptions, and Objective A

Jack Mustard, Brown University

<u>NOTE</u>: The content of this presentation is drawn from the SDT's text report, and for further information, the interested reader is referred there (http://mepag.jpl.nasa.gov/reports/mep_report.html).

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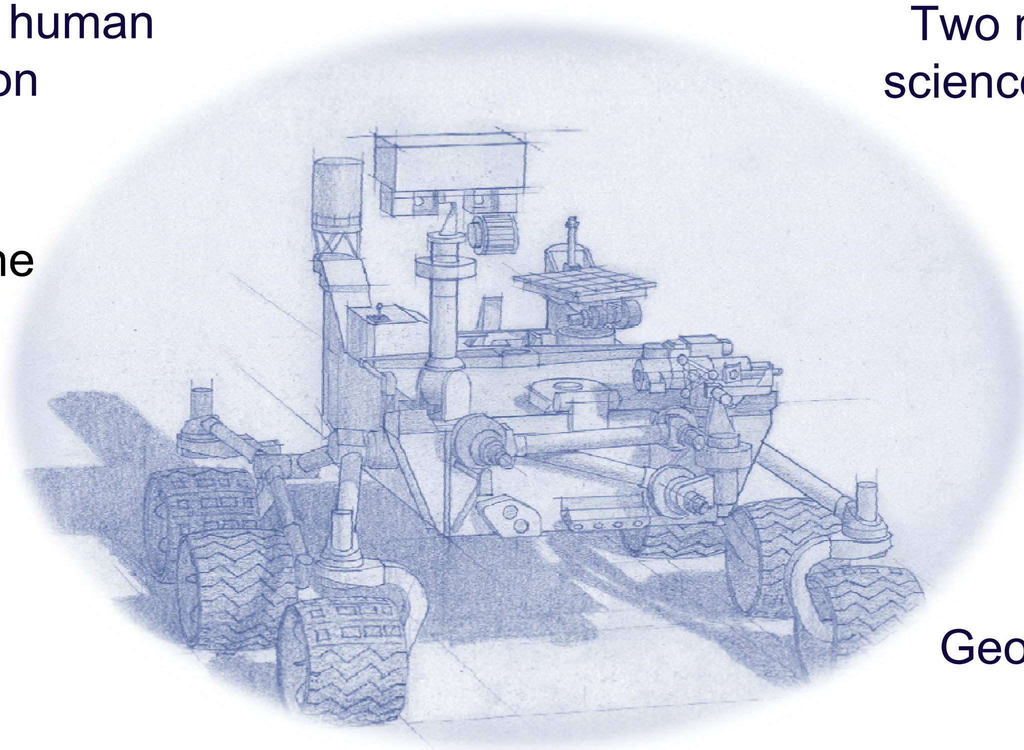
Summary of the SDT's Vision

Seeking signs of past life

Prepare for human exploration

Two major *in situ* science objectives



Returnable cache of samples

Coordinated, nested context and fine-scale measurements

Coring system

Geologically diverse site of ancient habitability

Efficient surface operations, one Mars-year lifetime

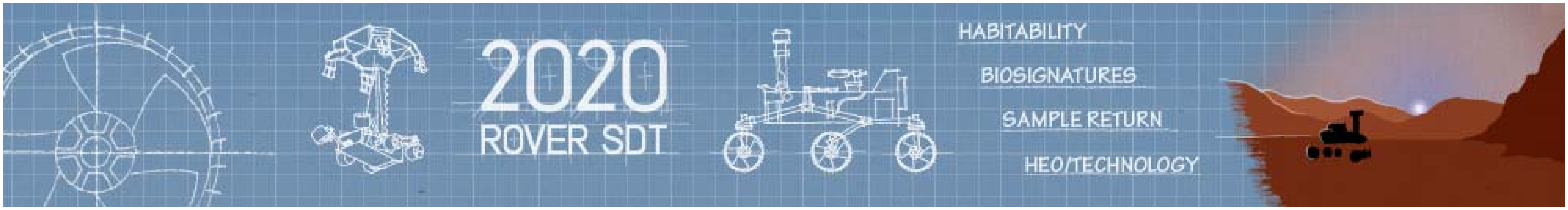
MSL heritage rover

Improved EDL for landing site access

Executive Summary

The SDT envisions a 2020 Mars Rover mission that would:

- **Conduct Rigorous *In Situ* Science**
  - **Geologic Context and History** Carry out an integrated set of sophisticated context, contact, and spatially-coordinated measurements to characterize the geology of the landing site
  - ***In Situ* Astrobiology** Using the geologic context as a foundation, find and characterize ancient habitable environments, identify rocks with the highest chance of preserving signs of ancient Martian life if it were present, and within those environments, seek the signs of life
- **Enable the Future**
  - **Sample Return** Place carefully and rigorously-selected samples in a returnable sample cache as the most scientifically, technically, and economically compelling method of demonstrating significant technical progress toward Mars sample return
  - **Human Exploration** Conduct a Mars-surface critical ISRU demonstration to prepare for eventual human exploration of Mars
  - **Technology** Demonstrate technology required for future Mars exploration
- **Respect Current Financial Realities**
  - Utilize MSL-heritage design and a moderate instrument suite to stay within the resource constraints specified by NASA



Recap of SDT Process and Key Concepts

Introduction

Scientific Theme	NASA's Mars Exploration Program Scientific Theme: ***Seeking Signs of Life*** *(Decadal Survey, MEPAG, etc.)*
Highest Priority Science Goal	Following the MSL, MAVEN, ExoMars, and InSight missions, ***to address in detail the questions of habitability & the potential origin and evolution of life on Mars***. *(Planetary Decadal Survey–Mars Chapter)*
Next Step To Achieve Highest Priority Science Goal	***To explore on the surface an ancient site relevant to the planet's early habitability with sophisticated context, contact, and spatially coordinated measurements*** in order to perform detailed exploration of sites on Mars that could reveal past habitability and biosignature preservation potential.
Mars 2020 Science Definition Team Task	With this overarching strategy in mind, to define ***detailed objectives, measurements, payload options and priorities & an integrated mission concept for a 2020 rover mission to address***: ***A. past habitability,*** ***B. potential biosignature preservation,*** ***C. progress toward sample return, &*** ***D. contributed technology/human exploration payloads.***

Mission Objectives & Assumptions

MISSION OBJECTIVES

A Explore an astrobiologically relevant ancient environment on Mars to decipher its geological processes and history, including the assessment of past habitability.

B Assess the biosignature preservation potential within the selected geological environment and search for potential biosignatures.

C Demonstrate significant technical progress towards the future return of scientifically selected, well-documented samples to Earth.

D Provide an opportunity for contributed Human Exploration & Operations Mission Directorate (HEOMD) or Space Technology Program (STP) participation, compatible with the science payload and within the mission's payload capacity.

Note: The phrasing of Objectives A and B above is modified slightly from that given in the SDT charter, and the analysis in this package is organized along the lines of the above objectives statements.

ASSUMPTIONS & CONSTRAINTS

1 Launch in 2020

2 Instrument cost nominal limit of $100M (including margin/reserves)

- ~$80M for SMD instruments
- ~$20M for contributed elements
- Surface operations costs and science support equipment (e.g., arm) not included in the above limits

3 Utilize MSL Sky Crane EDL flight systems and Curiosity-class roving capabilities

- Address potential value and cost for improving access to high-value science landing sites

4 Mission lifetime of one Mars year (~690 Earth days)

5 Mission pre-project will provide additional constraints on payload mass, volume, data rate, and configuration

Linkages between Objectives A, B, C

Deciphering geologic processes and history and assessing habitability:

1. Provides science results in its own right
2. Lays the foundation for objective B (Assessing potential for preservation of biosignatures, and seeking potential biosignatures)
3. Lays the foundation for objective C (careful selection of well-documented samples for MSR)

→

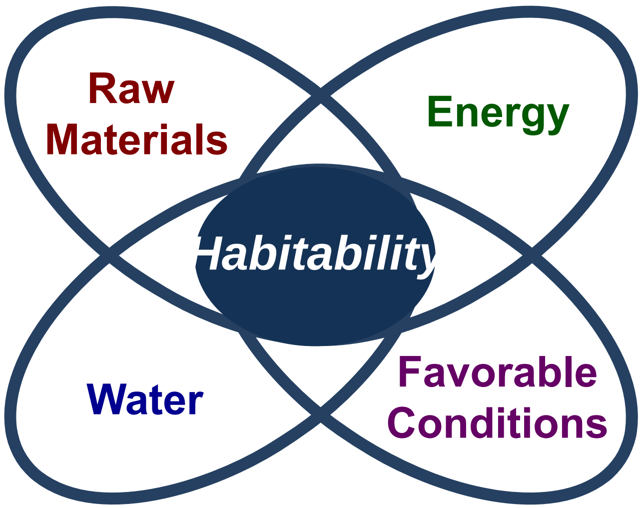
In situ science results

+

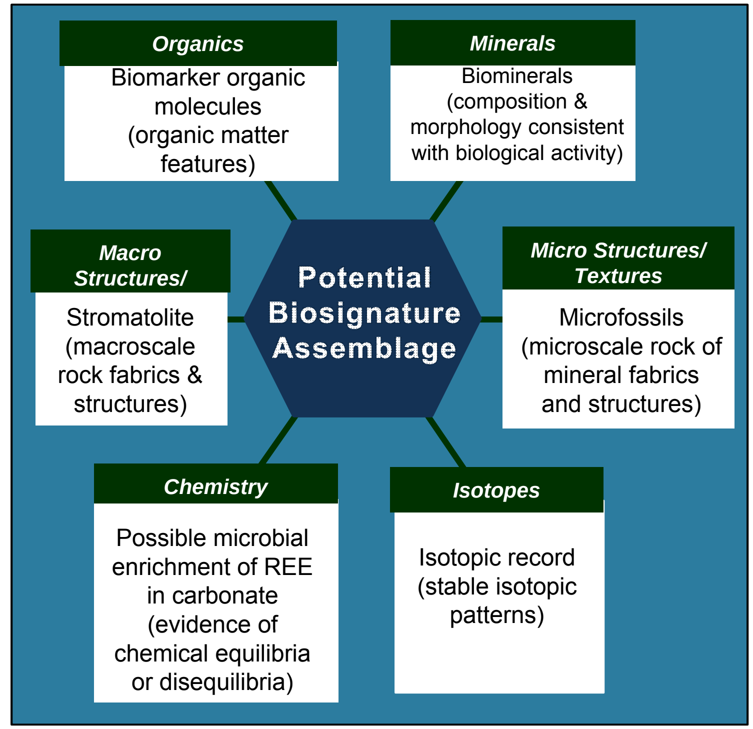
Essential scientific foundation for MSR science results

Key Concepts

Habitability and Potential Biosignatures



Adapted from Tori Hoehler



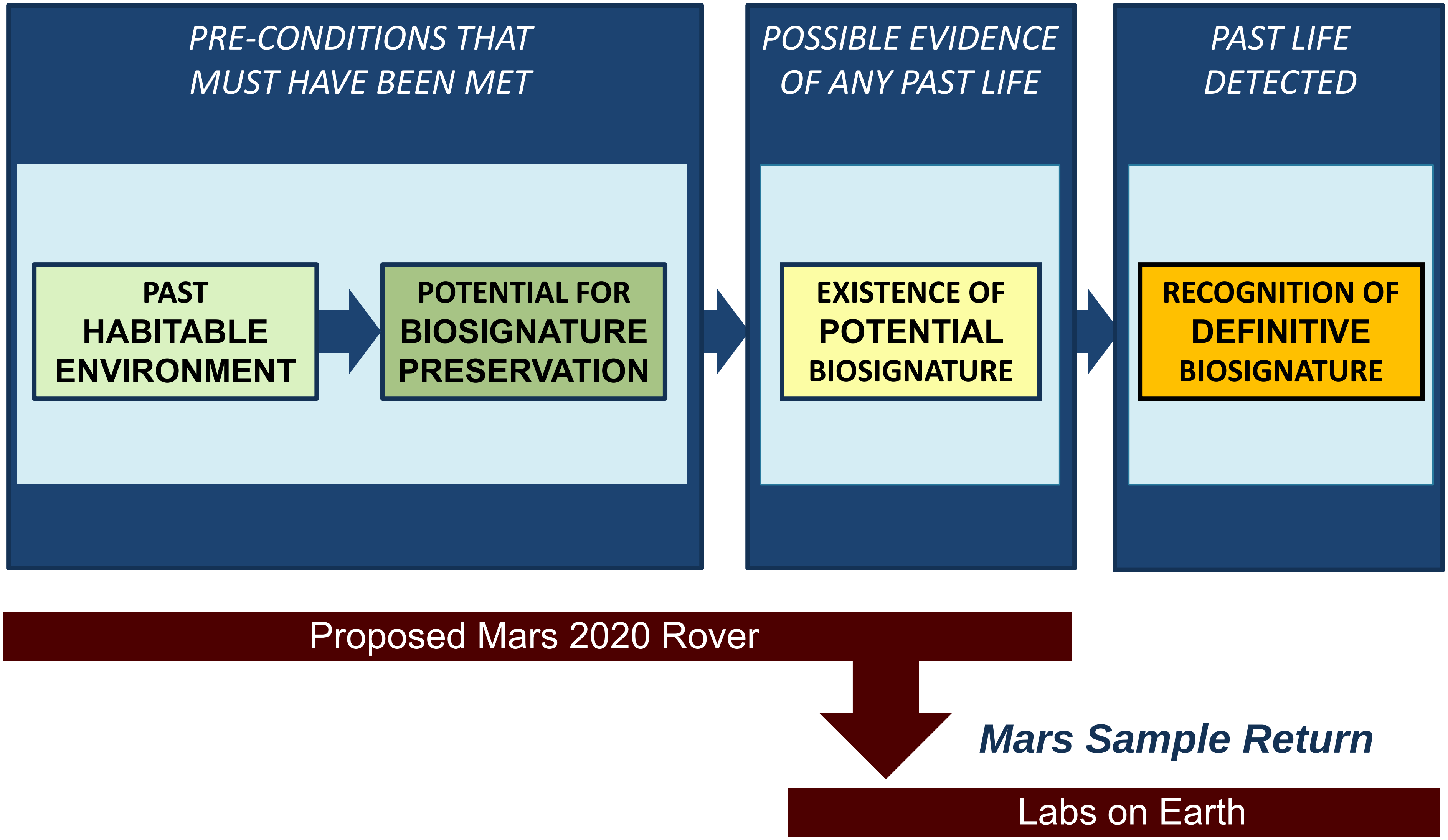
Preservation (Two Issues)

Preservation of the Evidence of a Prior Habitable Environment
Evidence for the criteria above are preserved as geological or geochemical proxies, or may not be preserved at all

Preservation of Biosignatures
If life existed in the past, biosignatures will exist today ONLY if conditions were favorable for biosignature preservation

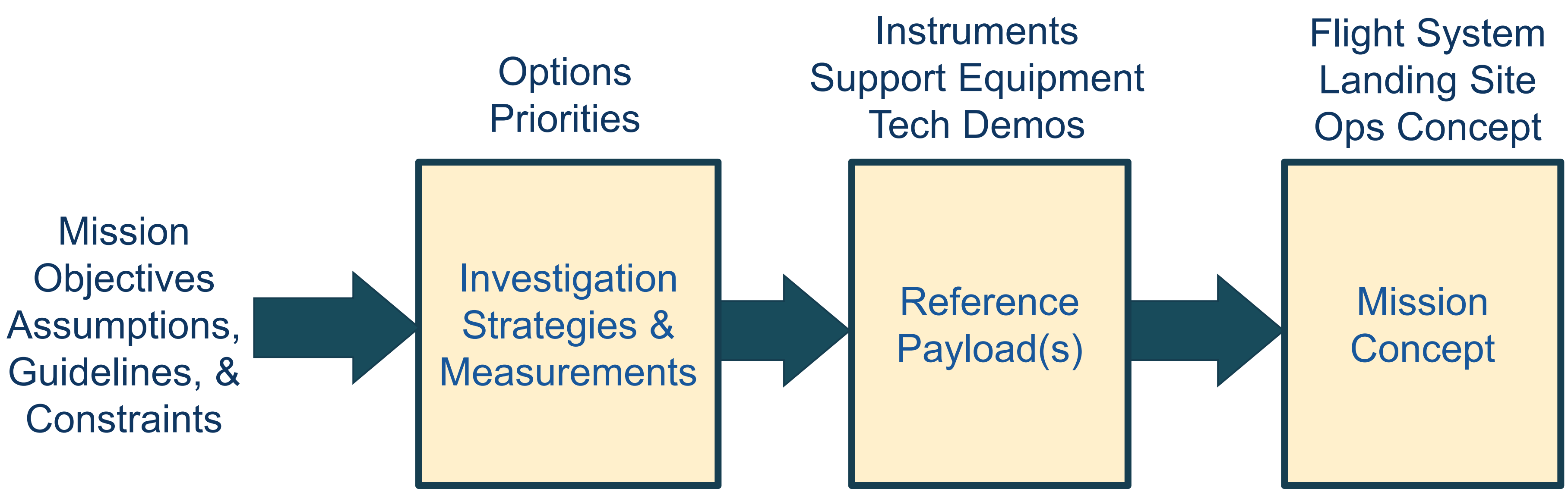
Key Concepts

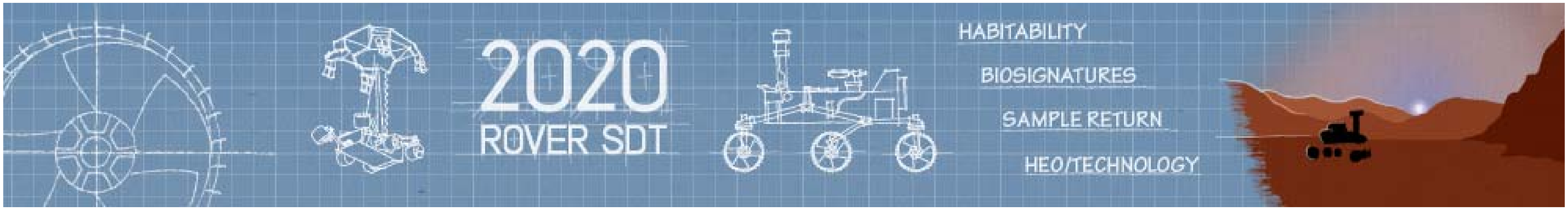
Scientific Process for Detecting Past Martian Life



