National Aeronautics and Space Administration

Scientific Objectives for the MPD Mission

SUBTEAM #1

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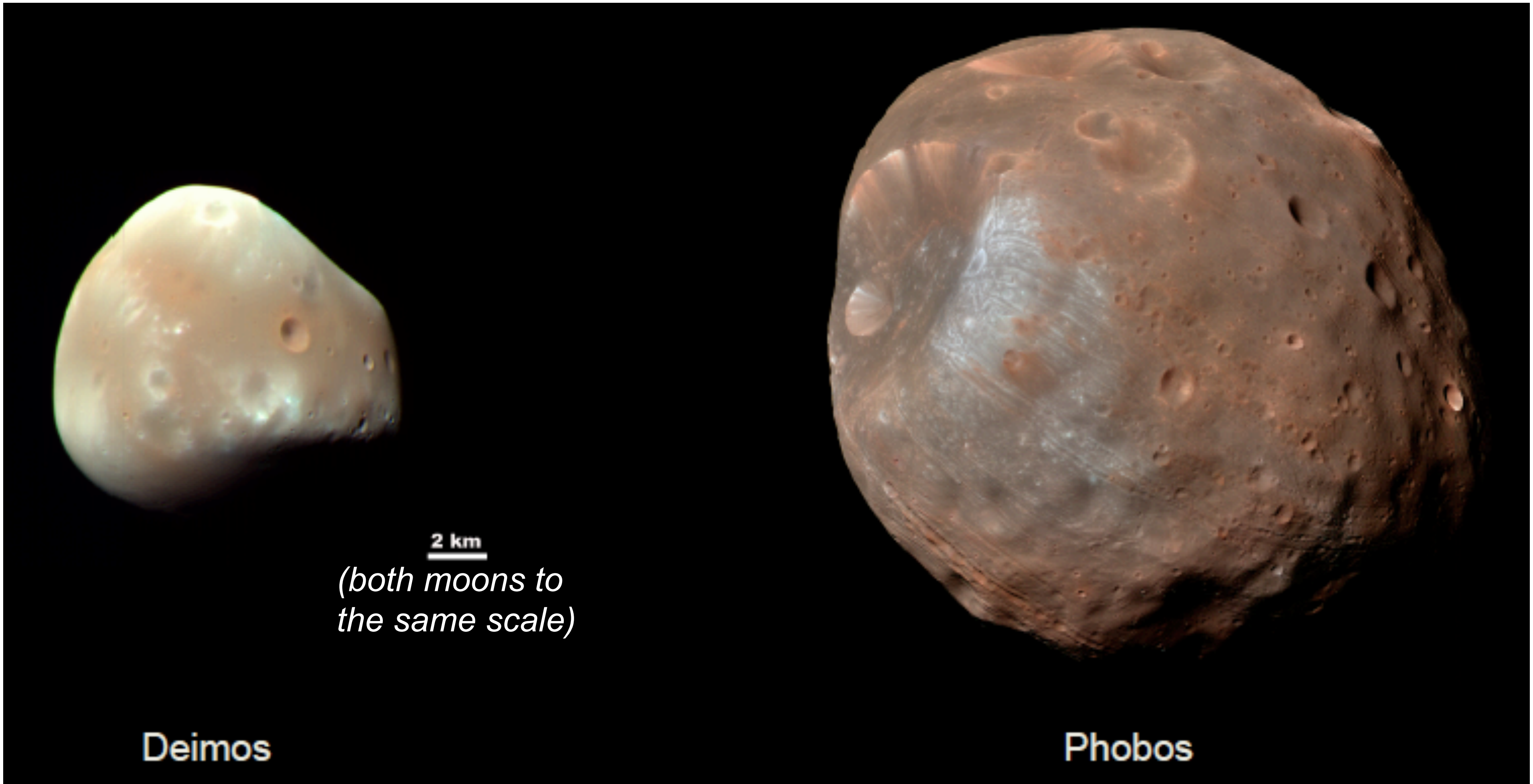
INTRODUCTION: Some essential facts about Phobos/ Deimos/Mars of relevance to science planning.



This color-enhanced view of Deimos, the smaller of the two moons of Mars, was taken on Feb. 21, 2009, by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter. Deimos has a smooth surface due to a blanket of fragmental rock or regolith, except for the most recent impact craters

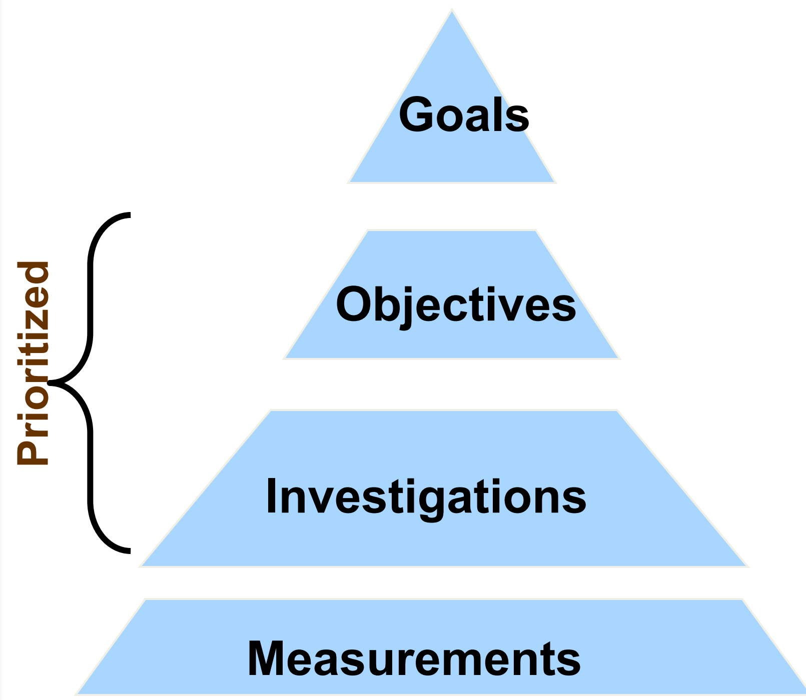
The High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter took this image of Phobos on March 23, 2008. This was taken from a distance of about 6,800 kilometers. It is presented in color by combining data from the camera's blue-green, red, and near-infrared channels.