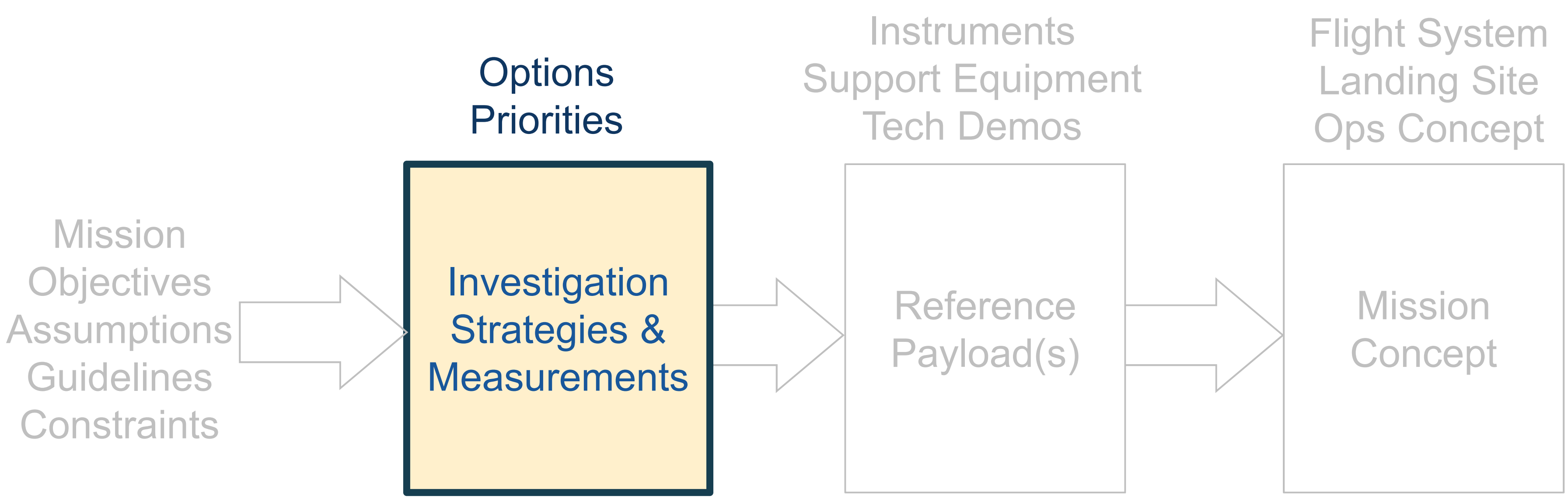
SDT Process Roadmap (Simplified)

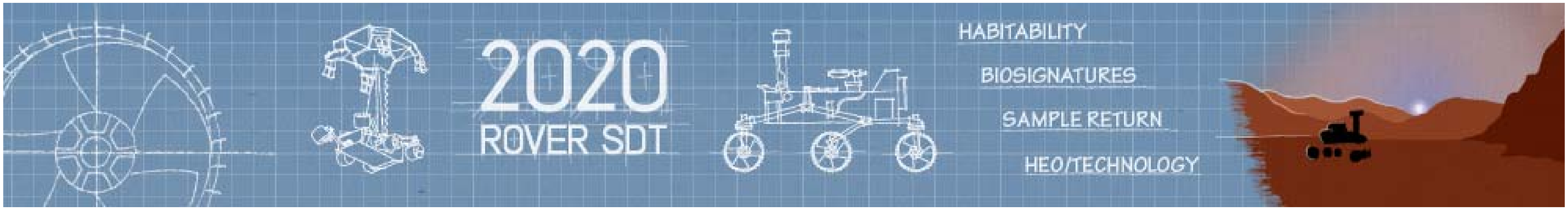
<u>Optimize</u>: Science Return; Progress Toward NASA Goals





Investigation Strategies & Measurements





Options and Priorities to Achieve

Objective A

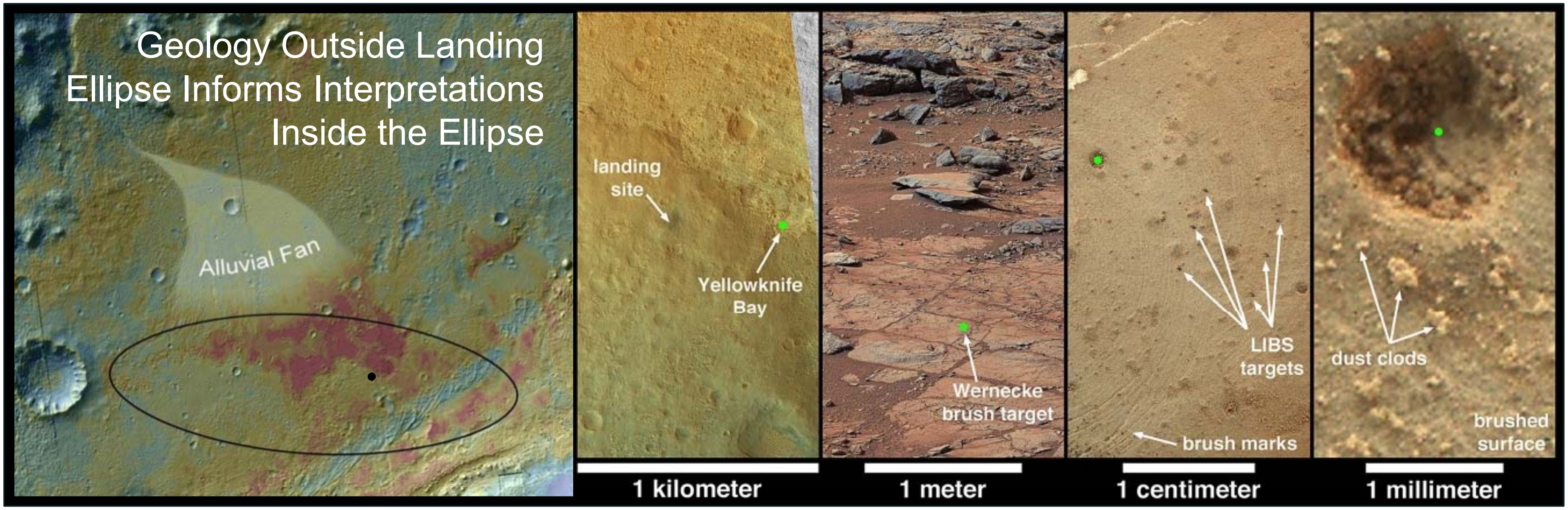
OBJECTIVE A

Explore an astrobiologically relevant ancient* environment on Mars to decipher its geological processes and history, including the assessment of past habitability.

**"Ancient" implies a location where the astrobiologically relevant environment no longer exists, but is preserved in a geologic record.*

Integrate Observations Across km to mm Scales

In order to explore and document geologic processes and history of a site, it is essential to integrate observations from orbital (regional) scales to microscopic (sub-millimeter) scales.



The footprint and spatial resolution of measurements is critical for ensuring observations can be correlated across scales.

Types of Geologic Observations

What kinds of in situ observations and measurements are required?

Full details of the required observations at a particular site cannot be predicted precisely. However, the *types* of observations that are likely to be critical are well understood, as shown by the following examples among two broad rock classes.

Relevant Features When Interpreting Water-laid or Water-altered Rocks

- Lateral/vertical changes in a sedimentary deposit or hydrothermal sediments
- 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 detectable organic matter: host mineralogy, concentration, spatial arrangement
- 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

Relevant Features When Interpreting Unaltered Igneous Rock

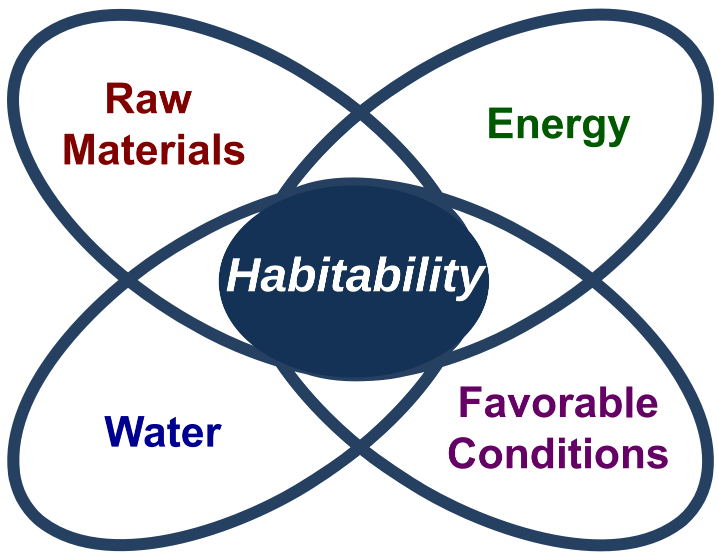
- Petrologic character: ultramafic to granitic, mineralogic, trace element properties
- Age
- Type and intensity of aqueous alteration [if they are unaltered (see above) this bullet is not relevant]
- Type of occurrence: outcrop, "subcrop," or float
- Igneous setting: intrusive, extrusive
- Grain size, chemical variation in minerals
- Degree of weathering
- Degree of impact shock metamorphism, including brecciation

After E2E-iSAG

Objective A

The Process of Assessing Habitability

To assess the habitability of a past environment, the rover must be able to examine the geologic record of that environment and evaluate the following characteristics of that environment:



<u>Availability of CHNOPS elements</u> (beyond those species present in the atmosphere) and electron donors

<u>Energy sources</u> and availability (i.e., mineral suites of mixed valence states for redox energy; proximity to paleosurface for photosynthesis; radiogenic elements for radiolysis)

- **<u>Amount of water</u> that was present (e.g. mineral-bound or interstitial fluids in subsurface; small/shallow surface water or large/deep surface water body)**
- **<u>Persistence</u> of the aqueous conditions**

- **<u>Water properties</u> (e.g., salinity, pH, and temperature)**
- **<u>Protection from radiation</u> (e.g. planetary dipole field)**
- **<u>Water energy</u> (quiet vs. high energy - implications for stabilization of microbial communities)**
- **<u>Rate of burial</u> (e.g. lacustrine - implications for establishment of microbial communities)**

Adapted from Tori Hoehler

Habitability, Preservation Potential at a Field Site

Fundamental Principles of Past Environment Assessment in the Field	Capabilities that a Rover Would Need
Evidence of an ancient environment's characteristics lie in the mineralogy, chemistry, texture, and structure of the rocks. The evidence is subject to alteration over time.	• Ability to measure **mineralogy, chemistry, texture and structure** of the rocks. • Ability to make **sufficient quantity and quality of measurements** to decipher the record of ancient environments and subsequent alteration
Environments typically vary spatially and in time, which manifests as spatial variations in the rock record.	• **Mobility** (e.g., range, ability to navigate rough terrain and slopes, etc.) • Ability to **perform and integrate measurements across multiple scales**

SDT MAJOR FINDING #1

Assessing habitability and preservation potential at a site with a record of an astrobiologically relevant ancient environment requires a rover that can navigate the terrain to conduct lateral and stratigraphic surveys across multiple scales and targets.

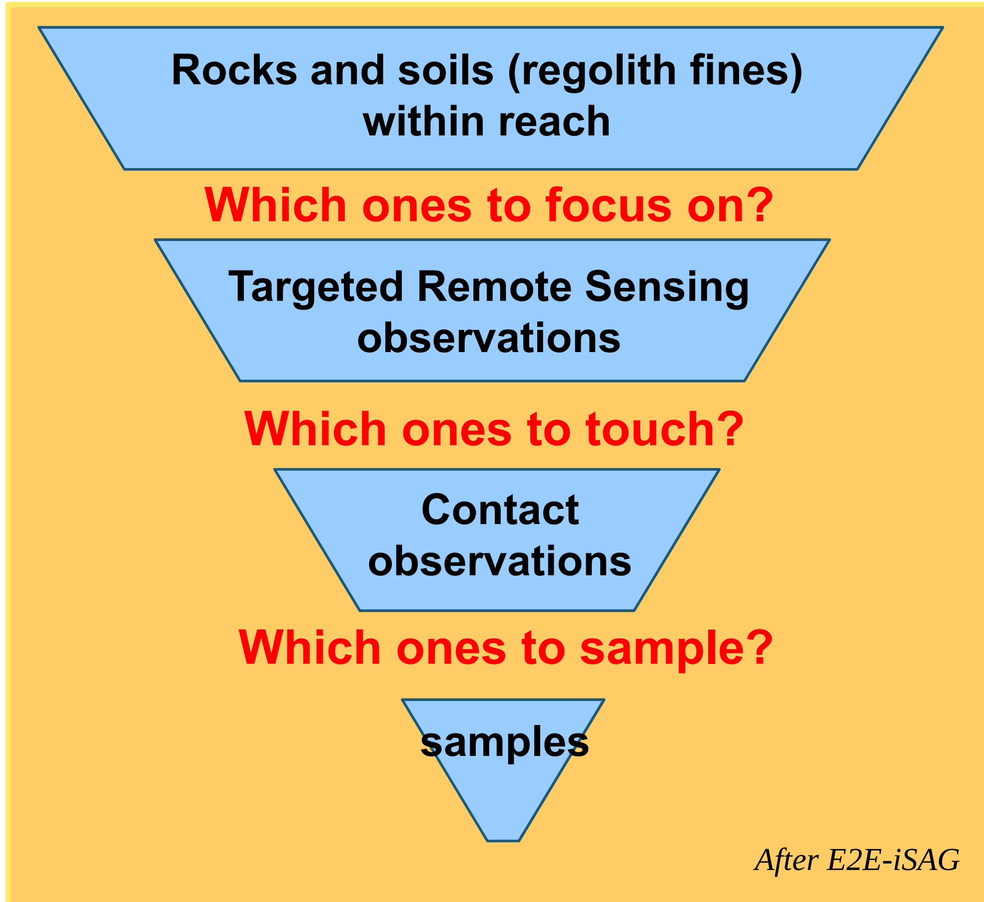
Quantity of Geologic Observations

"Well documented" means that the appropriate geologic measurements have been carried out across the exploration area to provide maximum constraints on the interpretation of the sample analysis.

SDT FINDING

To ensure that a site, or samples from it, are "well documented" requires using the rover's tools and instruments to make a sufficient quantity, variety and quality of geologic observations to interpret past environmental conditions and understand spatial and temporal relationships in the geologic record.

QUANTITY OF GEOLOGIC OBSERVATIONS



Objective A

Rover-based Scientific Measurement Types

Seventeen different categories of measurements were identified from two community workshops (see Appendix) and evaluated for responsiveness to the four objectives of the Mars 2020 mission.

- Contact mineralogy
- Context imaging
- Elemental chemistry
- Microscopic imaging
- Context mineralogy
- Atmospheric trace gas detection
- Contact organic detection/characterization
- Stable Isotopic ratios
- Organic characterization in processed samples
- Mineralogy in processed samples
- Redox potential
- Subsurface characterization
- Geochronology
- Remnant Magnetic Properties
- Radiation environment
- Regolith/dust properties
- Meteorology

Deciphering Geological Processes and History

Correlate Composition with Fine Texture & Structure

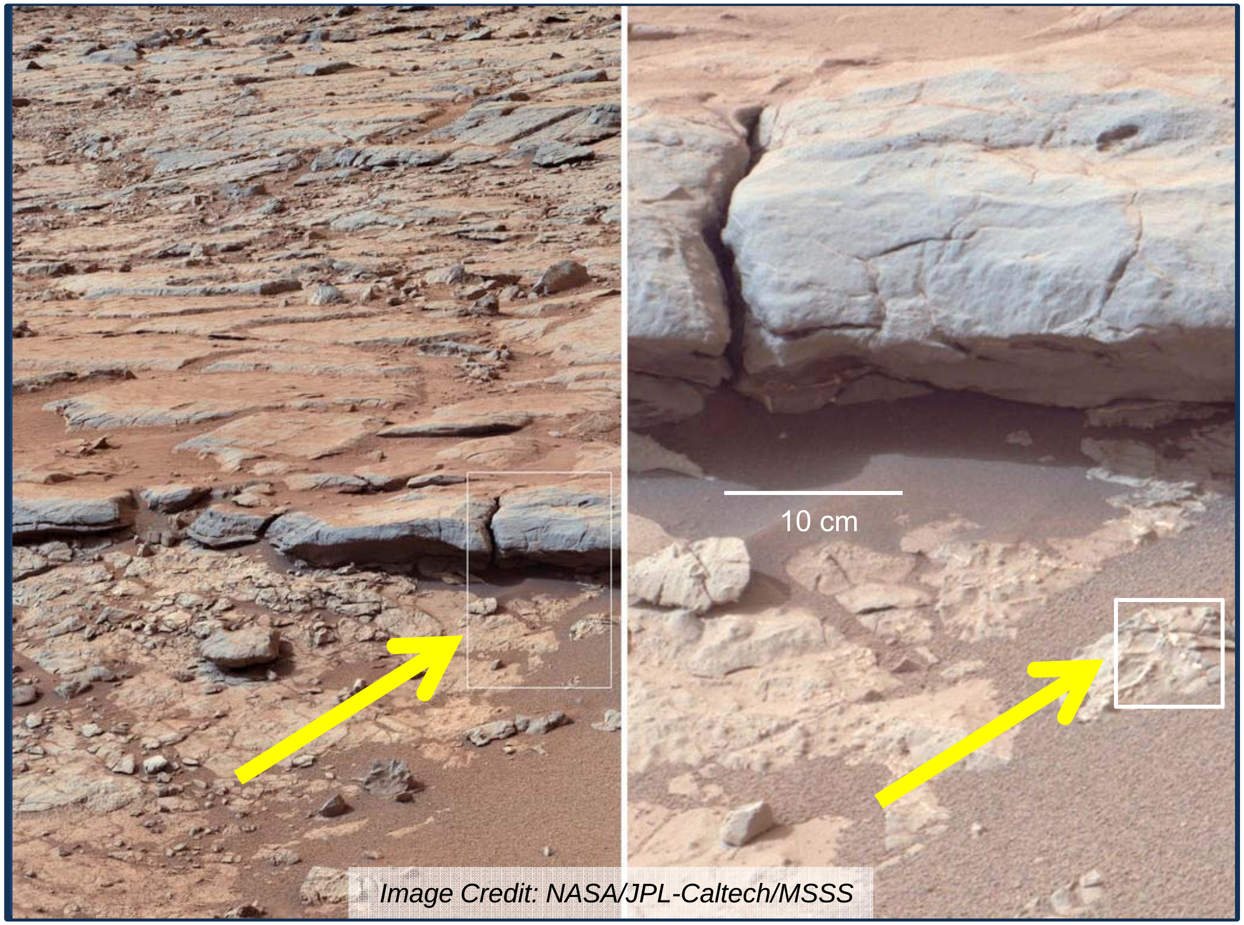
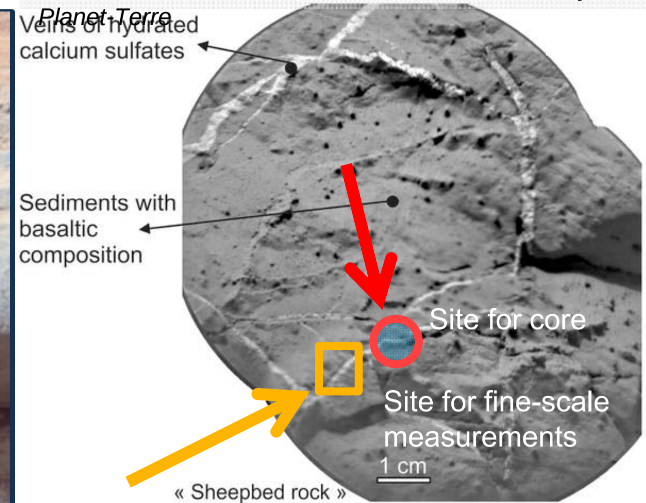
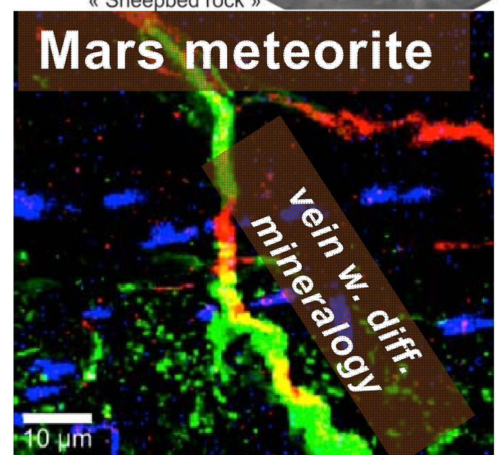


Image Credit: NASA/JPL-Caltech/MSSS

Image Credit: NASA/JPL-Caltech/LANL/CNES/IRAP/LPGNantes/CNRS/LGLyon/Planet-Terre





SDT FINDING

The ability to spatially correlate variations in rock composition with fine scale structures and textures is critical for geological and astrobiological interpretations.

Implementation Priorities for Objective A

These are the measurement priorities for effectively and efficiently characterizing the geology of a site, assessing habitability, and supporting the informational/decisional needs of Objectives B and C.

- Required Measurements:
  - Context imaging
  - Context mineralogy
  - Fine-scale imaging of arm work volume
  - Fine-scale elemental chemistry of arm work volume
  - Fine-scale mineralogy of arm work volume

Science Threshold

- Additional "Baseline" Measurements
  - Organic detection
  - Subsurface characterization

Science Baseline

- Additional Desirable Measurements (unranked)
  - Geochronology (absolute age dating)
  - Redox potential in target material
  - Isotopic ratios in target material
  - Surface physical properties (e.g., regolith; dust)
  - Paleomagnetic data

Priorities determined using the traceability matrix

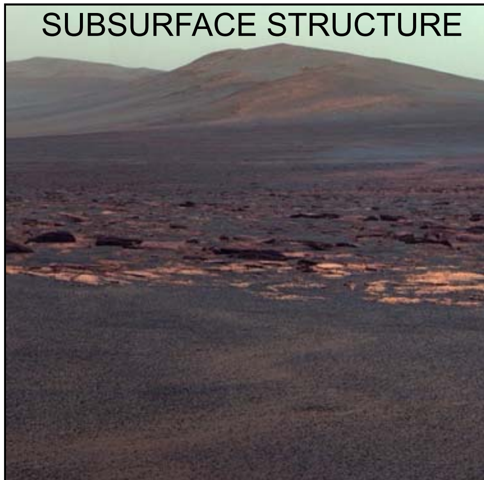
Potential Role of Organic Matter Detection

Organic matter detection provides valuable observations for assessing the processes that influence preservation of information about ancient environments

- Detection of organic matter helps to characterize meteoritic inputs, hydrothermal processes, and other potential processes that might form abiotic (pre-biotic?) organic matter
- Acquiring rock samples that contain organic matter is a very high priority for MSR scientific objectives 1, 3-6 and 8 of the E2E-iSAG report

Potential Importance of Subsurface Characterization

Knowledge of *structure* and *composition* of subsurface materials could augment identification and refine context of targets for detailed measurement



Problem:

- Information on setting is gained from limited outcrops accessible to threshold instruments. MER experience shows that considerable time spent traversing to outcrops could be saved by better knowledge of stratigraphy.

Example:

- Opportunity crossed multiple contacts as it traversed the onlap of sulfate-bearing deposits onto Noachian terrain; unclear relationship of units at Cape York
- 3D structure would inform a continuous cross-section, providing context

Relevant measurements:

- Lateral, depth variation in structure, density, conductivity; depth of discontinuities

Examples: ground-penetrating radar

Problem:

- Lithologies of interest for detailed measurement or sampling can be hidden from threshold instruments by centimeters or more of dust or regolith

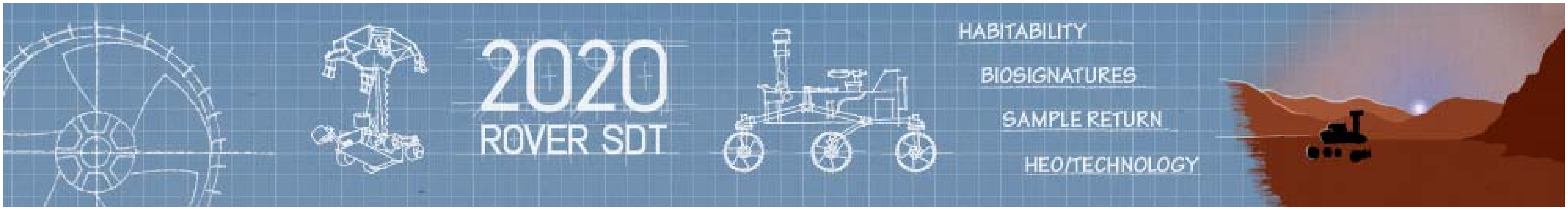
Example:

- Spirit discovered high concentrations of silica where a stuck wheel removed a few cm of overburden
- Ability to sense to ~ >5 cm depth **by design** could detect scientifically important lithologies that would otherwise not be investigated

Relevant measurements:

- Detection at depth of key minerals or associated elements – sulfates (S), silica (Si), carbonates (C), highly hydrated minerals (H) – can pinpoint key locations for sampling and/or evaluation of stratigraphy

Examples: gamma-ray spectrometer, neutron spectrometer, trenching tool



Mars 2020 Science Definition Team Report:

Part 2. Objectives B and C

David Des Marais, NASA Ames Research Center

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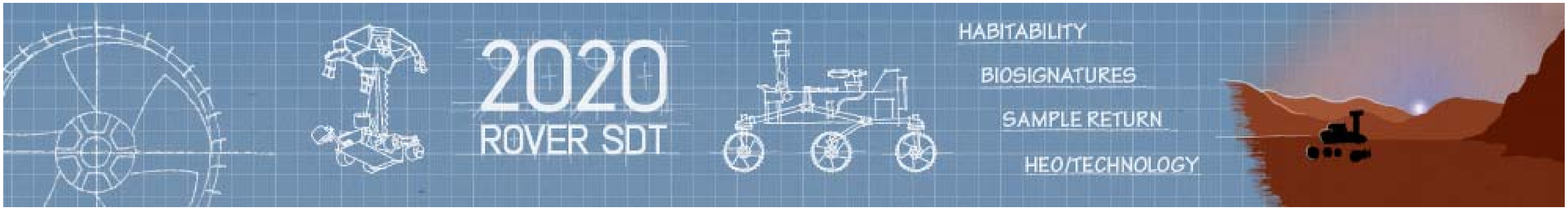


Options and Priorities to Achieve

Objective B

OBJECTIVE B	Assess the potential for preservation of biosignatures within the selected geological environment and search for potential biosignatures.

Objective B

Scientific Process for Detecting Past Martian Life

PRE-CONDITIONS THAT MUST HAVE BEEN MET		*POSSIBLE EVIDENCE OF ANY PAST LIFE*	*PAST LIFE DETECTED*
PAST HABITABLE ENVIRONMENT	**POTENTIAL FOR BIOSIGNATURE PRESERVATION**	**EXISTENCE OF POTENTIAL BIOSIGNATURE**	**RECOGNITION OF DEFINITIVE BIOSIGNATURE**
Past conditions suitable for the existence of life at the site.	**Past conditions suitable for the preservation of past life in the geologic record.**	**An observable feature that might be evidence of past life.**	**An observable feature that is confirmed to be evidence of past life.**

Proposed Mars 2020 Rover

MSR

Labs on Earth

SDT MAJOR FINDING

To search for potential biosignatures, it is necessary to (a) identify sites that very likely hosted past habitable environments, (b) identify high biosignature preservation potential materials to be analyzed for potential biosignatures, and (c) perform measurements to identify potential biosignatures or materials that might contain them.

Objective B

Categories of Ancient Biosignatures

Hypothesized to Exist in Martian Rocks

These hypothesized potential Martian biosignatures represent independently observable features.

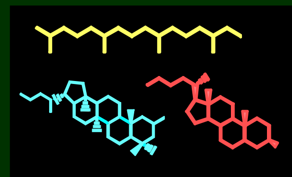
Legend:
- Biosignature Category
- *Detection method using Proposed M-2020 Rover*

Potential Biosignature Assemblage

Organics

Organic Detection, Characterization

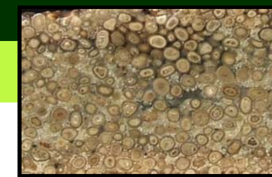
Biomarker organic molecules (organic matter features)



Minerals

Context, Fine-Scale Mineralogy

Biominerals (composition & morphology consistent with biological activity)



Macro Structures/ Textures

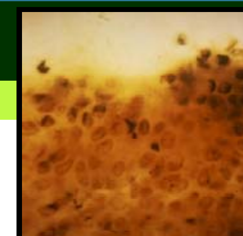
Context Imaging

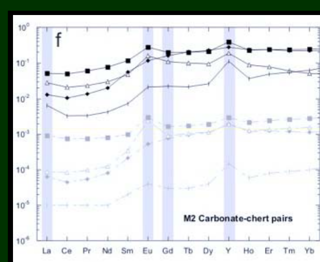
Stromatolite (macroscale rock fabrics & structures)

Micro Structures/ Textures

Fine-scale Imaging

Microfossils (microscale rock of mineral fabrics and structures)





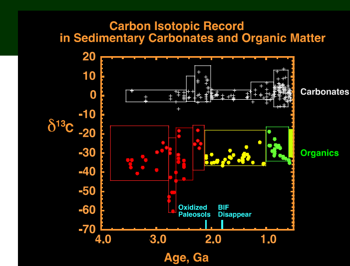
Chemistry

Context, Fine-Scale Chemistry

Possible microbial enrichment of REE in carbonate (evidence of chemical equilibria or disequilibria)

Isotopes

Isotopic record (stable isotopic patterns)



The *2020* Mars *Rover must have the capability to detect as many of these signatures as possible* to have a credible chance to find evidence of past life on Mars, because:

1. We cannot anticipate which of these (if any) will be present or well-preserved…
2. …therefore we cannot anticipate which categories will provide the most information.
3. Confidence in confirming biological origin(s) increases as more categories are detected.

Relationship to Minerals and Rocks

Minerals & Rocks that Preserve Terrestrial Biosignatures

Least Stable	Dominant Process Controlling Loss
Ice	Climatic warming
Halides, Sulfates	Dissolution
Metallic Sulfides	Oxidation
Clay-rich Shales Water-laid Pyroclastics Marine Carbonates Metallic Oxides	Metamorphism Recrystallization Dissolution
Phosphates Silica	Deep Burial Recrystallization Metamorphism
Most Stable	

After *Farmer & Des Marais (1999)*

Certain minerals and rock types are more effective than others for enhancing the preservation of biosignatures in Earth's geologic record.

An assessment of Biosignature Preservation Potential (BPP) should consider the minerals and rock types that might contain Potential Biosignatures (PBS).

The Effect of Geologic Time

Biosignatures must “run a gauntlet” of processes through geologic time that can either lower or elevate their BPP.

GEOLOGIC TIME →

Environment of PBS Formation	Initial Sequestration of PBS in a Geologic Deposit	Long-term sequestration of PBS	Surface exposure to impacts, erosion and/or weathering of the host deposit
e.g., microorganisms degrade or recycle organic and mineral PBS*, OR PBS preservation is enhanced in reducing environments that minimize degradation of organics and/or reduced minerals	e.g., degrade PBS by microorganisms*, reactions with minerals, dissolution, compaction, etc. OR preserve PBS by rapid burial and/or entombment in impermeable matrices	e.g., degrade PBS by microorganisms*, oxidation, radiolysis, dissolution, thermal degradation, impact, deformation, chemical replacement due to migrating fluids, etc. OR preserve PBS by desiccation, sequestration in impervious host rock, low irradiation, and benign temperatures and pressures	…same examples as those indicated for long-term sequestration of PBS

** Thereby at least partially replacing PBS from the initial environment of formation with a new set of PBS*

SDT FINDING

Assessing the potential for preservation of any given type of biosignature requires interpretation of past geological environments and processes. This interpretation requires measurements of rock chemistry, mineralogy, oxidation state, and rock texture, morphology and context.

Field Strategies For Finding & Recognizing PBS

The strategy first to evaluate habitability and BPP in an area, and then to search for PBS, though logical, is typically not practical during rover operations. Because a rover rarely returns to previously visited locations, it must complete all observations before it moves to the next location. Accordingly, evaluations of habitability and BPP and any measurements of PBS must be executed concurrently before leaving a particular location.

EVALUATE CONCURRENTLY

HABITABILITY?
Could life (if it existed) have survived in the paleoenvironment? How favorable were the conditions for life?

\+

PRESERVATION POTENTIAL?
(If life existed)
Could biosignatures have been preserved in the rocks until today?

\+

EXISTENCE OF PBS?

SDT FINDING

Although it would be logical to assess habitability and biosignature preservation potential before seeking potential biosignatures, for practical considerations, evidence for all three would be sought concurrently during exploration at a particular rover location.

Different types of organic matter measurements provide different levels of confidence in a biological origin for the organic matter (OM)*

Confidence Scale: High

Organic Matter Characterization

- Distributions of identifiable molecular structures and/or components (if macromolecular)
- Isomer ratios of amino acids
- molecular mass distribution of organic components
- compound specific isotopic composition
- aliphatic/aromatic ratio
- organic functionalization (polar/nonpolar)
- C, H, O, S, N, Cl ratios of organic matter
- fine scale OM distribution in materials

Stable isotopic composition of organic carbon

Basic molecular bond information

OM Detection

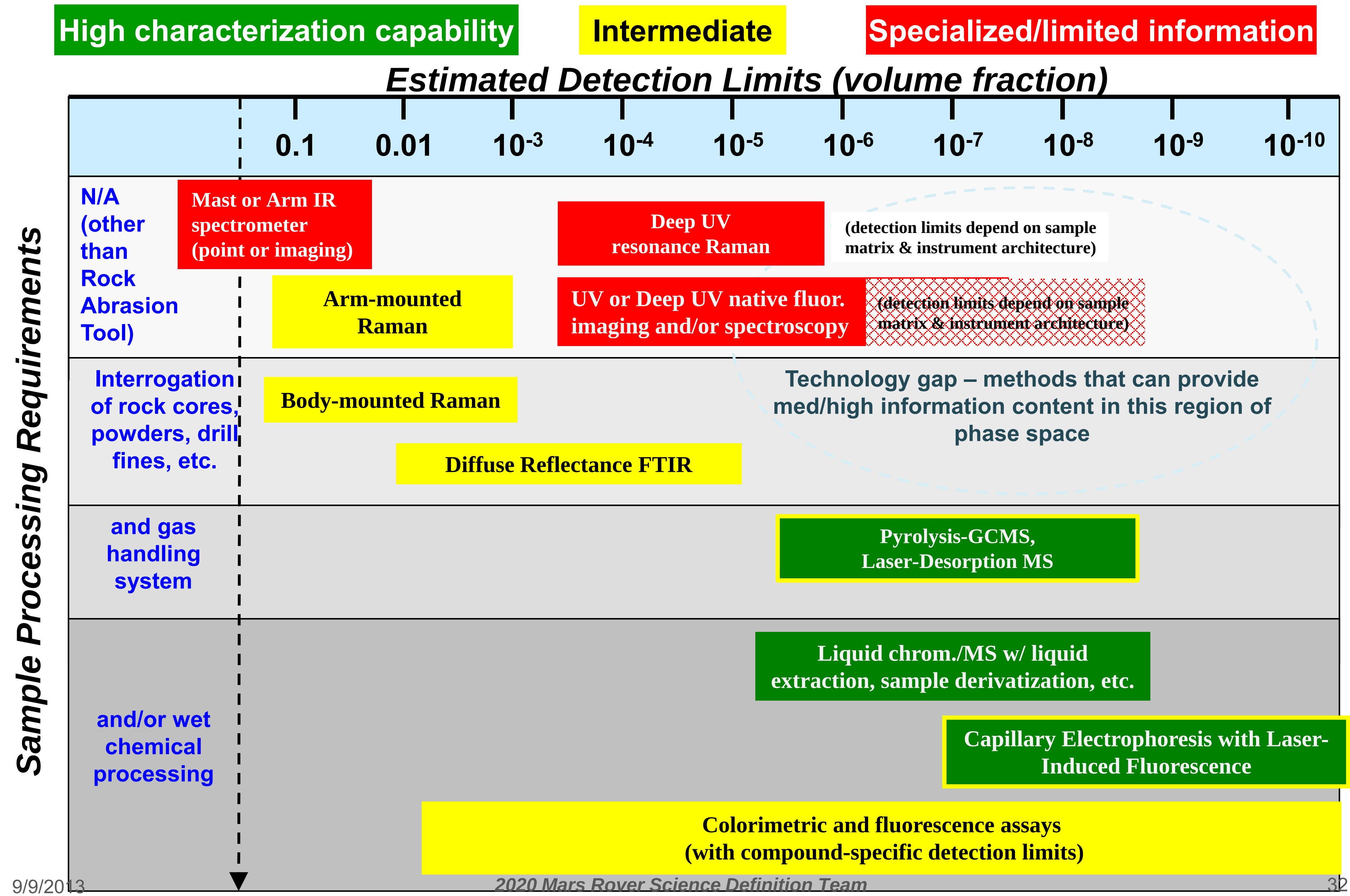
presence of organic carbon (compounds with C-H bonds)

presence of reduced carbon (e.g., graphite, diamonds)

Confidence Scale: Low

* The level of confidence provided by a given measurement varies depending on the specific details (e.g. degree of thermal degradation) of the sample being investigated

Ability to Characterize Reduced Carbon Compounds That Might Be Present in Planetary Materials



Organic Molecular Analysis

Value of organic characterization:

- The complexity and diversity of organic compounds can help to characterize processes that are very important for habitability and any life. A more thorough characterization of a sample's organic components will access more of this important information that is stored in a sample's organic components.
- Characterization and molecular analysis of organic matter helps to characterize more precisely any meteoritic inputs, hydrothermal processes, and other abiotic processes that create organic matter.
- The caching and return of samples bearing organic carbon provides critical insight into the origin of organic carbon signatures in Martian meteorites (e.g. ALH84001, Steele et al. 2012a,b, Agee et al., 2013).
- Confidence in interpretation of the other five classes of biosignatures is greatly enhanced if any associated organic matter is analyzed more thoroughly.
- Organic matter characterization of bulk and molecular components would help to constrain the assessment of processes that influence various types of BPP.

SDT FINDING

Additional *in situ* organic detection and characterization of organic matter, such as provided by a second spectroscopic technique, would significantly improve our understanding of biosignature preservation potential and ability to detect potential organic biosignatures.

Implementation Priorities for Objective B

- Required Measurements
  - Context imaging
  - Context mineralogy
  - Fine-scale imaging – co-registered with Mineralogy
  - Elemental chemistry (mapping at fine scale is desired)
  - Fine-scale Mineralogy
  - Reduced C detection
  - Organic detection method #1

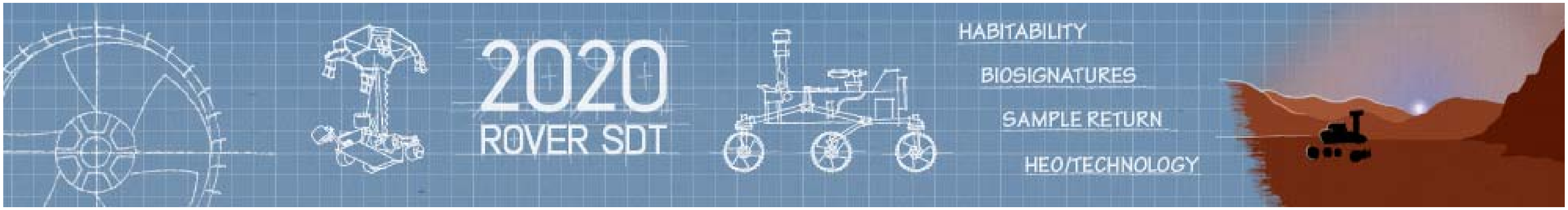
Note: These five measurements are common with Obj. A

Science Threshold

- Additional "Baseline" Measurements
  - Organic detection method #2 (enables characterization)

Science Baseline

- Additional Desirable Measurements
  - Organic molecular analysis (characterization)
- Other Required Capabilities:
  - Ability to remove rock coating and weathering layers



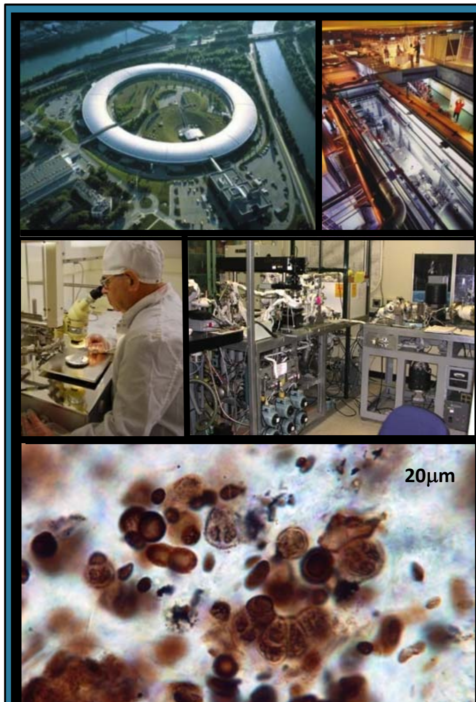
Options and Priorities to Achieve

Objective C

OBJECTIVE
C

Demonstrate significant technical progress toward the future return of scientifically selected, well-documented samples to Earth.

The Importance of Mars Sample Return



Reasons for returning samples for analysis on Earth…

- Perform definitive detection of a biosignature. As the range of measurements that can be accommodated on a single rover is extremely limited, neither the detection of a PBS nor the non-detection of one would be considered definitive until performed in a lab.
- Use advanced instrumentation not amenable for flight to Mars
- Employ techniques requiring complex sample preparation
- Use a virtually unlimited array of different instruments, including future instruments not yet even designed
- Gain the ability to run sequential analyses and replicate analyses in different labs.

Adapted from iMARS (2008); NRC Decadal Survey (2011)

From ***Vision and Voyages for Planetary science in the Decade 2013-2022:***

Committee on the Planetary Science Decadal Survey; National Research Council, March 2011

"*The analysis of carefully selected and well documented samples from a well characterized site [on Mars] will provide the highest scientific return on investment for understanding Mars in the context of solar system evolution and addressing the question of whether Mars has ever been an abode of life.*"

SDT FINDING

The SDT concurs with the detailed technical and scientific arguments made by the Decadal Survey (2011) and MEPAG (most recently summarized in E2E-iSAG, 2012) for the critical role returned samples will play in the scientific exploration of Mars.

Has Anything Changed?

Have there been any very recent new findings that could alter the logic leading to the conclusions of those reports?

- **Post-Decadal Survey Discovery of Recurring Slope Lineae (RSLs)**
  - Might be signs of present-day surface release of liquid water. However, understanding of RSL is too immature to conclude that exploring them *in situ* is more compelling for astrobiology than sample return. Also, their possible "special region" status could place complex and/or costly Planetary Protection constraints on potential missions to RLSs.

- **Recent MSL and MER mission results**
  - Discovery of sedimentary rocks containing reducing components, water-formed conglomerates, phyllosilicate minerals, water-deposited minerals in veins, etc., reinforces inference of past habitability and of BPP; provides even stronger support for the need for sample return!

- **Recent Mars meteorite results**
  - Findings of abiotic macromolecular carbon (with N, O, H) in martian meteorites, and of abundant water in NWA7034, confirm availability of compounds needed for life, and show that organic PBS can be preserved near the martian surface. Provides support for Mars' BPP; emphasizes need for sophisticated analyses capabilities on Earth.

None of the discoveries of the last decade have changed the fundamental rationale for Mars Sample Return.

What Role Should the Mars 2020 Rover Play?

Demonstrate significant technical progress toward the future return of scientifically selected, well-documented samples to Earth.

Because of the overall importance of Mars Sample Return to NASA's strategic objectives, the Mars 2020 mission is expected to make significant technical progress towards MSR.

How does the SDT interpret "significant technical progress"?

As shown on the following slides, delivering scientifically selected martian samples to Earth involves a series of functional steps (spanning several missions) that must be completed in order, beginning with the selection and acquisition of samples.

SDT Interpretation of "Significant Technical Progress"

Spacecraft Launch from Earth/Land on Mars → Rover Select Samples → Acquire/Cache Samples

If we don't advance to here we would need to send another rover in the future, with science and sampling capability, to complete the first step of MSR. → **Samples on Mars**

Options for Technical Progress Towards MSR	New Capability?	Consistent with Proposed Mars-2020 Resources?	Resulting contribution to MSR	
			Reduces Science or Engineering Risk	Achieves Major Campaign Milestone
Select Samples (for future collection)		✓		
Select Samples & Assemble Demonstration Cache	✓	✓	✓	
Select Samples & Assemble Returnable Cache	✓	✓	✓	✓

Note: A variety of candidate MSR technology demonstrations were identified and evaluated during the Mars Program Planning Group effort in 2012. Those demonstrations were not addressed again by this SDT.

SDT MAJOR FINDING

Significant technical progress by Mars 2020 towards the future return of samples to Earth within the mission constraints demands the development and deployment of a sampling and encapsulation system and the assembly of a cache of scientifically selected, well-documented samples packaged in such a way that they could be returned to Earth.

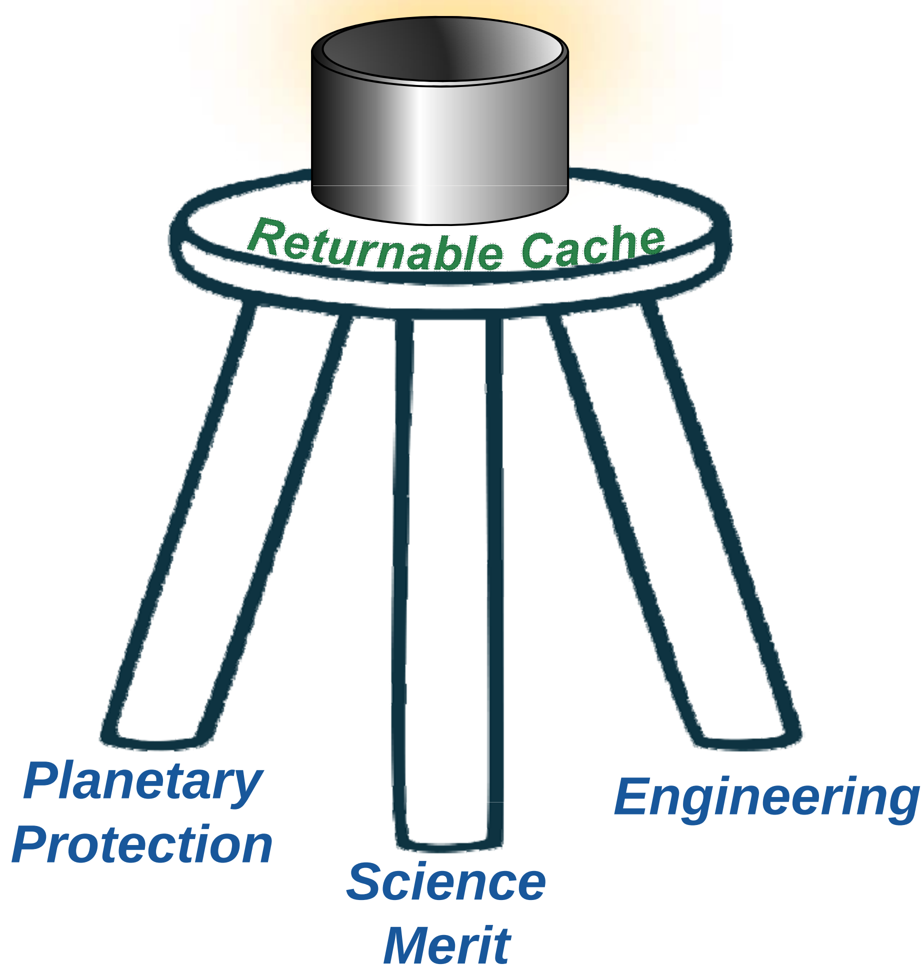
What Constitutes a "Returnable Cache"?

The SDT concludes that three attributes are essential to making a cache returnable:

1 The cache has enough scientific value to merit returning.

2 The cache complies with planetary protection requirements.

3 The cache is returnable in an engineering sense.



Objective C

What Constitutes a "Returnable" Cache

Scientific Merit of Samples to be Returned

SDT FINDING

A cache that merits returning in a scientific sense is one that has the potential to achieve the scientific objectives of sample return identified by E2E-iSAG (2012).

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

2/7/13

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

Engineering Factors for Cache Returnability

Key engineering factors for M2020 cache design

Interfaces to downstream elements

- Transfer equipment (arm, etc.)
- Mars Ascent Vehicle/Orbiting Sample

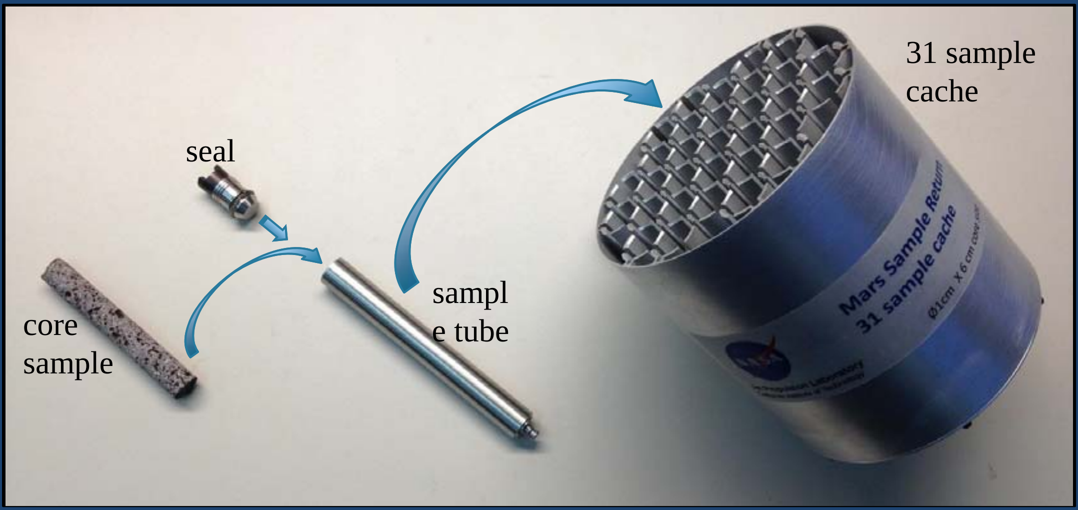
Long-term storage in Mars surface environment

- External or internal to rover
- Nominal or anomalous retrieval by later mission

Thermal design and history of cache environment over time

- Characterize exchange of volatiles into or out of the samples
- Analyze/predict thermal history of the cache

The Cache Enables Future Science



The ability to collect compelling samples for potential future return

Information Source: Whetsel/Parrish

Planetary Protection Requirements

SDT FINDING

For a cache to be returnable, it must comply with NASA Planetary Protection requirements in order for future planners to request permission to return it, should they choose to do so.

Direct excerpts from the current NASA Procedural Requirement document for PP related to the returning a sample cache

5.3.3 PP Category V. The Earth return portion of a Mars Sample Return mission is classified as "Restricted Earth return," with all outbound portions required to meet associated requirements.

5.3.3.2 Unless specifically exempted, the outbound leg of the mission **shall meet PP Category IVb** requirements. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in the search for life in the sample after it is returned.

a. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later Mars missions.

5.3.2.2 PP Category IVb. Lander systems designed to investigate extant Martian life shall comply with all of the requirements of PP Category IVa and also with one of the following requirements:

EITHER

a. The entire landed system is restricted to a surface biological burden level of

≤ 30 spores (see 5.3.2.4) or to levels of biological burden reduction driven by the nature and sensitivity of the particular life-detection experiments, whichever are more stringent, and protected from recontamination.

OR

b. The subsystems which are involved in the acquisition, delivery, and analysis of samples used for life detection are sterilized to these levels. Methods for preventing recontamination of the sterilized subsystems and preventing contamination of the material to be analyzed is provided.

Information Source: K. Buxbaum

Implementation Priorities for Objective C

Measurements required by the 2020 Mars Rover **to achieve Objective C** are almost identical to those required for Objectives A and B.

- Required Measurements
  - Context imaging
  - Context mineralogy
  - Fine-scale imaging of arm work volume
  - Elemental chemistry of arm work volume
  - Fine-scale mineralogy of arm work volume

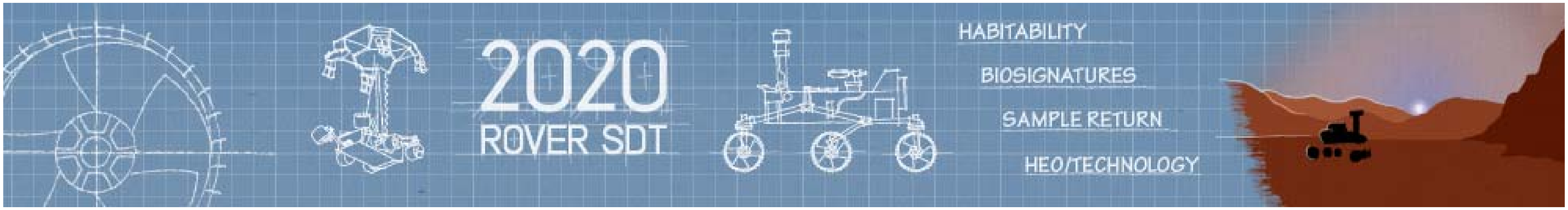
Science Threshold

- Additional "Baseline" Measurements
  - Organic detection

Science Baseline

UNRANKED Additional Possible Measurements Below the Baseline

Observations of the Collected Sample	Magnetometer	Age Dating



Mars 2020 Science Definition Team Report:

Part 3. Landing Site Considerations

John Grant, National Air and Space Museum

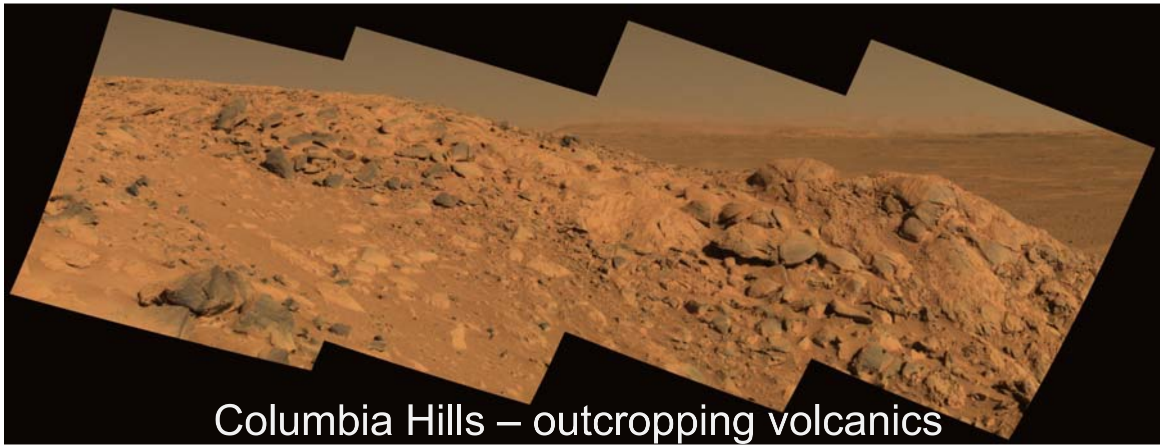
<u>NOTE</u>: The content of this presentation is drawn from the SDT's text report, and for further information, the interested reader is referred there (http://mepag.jpl.nasa.gov/reports/mep_report.html).

The content of this document has been cleared for public release by JPL Document Review, clearance number CL#13-2766

New science goals and objectives require a new landing site selection process

MSR Suggested Criteria	vs.	**MSL** Science Criteria	vs.	**2020** Science Criteria
Search for Habitability Search for Potential Biosignatures Biosignature Preservation **In-Place Igneous Rocks** …are all required to satisfy MSR science objectives.		Search for Habitability		Search for Habitability Search for Potential Biosignatures Biosignature Preservation

MSR E2E-iSAG (2012)



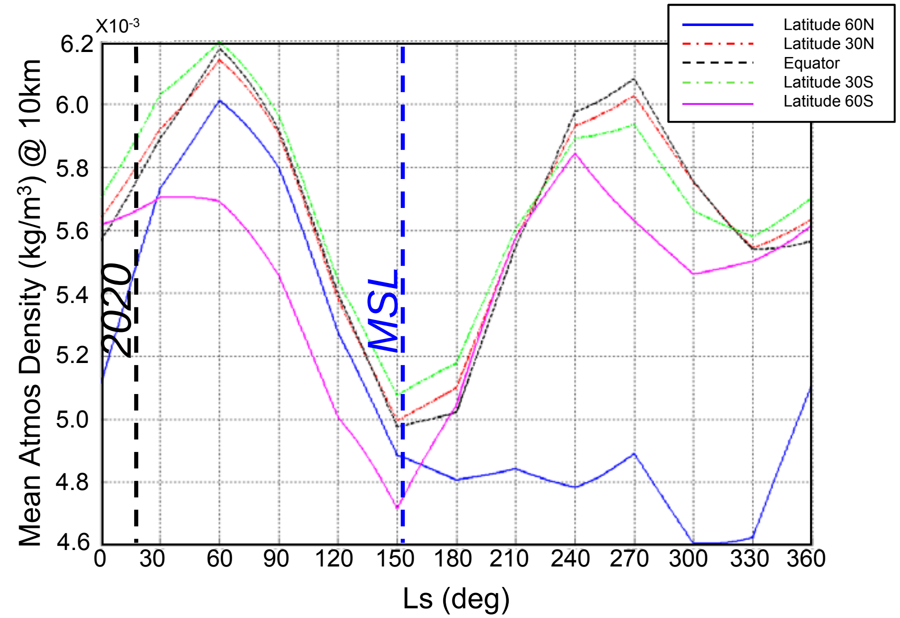
Outcropping igneous rocks are usually found in rocky, uneven locations with scarps, buttes, boulders – obvious landing challenges.

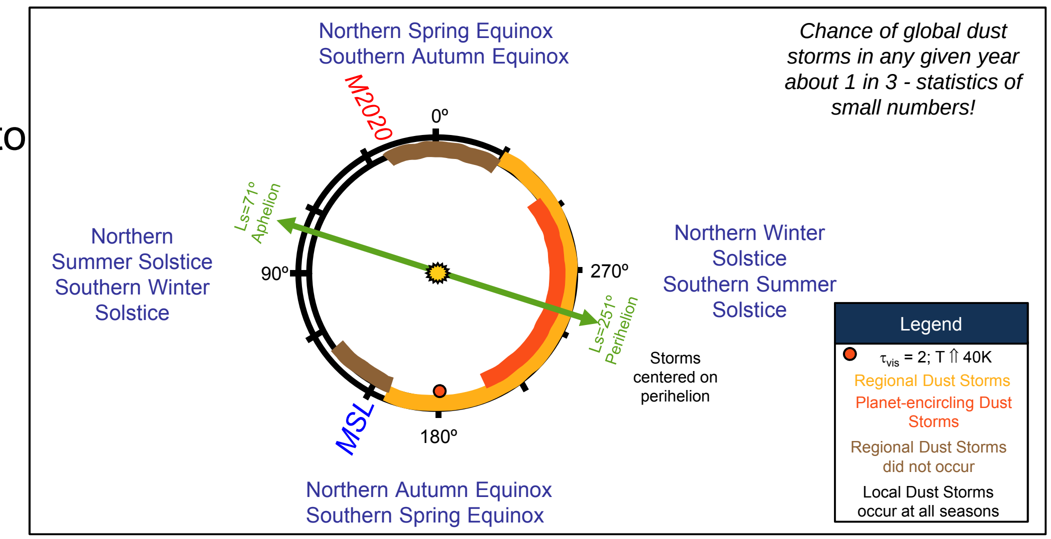
**Slide from 2020 Project Science, post SDT*

Differences Between MSL EDL As Applied and Access for 2020 Mission

Landing Site

- Pressure cycle very favorable for 2020
  - Mars orbit eccentricity transfers CO_2 from polar caps to atmosphere
  - Atmosphere significantly more dense than for MSL landing
- More density = capability to land safely at higher elevation
- 2020 atmosphere provides *significant "no cost" improvements* to landing elevation for same mass
- Expect 2020 unmargined capability up to 0.5 km elevation, -0.5 km margined
  - Some variability depending on landing site specific characteristics
  - Generic atmosphere assumptions believed to be conservative





Mars 2020 Field Site Selection Process

- Previous landing sites (e.g. Gale, Gusev, Meridiani) merit consideration as landing sites for Mars-2020, science Objectives B and C are different from those of prior missions and discoveries to date do not warrant pre-selection of any prior landing sites as the Mars-2020 landing site.
- There is also a growing inventory of diverse data available for evaluating the relative merits of varied existing and new candidate landing sites that will shed new light on their potential when evaluated by the broad expertise of the science community.
- If the 2020 mission carries Range Trigger, Terrain Relative Navigation (TRN), and/or Terminal Hazard Avoidance (THA) capabilities (discussed later), it will be able to access landing sites that could not have been considered or suggested previously.
- The SDT recommends that a landing site selection process be conducted, which would gather community input on candidate field sites and on critical decisions that will influence mission design and final site selection.

SDT FINDING

Mars 2020 would be the first mission to cache samples for possible return to Earth and may require a landing site selection process differing from those previous and tailored to a diverse set of scientific goals. It is therefore crucial to involve the broad expertise of the science community in proposing and evaluating candidate sites for the 2020 rover, thereby leading to science community consensus on the optimal site for meeting the mission goals

An Issue Regarding Igneous Rocks

- E2E-iSAG observed that to maximize returned sample science, the MSR sample collection would need to include **unaltered igneous rocks collected from outcrop**.
- E2E-iSAG evaluated the ~65 landing sites proposed for MSL, and found ~10 where **outcrops** of both igneous rocks and sedimentary/ hydrothermal rocks appear to be present at the same landing site. However, most of these sites would not be accessible to the MSL system as applied (see Slides 105-106).
- If unaltered igneous rocks in outcrop is a threshold-level landing site requirement (final decision on this to be reached by later groups/activities), then there may not be a sufficient population of sites to choose from given MSL as-flown EDL capabilities.

Reconciling the Issue: one or both of the following steps needs to be taken:

1. Relax the E2E-iSAG-proposed landing site criterion to **unaltered igneous rocks collected from either outcrop or float**. The latter would have adverse science consequences for the sample caching objective of Mars 2020.
2. Improve the MSL as-flown EDL system to increase the number of sites that can be accessed.

Sample community take note

SDT FINDING

Access to unaltered igneous rocks as float is considered a threshold-level field site requirement, but requiring that they be collected from known stratigraphic context would add significant science risk to the mission—it may be impossible to access a suitable field site using 'as applied' MSL capabilities.

Proposed 2020 Mission Reference Field Sites*

Reference Landing Site	Stressing Parameter	TRN† Required	THA† Required	Notes
Holden Crater	Latitude (-26° S)	Maybe – land closer to layers	No	Pushes southerly lat limits; TRN might enable "land on"
Jezero Crater	Rock Abundance	No	Yes	>1% failure without THA
Nili Fossae	Elevation (-0.6 km)	Yes	Yes (No if smaller ellipse)	Landing ellipse ranges up to 0 km elevation, 6% area scarps
E Margaritifer	Inescapable Hazards	Yes	Probably Not	>3% of landing ellipse is inescapable, 99% success with 300 m divert
NE Syrtis	Scarps	Yes	Maybe	>4% ellipse scarps, 99% success with 300 m divert
Melas Chasma	Landing Ellipse Size Wind	Yes	Probably	V. Marineris - Wind and Relief Issues? (ellipse size)

SDT FINDING

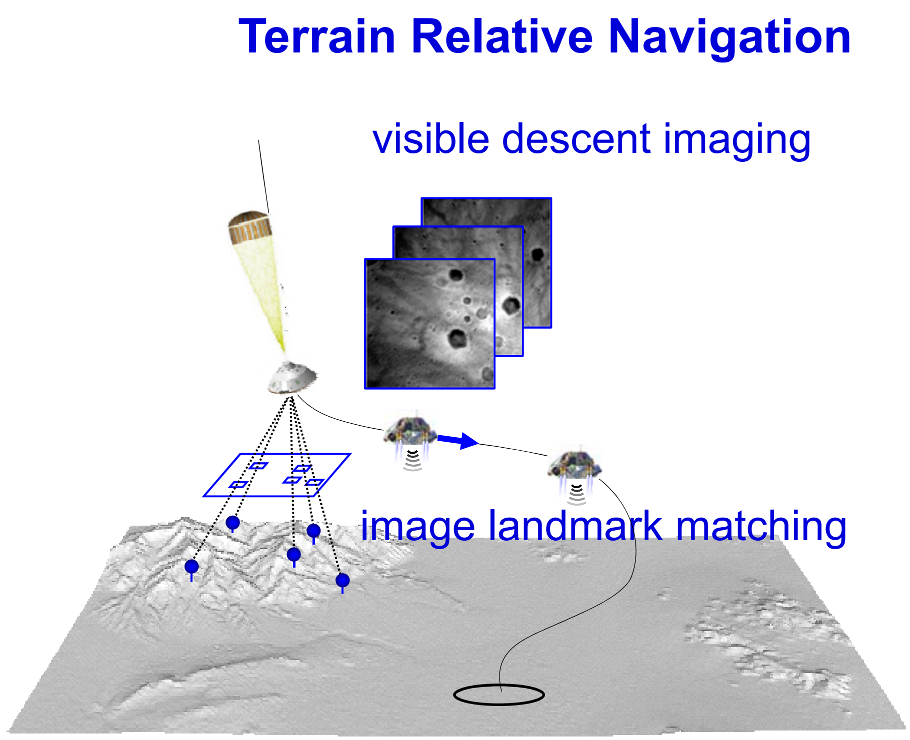
Six potential landing/field sites are identified as "stressors" on landing capabilities and encompass a sufficiently large population of candidate sites (>60, see table in Appendix 6) as to ensure high priority candidates remain as constraints evolve. These form an envelope which includes accommodation of the prior MER and MSL landing sites and many of the > 60 other sites between 30˚N and 30˚S that have been proposed by the science community for MSL and future missions.

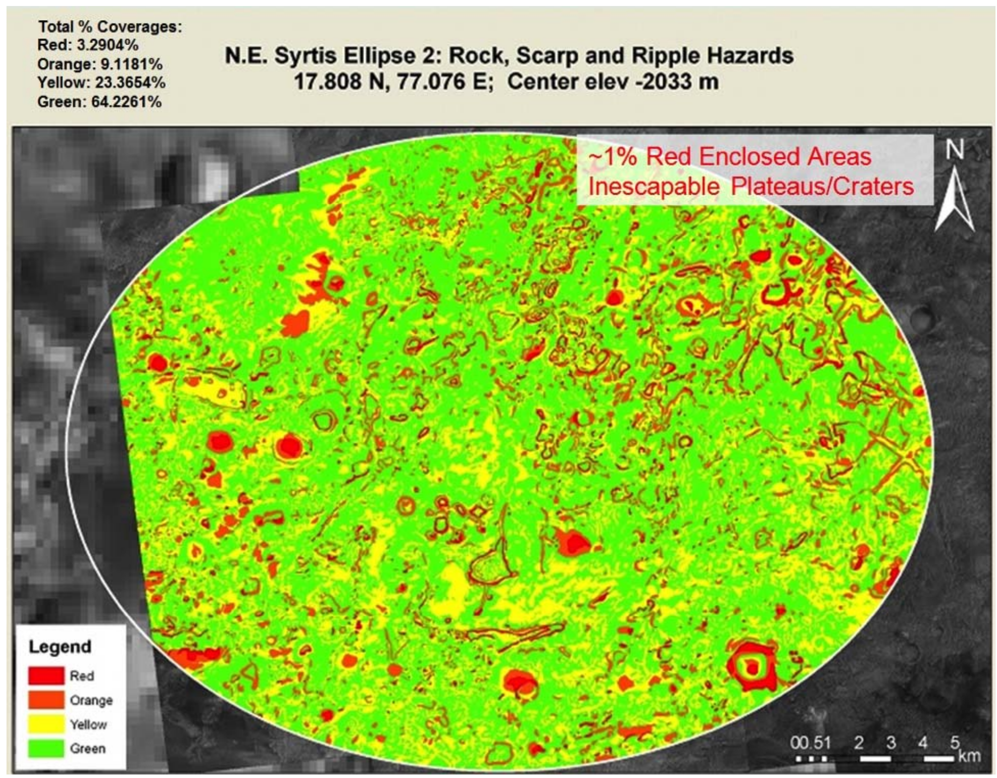
** The threshold engineering requirements defined by these reference sites enable access to prior landing sites in Gale, Gusev, and Meridiani*

† TRN = Terrain-Relative Navigation; THA = Terminal Hazard Avoidance.

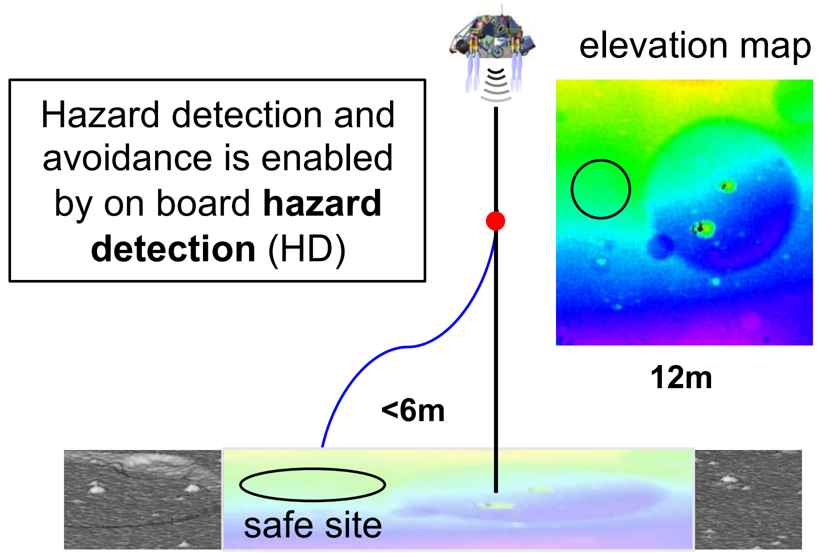
Terrain Relative Navigation

- Terrain Relative Navigation (TRN) allows improved accuracy of estimated location of vehicle during entry
- Could be used to avoid hazard areas within a landing ellipse by diverting around these hazards
- Enables access to landing sites that would otherwise be ruled out due to rock, scarp, and ripple hazards (see NE Syrtis example below)





- Terminal Hazard Avoidance (THA) is a combination of autonomous, real-time hazard detection and guided avoidance
- Enables access to landing sites with hazards that might not be visible in orbiter images, such as rocks and small-scale high slopes (see Jezero Crater example below)



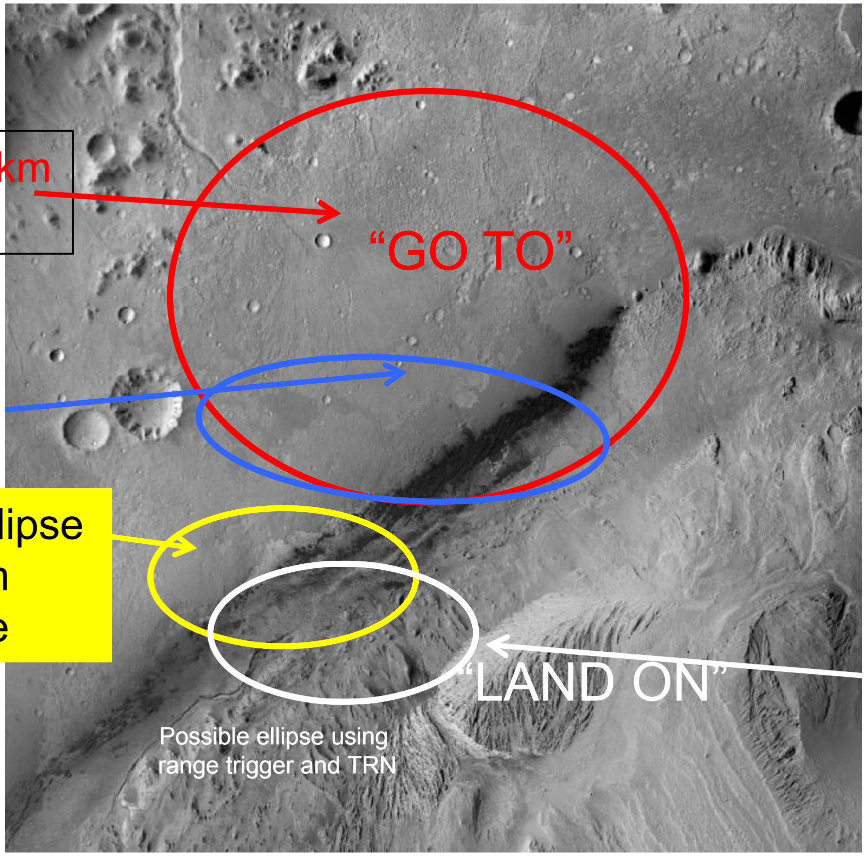
Example Benefits of Using Range Trigger & Terrain-Relative Navigation:

Eliminating the Drive to Mt. Sharp in Gale Crater

Proposed 25X20 km landing ellipse

Final MSL landing ellipse

Range Trigger ellipse
13 km x 7 km
best estimate



The combination of range trigger and TRN effectively makes Gale crater "land on" the lower slopes of Mt. Sharp.

Possible Ellipse in Gale crater using range trigger (best estimate) and TRN

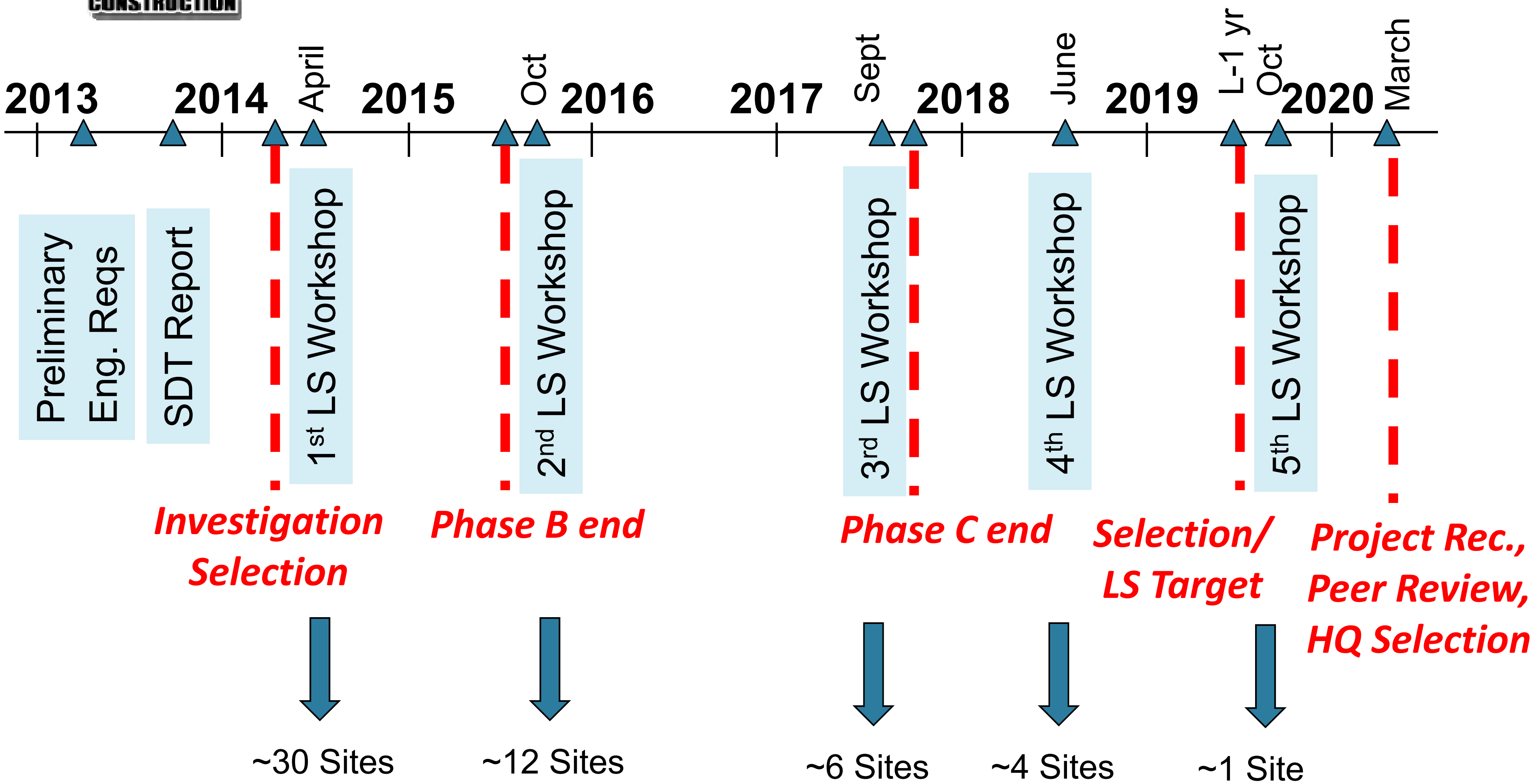
From Matt Golombek

SDT MAJOR FINDING #24

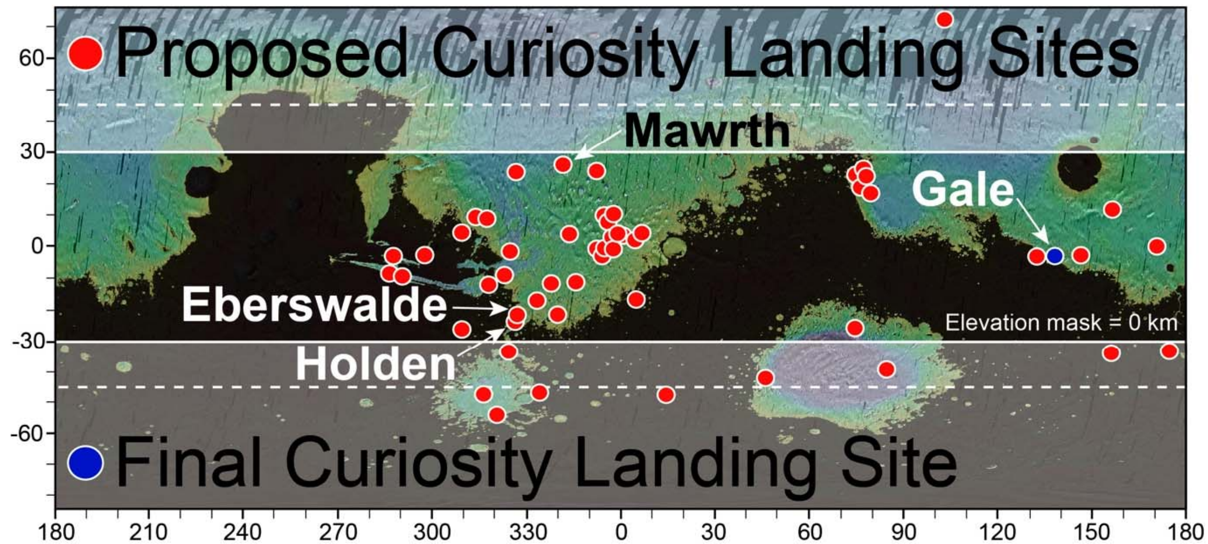
The SDT concludes that Range Trigger should be a threshold capability and strongly recommends inclusion of TRN as highest priority baseline to help ensure access to a sufficient number of high priority sites and to reduce science risk related to site selection. Terminal Hazard Avoidance (THA) has less impact on access to unique classes of sites and is considered "enhanced."

Possible Landing Site Selection Process Timeline

(derived in Post-SDT time period—not an SDT product)



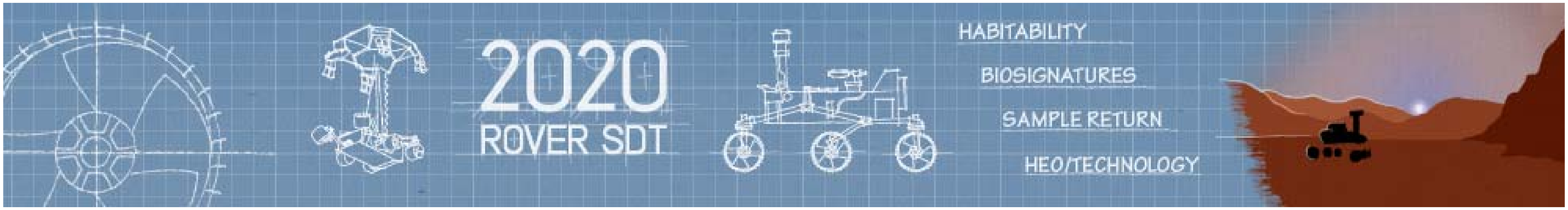
Access to High-value Science Landing Sites for Mars 2020



- Site selection for the Mars 2020 mission must satisfy the aspirations of *in situ* science and creating a returnable cache.
- A process to perform careful and full evaluation of diverse new and existing candidate landing sites is warranted.

SDT FINDING

The expertise of the science community can assist in making critical decisions about landing sites early enough in the mission design phase to limit costs for capabilities that are not adopted
(e.g., if community consensus finds that sites that need TRN can be eliminated from consideration for a Mars 2020 landing site, then TRN can be descoped before incurrent significant costs).



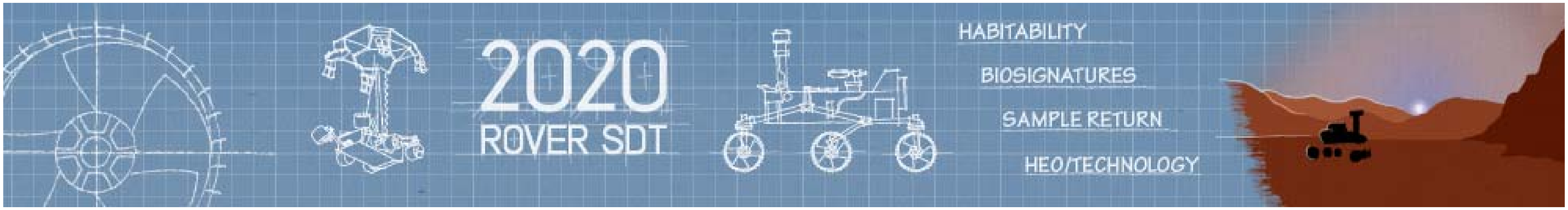
Mars 2020 Science Definition Team Report:

Part 4. Objective D, Mission-Level Investigation Strategy

Jack Mustard, Brown University

<u>NOTE</u>: The content of this presentation is drawn from the SDT's text report, and for further information, the interested reader is referred there (http://mepag.jpl.nasa.gov/reports/mep_report.html).

The content of this document has been cleared for public release by JPL Document Review, clearance number CL#13-2766



Options and Priorities to Achieve

Objective D

OBJECTIVE D

Provide an opportunity for contributed HEOMD or Space Technology Program (STP) participation, compatible with the science payload and within the mission's payload capacity.

Objective D

2020 Mars Rover: Why are these important NOW?

2010 National Space Policy: Humans to Mars by mid-2030s

2020s	2030s

Proof of Concept → Validation → Human Mission

2020 Rover

ISRU O_2 Production

- Demonstration of CO_2 collection in actual Mars environment reduces future risks. O_2 production is critical path of future human missions

MEDLI+

- Obtaining data lower in atmosphere reduces EDL uncertainties and risks

Surface Weather

- Understanding of long-term atmosphere behavior reduces future EDL risks

Biomarker

- Demonstrate detection of microbial contamination for future human missions

Human Sub-Scale Validation Demos

- Land Large Payload
- Advanced Aeroassist
- Supersonic Retro-Propulsion
- ISRU O_2 Production and Use
- Surface power

Future demonstration of sub-scale human relevant systems and technologies necessary to reduce risk and feed forward to human flight systems development

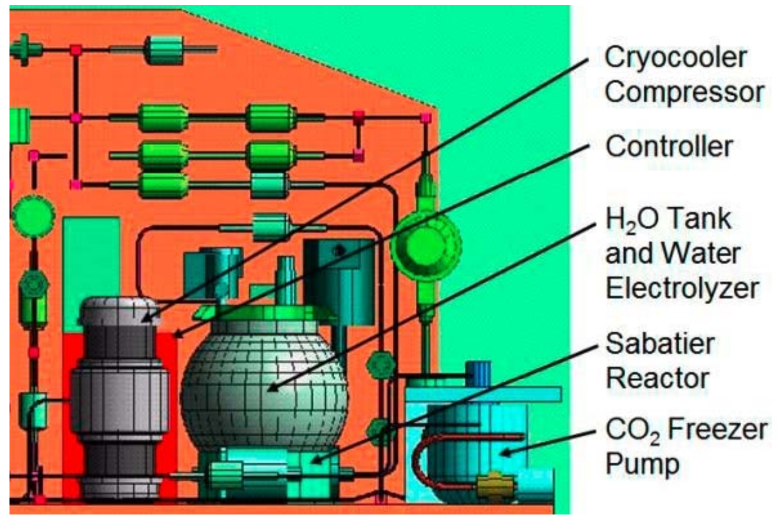
Human Systems Development

2020 Mars Rover: ISRU Is HEOMD's TOP priority

#1 HEO Priority: ISRU Demo

- Utilizing locally produced consumables (e.g. oxygen for ascent) provides great leverage for human exploration of Mars
- Key technical issue: Data needed to support performance and reliability assessments, before we bet the lives of a crew of astronauts on it
- Much progress can be made in Mars environmental chambers on Earth, but some things require information from a Mars surface mission.
  - Testing in the actual relevant environment (discover unknown unknowns)
  - Most important general area of concern is the dust environment, which varies in unpredictable ways, and could have severe consequences on a future ISRU systems

O2 ISRU Schematic



NOTE:

This kind of demo can be run on a non-interference basis with science ops.

The Importance of Supporting Atmospheric Data

- Need to understand regional dust context to understand WHY and HOW dust is affecting the ISRU demo.
- Needed to interpret data from the demo to apply to other places/times
- Data of value (priority order): Wind, Pressure, Temperature

In-Situ Resource Utilization is the HEOMD top priority demonstration for the 2020 Mars Rover

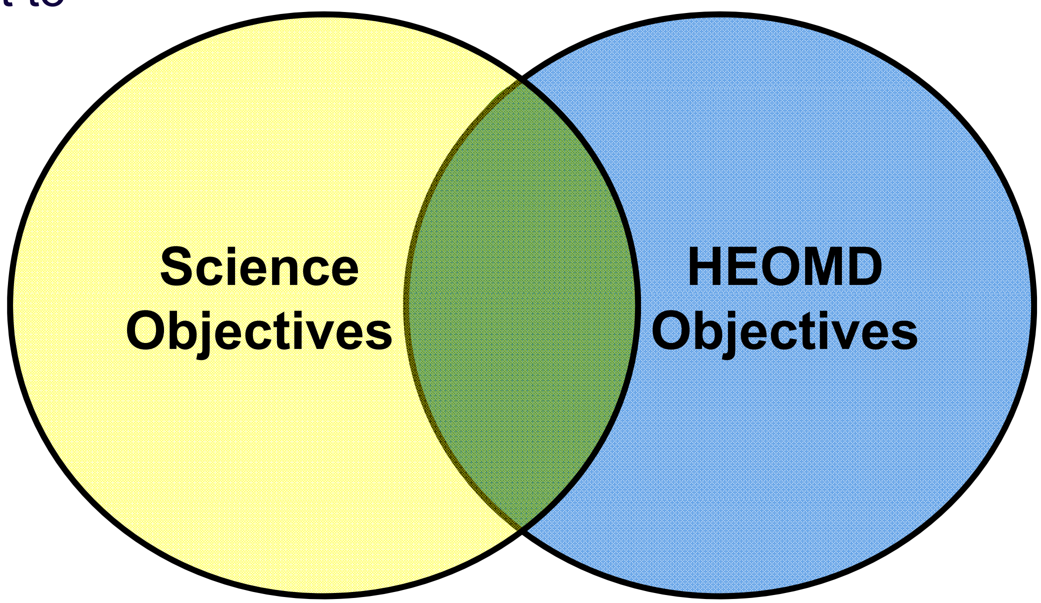
How much synergy between HEOMD & SMD?

In the proposed mission concept, science & human preparation objectives have synergy in three significant ways:

1 The instruments required for the science objectives are relevant to many SKGs.

2 The measurements/demos proposed by HEO satisfy some Mars science objectives.

3 A returnable cache of samples, if properly selected, would be of major interest to both.



SDT MAJOR FINDING

The top-priority measurements that address HEOMD strategic knowledge gaps also benefit Mars science.

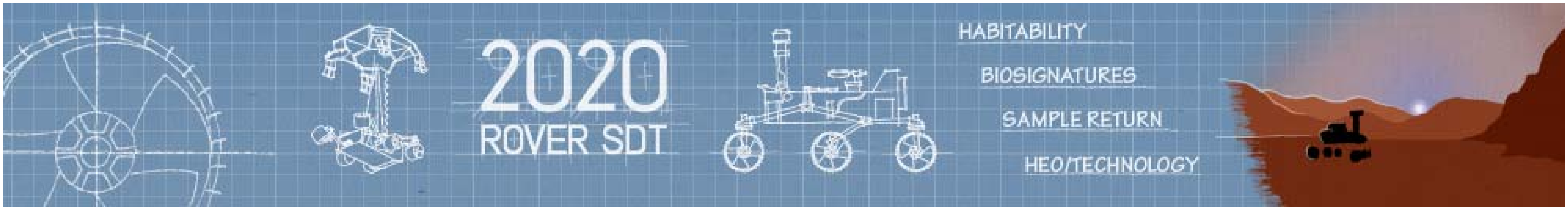
High Priority Candidate STMD Payloads

Instrument/Demo	Description	Forward Benefits	STP Priority	Funding
Range Trigger	Software for parachute deployment based on range to target	Precision landing, site access	H	SMD
Terrain-relative Navigation (TRN) [1]	Divert to avoid a priori hazards and/or get closer to science targets	Precision landing, site access, pinpoint landing	H[2]	STMD HEO
MEDLI	EDL instruments as flown on MSL	Inform future applications and developments	H	STMD HEO
MEDLI +Up[3]	Parachute deployment, operation and drag observations	Inform future applications and developments	H	STMD

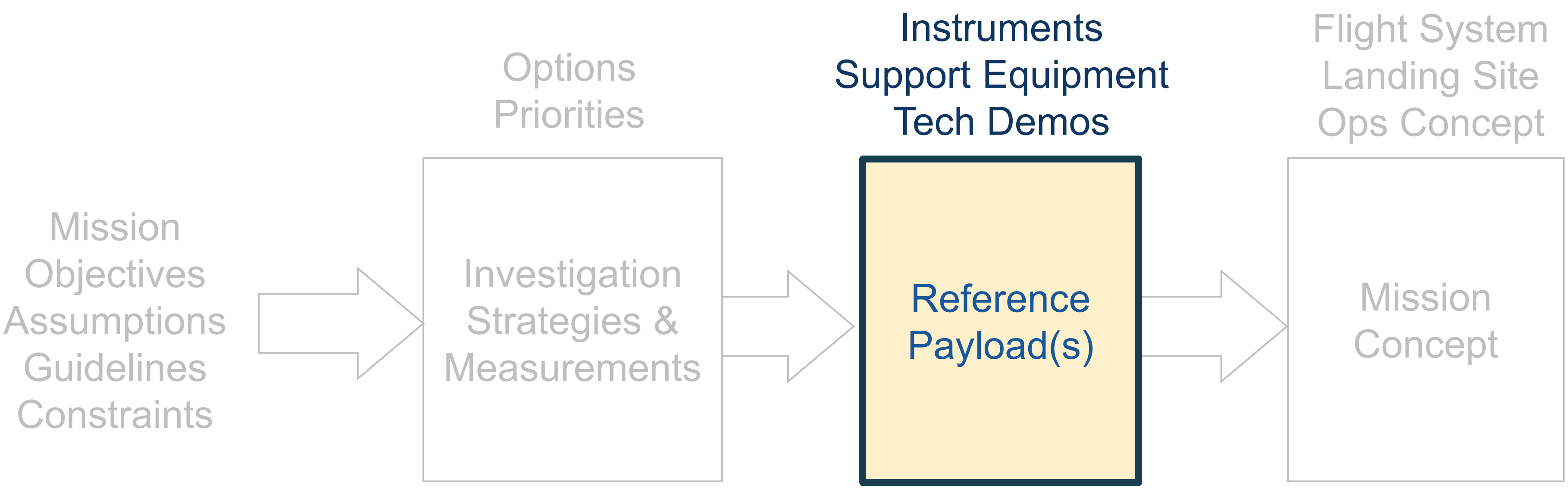
1. Recommended instantiation for 2020 would be location determination only — enhancements could include altimetry, velocimetry, and/or real-time hazard avoidance
2. To be considered by the Landing Site subteam in Phase II.
3. Development risk depends on existence and complexity of up-look camera and its interface.

SDT FINDING

The high-priority technology payloads, based on benefit and risk are: Range Trigger, Terrain-Relative navigation, and MEDLI/MEDLI+Up



Reference Payloads



Measurements/Demos by Objective

<table>
<tr><th>Objective A
Geology</th><th>Objective B
Biosignatures</th><th>Objective C
Caching</th><th>Objective D
HEO/Tech</th></tr>
<tr><td colspan="3">THRESHOLD
Instruments addressing all 6 threshold measurements</td><td rowspan="2">OPTIONS</td></tr>
<tr><td>Measurements/Capabilities</td><td>Measurements/Capabilities</td><td>Measures/Capabilities</td></tr>
<tr><td>•Context Imaging
•Fine-Scale Imaging
•Context Mineralogy
•Fine-Scale Elem Chem
•Fine-scale Mineralogy</td><td>•Context Imaging
•Fine-Scale Imaging
•Context Mineralogy
•Fine-Scale Elem Chem
•Fine-scale Mineralogy
•Reduced/Organic C detection</td><td>•Context Imaging
•Fine-Scale Imaging
•Context Mineralogy
•Fine-Scale Elem Chem
•Fine-scale Mineralogy</td><td rowspan="5">• ISRU Demo
• EDL Data
• EDL Precision & Site Access
• Surface Weather Monitoring
• Biohazards to Astronauts</td></tr>
<tr><td colspan="3">BASELINE OPTIONS
Enhanced-capability instrument(s) in THRESHOLD category OR add one of the following:</td></tr>
<tr><td>•Subsurface Sensing
•Organic C detection</td><td>•2nd method of Organic C Detection</td><td>•Organic C Detection</td></tr>
<tr><td colspan="3">ENHANCED OPTIONS
Enhanced-capability instrument(s) in THRESHOLD category AND an additional BASELINE or ENHANCED instrument</td></tr>
<tr><td></td><td>•Molecular Analysis</td><td></td></tr>
</table>

SDT MAJOR FINDING

The measurements that would be required to meet the geology and habitability, biosignatures, and caching objectives are similar. Thus, these three objectives are compatible and well-suited to be assigned to the same mission.

Proposed "Straw" Instrument Lists

The priority of baseline options depends on budget scaling up or down, and the strength of the proposals submitted in response to the AO.

Science Instrument Straw Payloads[1]

Functionalities Required	Blue Straw Payload	$ High, Med, Low	Orange Straw Payload	$ High, Med, Low
Context imaging	**Mastcam-like**	M	**Mastcam-like**	M
Context Mineralogy	**UCIS-like**	M	**mTES-like**	M
Elemental Chemistry	**APXS-like**	L	**µXRF-like**	L
Fine-scale imaging	**MAHLI-like**	M	**MMI-like**	M
Fine-scale mineralogy	**Green Raman-like**	H		
Organic Detection			**Deep UV-like**	H
Science support equipment	Includes cache, sampling system, surface prep tool			
Technology payload elements	Includes range trigger			
Threshold Total (SMD funded)		**~90**		**~90**
Additional Instrument Options	**GPR**	M	**GPR**	M
HEO contributed payload	**ISRU**		**ISRU**	
Technology payload elements	Includes TRN			
Baseline Total (SMD funded)		**~105**		**~105**

[1]Cost totals are instruments only; do not include science support equipment.

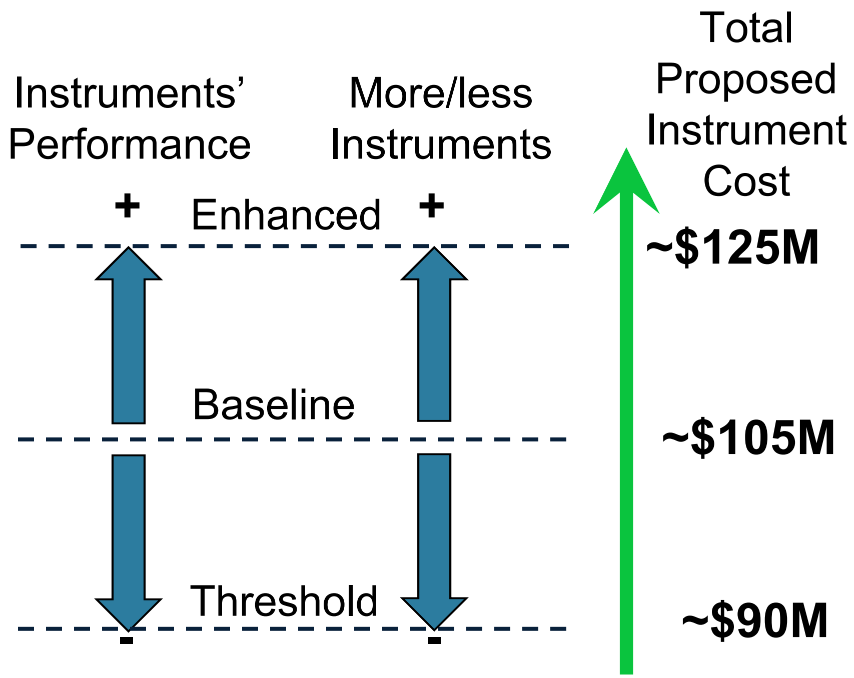
Baseline and Threshold Options

A baseline mission would include one or more of the following (not listed in priority order):

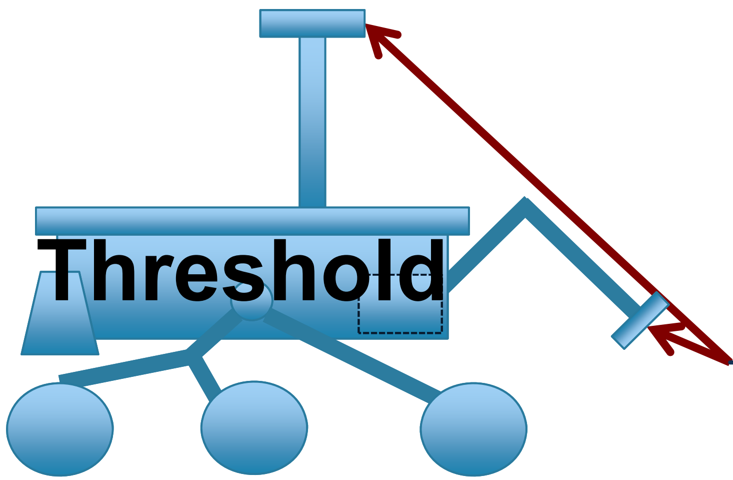
- **Superior capabilities (e.g., resolution, range of minerals detected, accuracy) for instruments in the threshold measurements category: "superiority" to be evaluated in the instrument competition**
- **A second organic detection capability complementary to the first one**
- **An instrument that measures subsurface structure or composition**

Scaling Up or Down

- The SDT has been asked to "*describe priorities for scaling the mission concept either up or down (in cost and capability).*"
- Many of the threshold measurements can be implemented by a range of instruments that vary in cost and performance.
- Thus, to first order, scaling either up or down can be accomplished within the SDT's vision of the mission by NASA selecting either higher or lower cost/performance instruments in each measurement category, and/or by selection of an instrument from the "baseline" and "enhancement" set.



This trade and cost scaling needs to be done as part of evaluating the response to the AO, not by this SDT.



Range Trigger
Improved EDL error ellipse.

All measurements below of "good" quality

Context Imaging
Panoramic color and stereo/ranging capabilities for science and operations

Context Mineralogy
Survey outcrop-scale mineralogy
Identify mineralogy and abundances

Fine-scale Imaging
Determine fine-scale details, textures, and structures

Fine-scale Mineralogy
Identify major, minor, and trace minerals and related features and textures

Fine-Scale Elem. Chemistry
Identify elemental abundances

Organic Detection
Detect and measure organic materials and compounds with good sensitivity

It is assumed that ~2-3 instruments would be located on the mast, with the remainder located on the arm, but some of these measurements can be performed from either position.

Science Support Functions

Sample Cache

Sample Encapsulation/Caching
- Encapsulation dust-tight

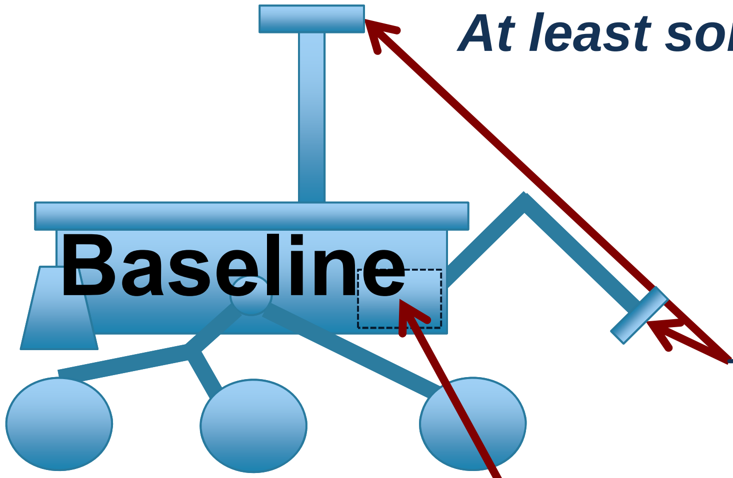
Surface Preparation Tool
Brushing and grinding capabilities

Rock/Regolith Coring Tool
For sample acquisition

Sampling Support
- blanks/standards
- Extra bits

Sample Cleanliness
Sample purity to <40 ppb Earth-sourced organics

Baseline Measurements and Capabilities



At least some measurements below of "better" quality

Context Imaging
Panoramic color and stereo/ranging capabilities for science and operations

Context Mineralogy
Survey outcrop-scale mineralogy
Identify mineralogy and abundances

Fine-scale Imaging
Determine fine-scale details, textures, and structures

Fine-scale Mineralogy
Identify major, minor, and trace minerals and related features and textures

Fine-Scale Elem. Chemistry
Identify elemental abundances

Organic Detection
Detect and measure organic materials and compounds with good sensitivity

or

7th Measurement
To be decided by competition among subsurface sensing, or organic detection method #2,

Range Trigger
Improved EDL error ellipse.

ISRU
Collect CO2. Analyze dust size and shape

TRN
Improved EDL—terrain hazards

Science Support Functions

Sample Cache

Sample Encapsulation/Caching
- Encapsulation air-tight

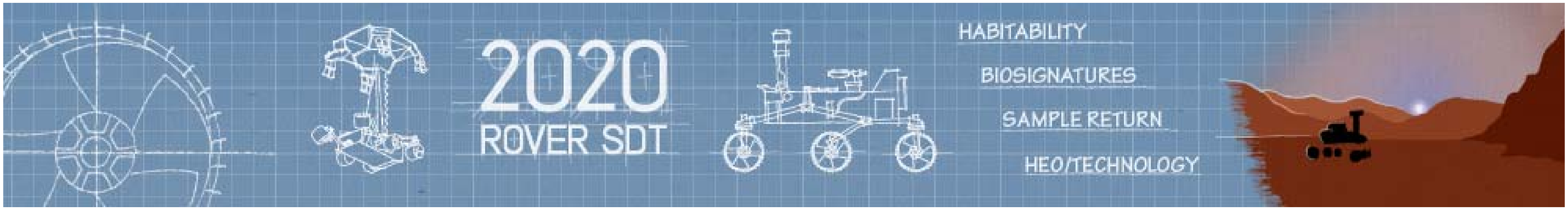
Surface Preparation Tool
Brushing and grinding capabilities

Rock/Regolith Coring Tool
For sample acquisition

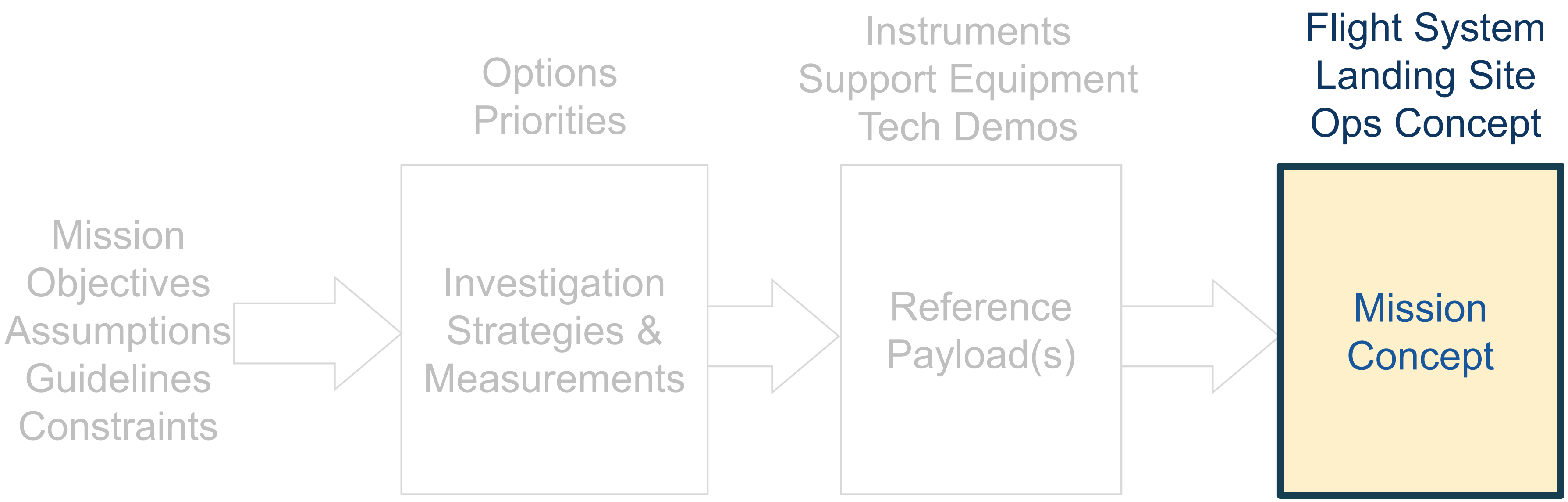
Sampling Support
- blanks/standards
- Extra bits

Sample Cleanliness
Sample purity to <10 ppb Earth-sourced organics

Capability to Observe Cores
Use instruments on cores



Mission Concept



Planning Considerations Related to the Surface Operations Scenario

Strategy: High-level Conclusions

Plausible mission scenarios can be found throughout this triangle –

**trading drive distance,
total number of cached samples,
& number of cached samples
within a characterized suite**

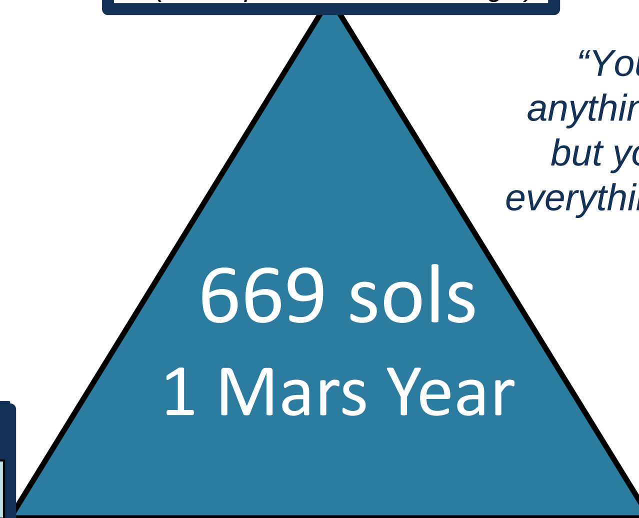
– to suit a variety of possible landing sites.

Quantity of

Field Work

e.g.,
3 km total driving
20 samples
full complement of fieldwork
(1 core per characterized target)

"You can get anything you want, but you can't get everything you want."



Quantity of

Coring/Caching

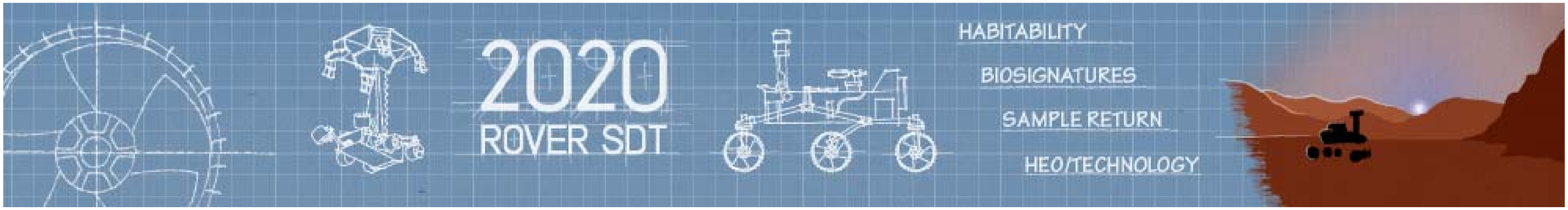
e.g.,
5 km total driving
34 samples
2 cores per characterized target

Quantity of

Driving

e.g.,
15 km total driving
20 samples
2 cores per characterized target

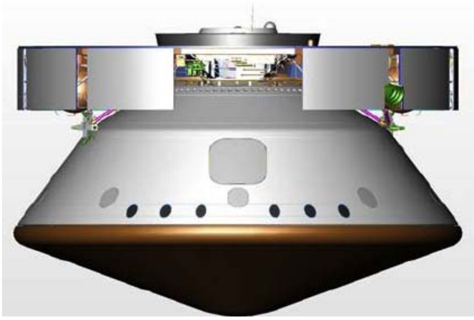
SDT FINDING	With the proposed mission concept, the charter-specified objectives for Mars 2020 can be achieved at a variety of different landing sites.
SDT MAJOR FINDING	Multiple strategies to improve on the modeled, reference operations scenarios Will be available as the proposed mission is further developed.



Strawman Spacecraft Accommodation

Strawman

Mission Overview – Strawman Independent

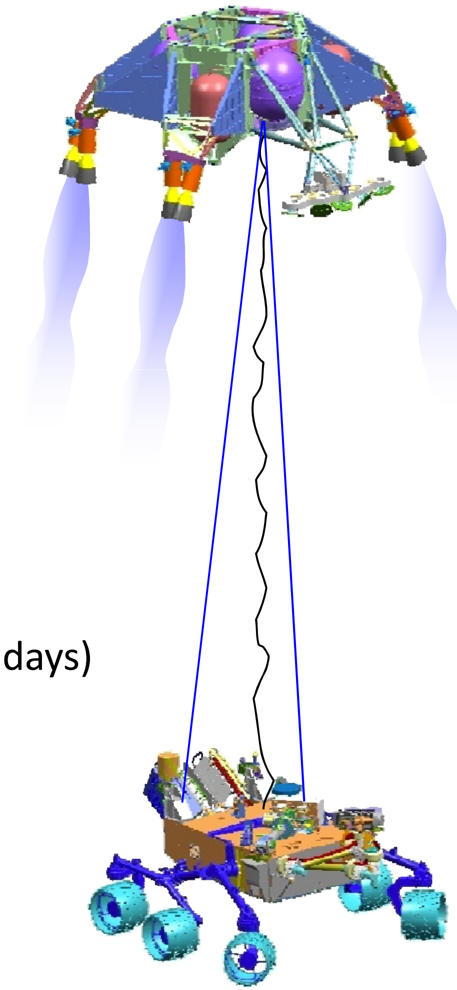


CRUISE/APPROACH

- 8 to 9-month cruise
- Arrive Jan/Mar 2021
- No changes from MSL (equivalent checkout capability, etc.)

ENTRY, DESCENT, LANDING

- MSL EDL system: guided entry and powered descent/Sky Crane
- 25 x 20 km landing ellipse*
- Access to landing sites ±30° latitude, ≤ 0 km elevation*
- ~950 kg rover
- Technology enhancements under consideration



SURFACE MISSION

- Prime mission is one Mars year (669 days)
- Latitude-independent and long-lived power source
- Ability to drive out of landing ellipse
- Direct (uplink/downlink) and relayed (downlink) communication
- Fast CPU and large data storage

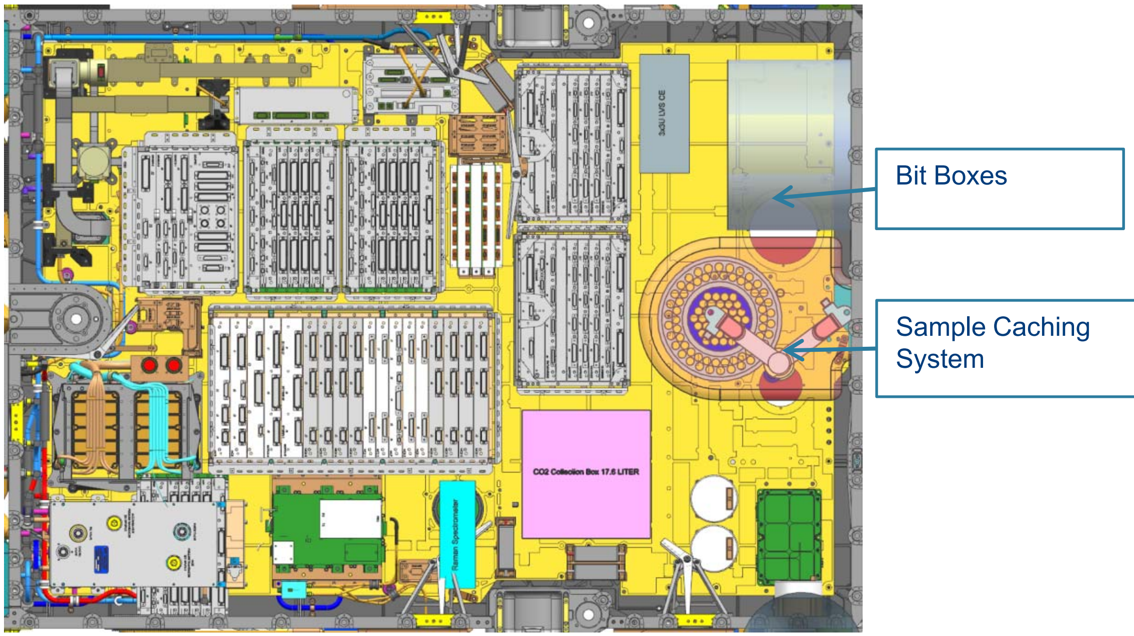
*EDL in work

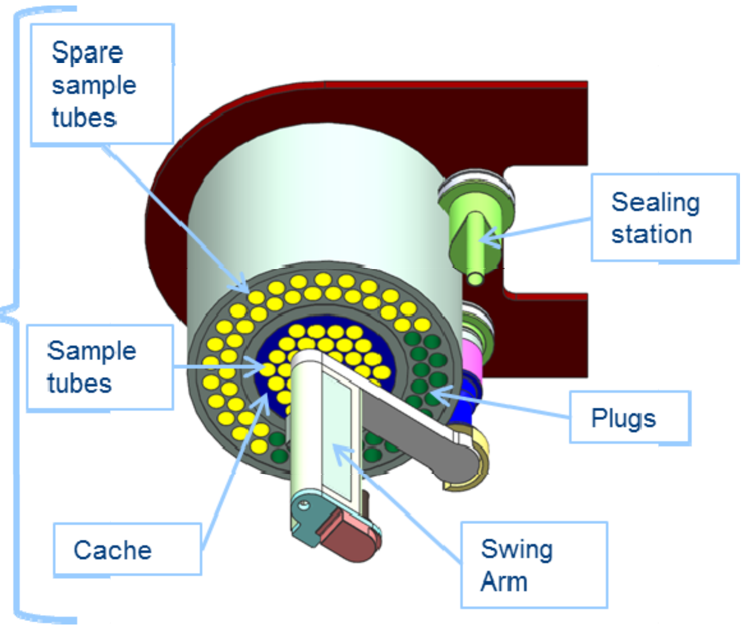
LAUNCH

- Atlas V Class
- Period: Jul/Aug 2020

Strawman

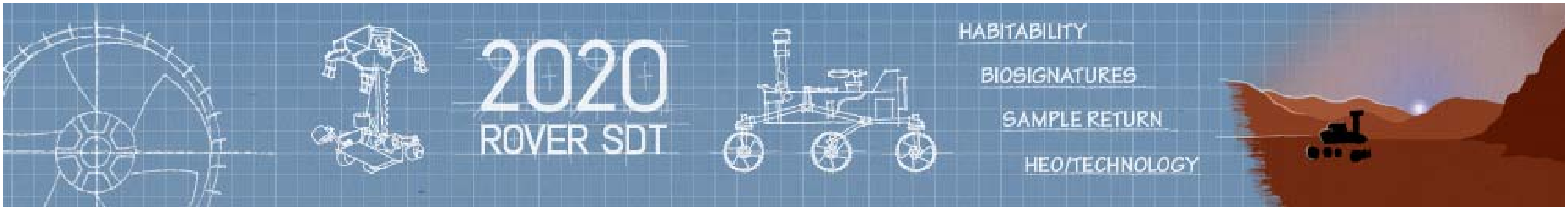
Rover Avionics Mounting Panel (RAMP)
Blue Straw Payload Accommodation Example





Concept shown is one of many possible design solutions

SDT MAJOR FINDING	This mission concept preserves maximum MSL heritage. The payload and a few specific elements are unique to the Mars 2020 rover concept.



Conclusions

Major Findings

Primary Technical Conclusions

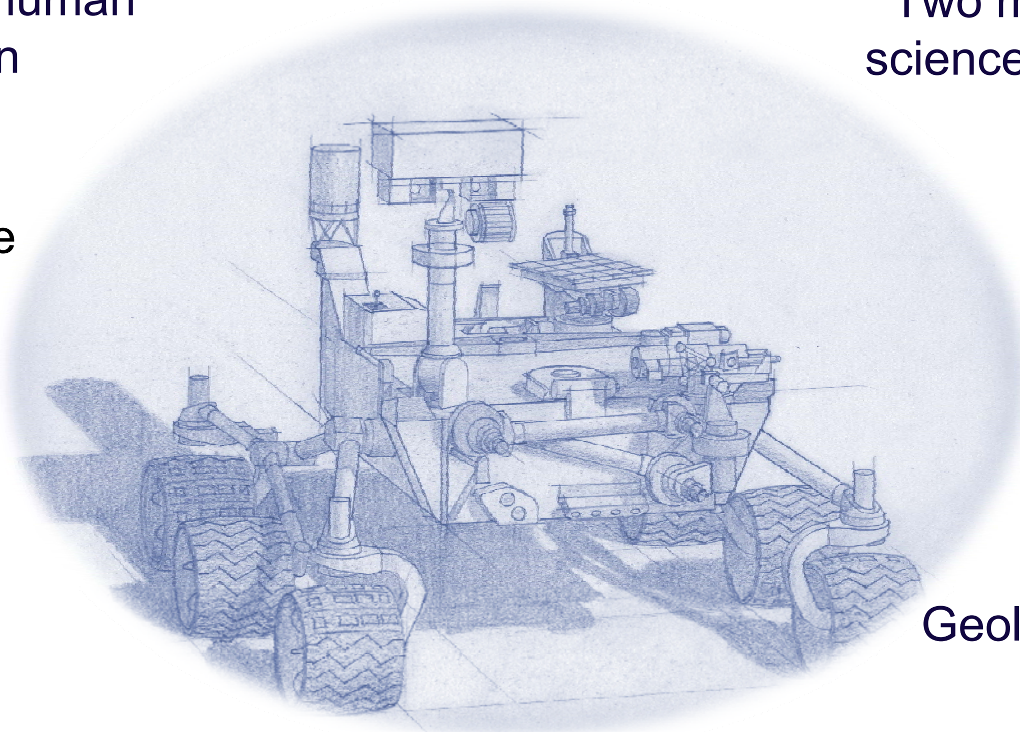
- The **measurements** needed to explore a landing site on Mars to interpret habitability and the potential for preservation of biosignatures and to select samples for potential future return to Earth are identical.
- Significant technical progress towards MSR requires a returnable cache.
- Arm- and mast-mounted instrument data are necessary and sufficient to achieve the required science.
- An instrument set capable of the following measurements would be the foundation of an efficient, lower cost rover.
  - Context Imaging
  - Context mineralogy
  - Fine-scale imaging
  - Fine-scale elemental chemistry
  - Fine-scale mineralogy
  - Organic detection
- The payload needed to achieve the three scientific objectives of the mission fill much, but not all, of an MSL heritage rover. This creates valuable opportunity for HEO to address long-lead strategic knowledge gaps.

Summary of the SDT's Vision

Seeking signs of past life

Prepare for human exploration

Two major *in situ* science objectives



Returnable cache of samples

Coordinated, nested context and fine-scale measurements

Coring system

Geologically diverse site of ancient habitability

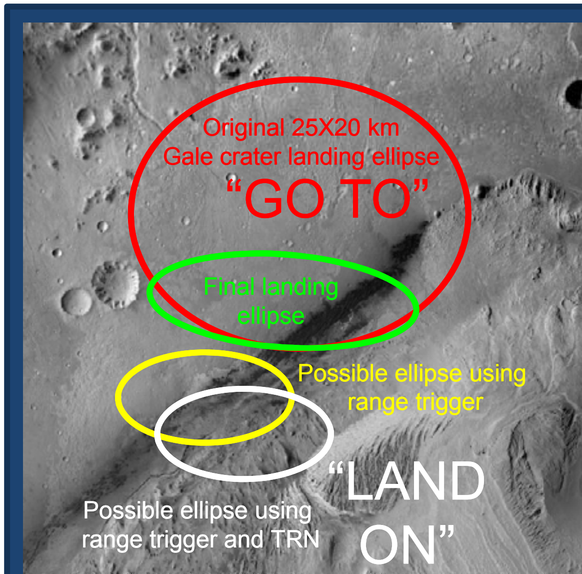
Efficient surface operations, one Mars-year lifetime

MSL heritage rover

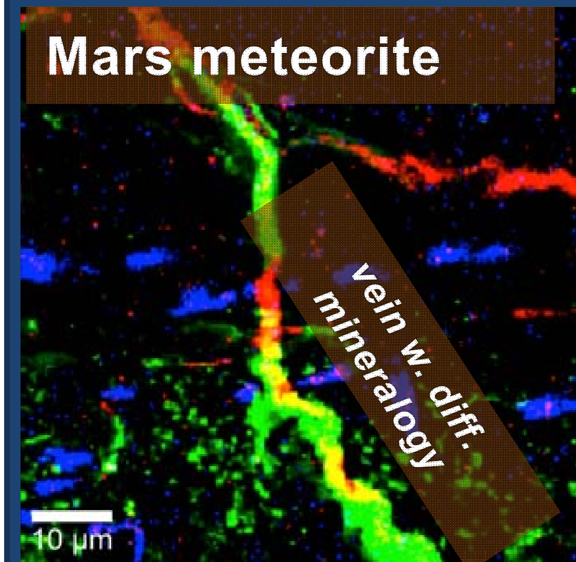
Improved EDL for landing site access

Why is the SDT Excited about this Mission?

The 2020 Mars Rover mission offers many important advances relative to MER and MSL:

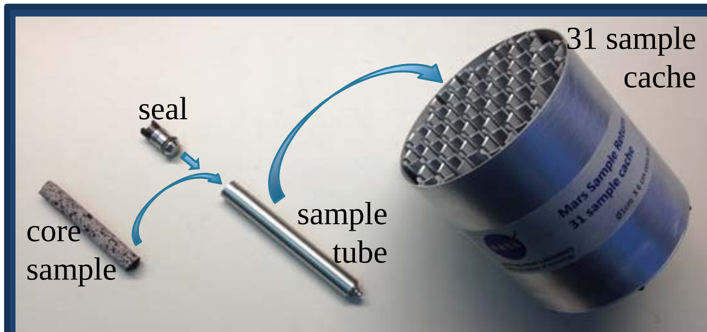


Potential to land on high priority scientific targets previously out of reach, shorten drive distances



Measurements of fine-scale mineralogy, chemistry, and texture in outcrop (petrology)

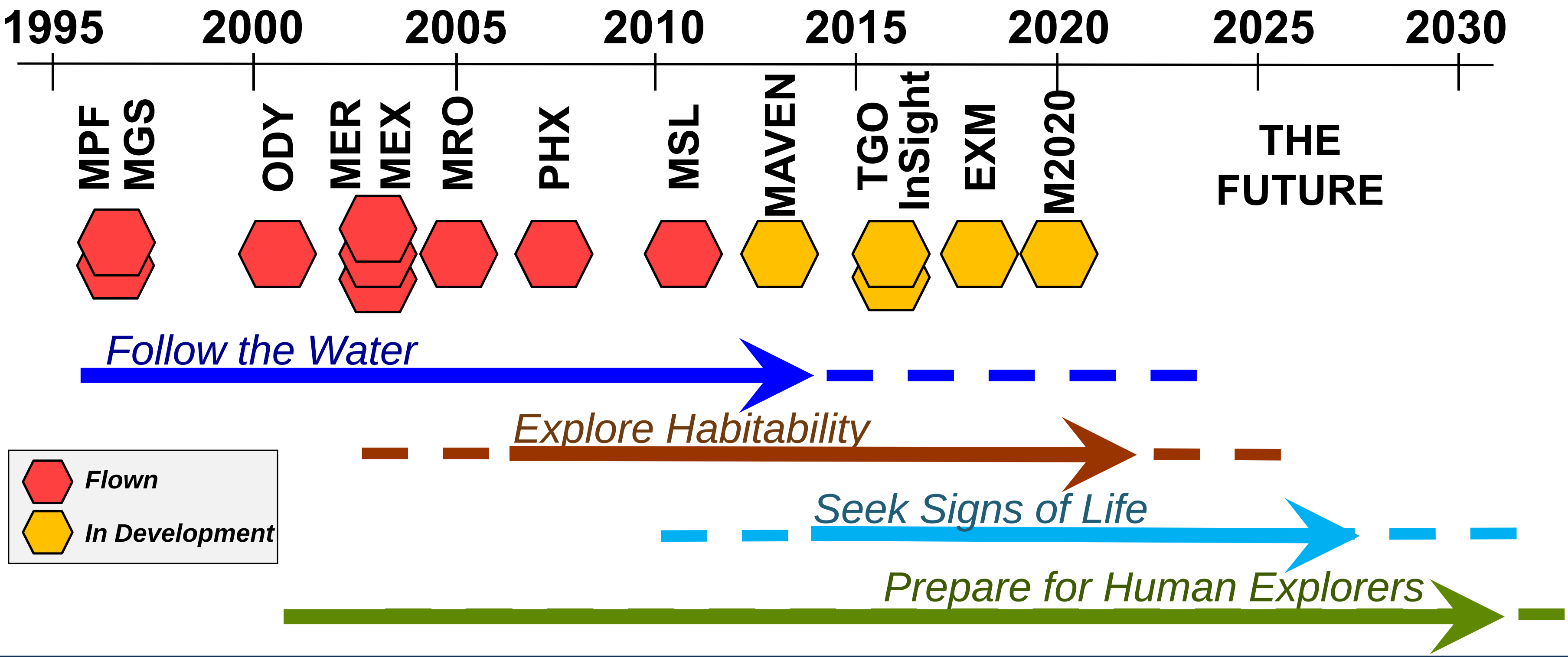
Payload designed to recognize potential biosignatures in outcrop



The ability to collect compelling samples for potential future return

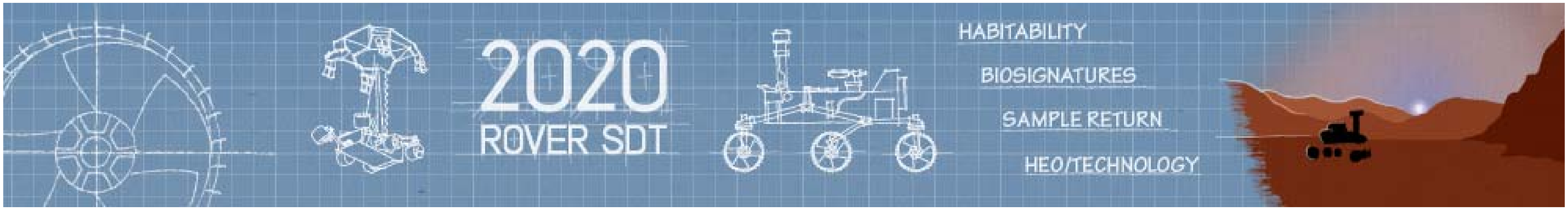
Prepare for the future human exploration of Mars

The Exploration of Mars – What's Next?



The proposed Mars 2020 mission would be:

- ***positioned to capitalize on past strategic investments at Mars, and to set the stage for direct testing of life-related hypotheses***
- ***A crucial element in executing NASA's strategic plan***
- ***The most important next strategic mission to Mars***
- ***Aligned with Decadal Survey's priorities for solar system exploration***



Backup Material

SDT Roster

Name	Professional Affiliation	Interest/Experience
Chair		
Mustard, Jack	Brown University	Generalist, geology, Remote Sensing, MRO, MEPAG, DS, MSS-SAG
Science Members (n = 16)		
Allwood, Abby	JPL	Field astrobiology, early life on Earth, E2E-SAG, JSWG, MSR
Bell, Jim	ASU	Remote Sensing, Instruments, MER, MSL, Planetary Society
Brinckerhoff, William	NASA GSFC	Analytical Chemistry, Instruments, AFL-SSG, MSL(SAM), EXM, P-SAG
Carr, Michael	USGS, ret.	Geology, Hydrology, ND-SAG, E2E, P-SAG, Viking, MER, PPS
Des Marais, Dave	NASA ARC	Astrobio, field instruments, DS, ND-SAG, MER, MSL, MEPAG
Edgett, Ken	MSSS	Geology, geomorph, MRO, MSL, MGS, cameras, E/PO
Eigenbrode, Jen	NASA GSFC	Organic geochemistry, MSL, ND-SAG
Elkins-Tanton, Lindy	DTM, CIW	Petrology, CAPS, DS
Grant, John	Smithsonian, DC	geophysics, landing site selection, MER, HiRISE, E2E, PSS
Ming, Doug	NASA JSC	Geochemistry, MSL (CHEMIN, SAM), MER, PHX
Murchie, Scott	JHU-APL	IR spectroscopy, MRO (CRISM), MESSENGER, MSS-SAG
Onstott, Tullis (T.C.)	Princeton Univ	Geomicrobiology, biogeochemistry
Ruff, Steve	Ariz. State Univ.	MER, spectral geology, MGS (TES), MER, ND, E2E, JSWG
Sephton, Mark	Imperial College	Organics extraction and analysis, ExoMars, Astrobiology, E2E
Steele, Andrew	Carnegie Inst., Wash	astrobiology, meteorites, samples, ND-, P-SAG, AFL-SSG, PPS
Treiman, Allen	LPI	Meteorites, Samples, Igneous Petrology
HEO/OCT representatives (n = 3)		
Adler, Mark	JPL	Technology development, MER, MSR,
Drake, Bret	NASA JSC	System engineering, long-lead planning for humans to Mars
Moore, Chris	NASA HQ	technology development, planning for humans to Mars
Ex-officio (n = 7)		
Meyer, Michael	NASA HQ	Mars Lead Scientist
Mitch Schulte	NASA	Mars 2020 Program Scientist
George Tahu	NASA	Mars 2020 Program Executive
David Beaty	JPL	Acting Project Scientist, Mars Program Office, JPL
Deborah Bass	JPL	Acting Deputy Proj. Sci, Mars Program Office, JPL
Jim Garvin	NASA	Science Mission Directorate
Mike Wargo	NASA	HEO Mission Directorate
Observer (n = 1)		
Jorge Vago	ESA	Observer
Supporting resources (n = 2)		
Wallace, Matt	JPL	Deputy Project Manager, 2020 Surface Mission, designated engineering liaison
Milkovich, Sarah	JPL	SDT documentarian, logistics

Glossary

AO Announcement of Opportunity
APXS Alpha-Particle X-ray Spectrometer
CCBU ChemCam Body Unit
CE Compute Element
CheMin Chemistry & Mineralogy X-Ray Diffraction/X-Ray Fluorescence Instrument
CHNOPS carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur
CPU Central Processing Unit
EDL Entry, Descent, and Landing
EPC Electronic Power Conditioner
EXM ExoMars
HA Terminal Hazard Avoidance
HEO or HEOMD Human Exploration and Operations Mission Directorate
IMU Inertial Mass Unit
ISRU In Situ Resource Utilization
LVS Lander Vision System
MAHLI Mars Hand Lens Imager
Mastcam Mast Camera, an MSL instrument
MAVEN Mars Atmosphere and Volatile EvolutioN
MEDLI MSL Entry Descent and Landing Instrument
MEDLI+ next generation of MEDLI
MEPAG Mars Exploration Program Analysis Group
MER Mars Exploration Rovers
MEX Mars Express
MGS Mars Global Surveyor
µXRF Micro X-Ray Fluorescence
MMI Mars Micro Imager
MPF Mars Pathfinder
MRO Mars Reconnaissance Orbiter
MSL Mars Science Laboratory
MSR Mars Sample Return
mTES or mini-TES Miniature Thermal Emission Spectrometer
IR Infrared
OCM Organic Check Material
ODY Mars Odyssey
OM Organic matter
PHX Mars Phoenix Lander
RAD Radiation Assessment Detector
RAT Rock Abrasion Tool
RCE Rover Compute Element
REE Rare Earth Elements
REMS Rover Environmental Monitoring Station
RGB red, green, blue
SAM Sample Analysis at Mars instrument suite
SCS Sample Caching System
SDST Small Deep Space Transponder
SDT Science Definition Team
SKG Strategic Knowledge Gaps
SMD Science Mission Directorate
SSPA Solid State Power Amplifier
STP Space Technology Program
TGO Trace Gas Orbiter
THA Terminal Hazard Avoidance
TRN Terrain-Relative Navigation
TWTA Travelling Wave Tube Amplifier
UCIS Ultra Compact Imaging Spectrometer
UV Ultraviolet
XRF X-Ray Fluorescence