Relevance to MEPAG and SBAG Themes and Objectives

Phobos and Deimos are small bodies and their study relates to all key science themes in the SBAG Roadmap

SBAG THEMES
Solar System Origins: May be remnant Mars building blocks & contain key info on Mars' accretional environment. May represent captured asteroidal materials linked to early planetesimal formation.
Solar System Dynamics: May be related to population of planetesimals involved in late intense cataclysm and offer insights into exchange of material from Mars to moons, to each other, and also from outside Mars system.
Current State of the Solar System: Present potential relationship with Tagish Lake chondrite, other primitive carbonaceous meteorites, and D-type asteroids, as well as Mars' surface dust. Also understanding of regolith processing.
In Situ Resource Utilization: Water (hydration or ice) suggested for Phobos, based on spectroscopy
Hazards: Do not present a direct hazard; physical study can help better understand PHAs (i.e., contribution to SKGs re: NEOs near-surface geotechnical properties and internal structure)
Astrobiology: May represent Mars ejecta or water-rich asteroids; may be repository for Mars' meteorites ejected through time; may offer insights/comparisons into delivery of volatiles to early Earth.

MEPAG Structure



Proposed Statements of Scientific Objective

1. Understand the origin and evolution of Phobos and Deimos as planetary objects, and how the major processes that have affected them relate to Mars and to other small bodies.
2. Advance our scientific understanding of Mars in the areas of its potential as a past or present abode for indigenous life, its climate and climate history, and the nature and evolution of geologic processes that have created and modified its crust and deep interior.
3. Capitalize on the science opportunities associated with the Mars-Earth neighborhood (some of which can be planned in advance and some of which are pathway-dependent opportunities) beyond those related directly to Mars and Phobos/Deimos.

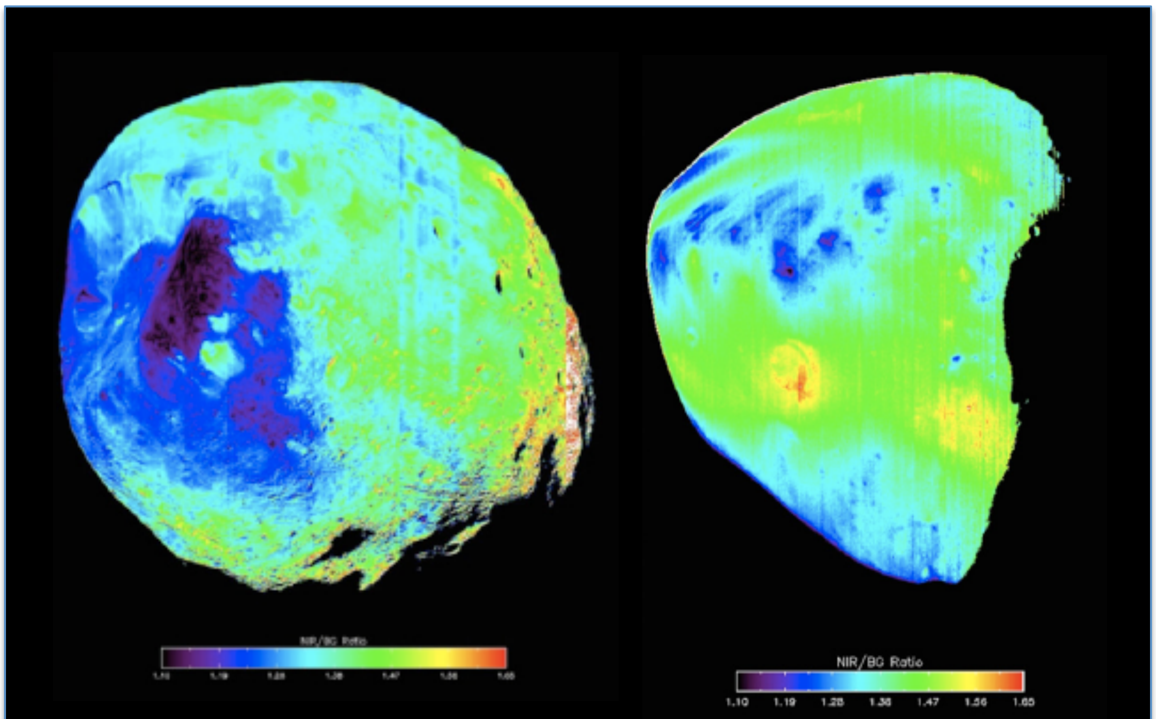
NOTE: Objectives/Investigations originating from MEPAG Goal IV are being bookkept with Exploration Objectives.

Objective #1: Origin and Evolution of Phobos/Deimos

Potential Investigations (listed in approximate priority order)

A. Determine the nature of the surface geology and mineralogy on Phobos / Deimos

- This provides context and sample selection information for the returned samples for which these measurements will be done in much more detail.



Color ratio (NIR/Blue-Green) maps of Phobos and Deimos obtained by the HiRISE instrument on Mars Reconnaissance Orbiter (source: Thomas et al. 2010)

Objective #1: Origin and Evolution of Phobos/Deimos (cont.)

Potential Investigations (listed in approximate priority order)

B. Determine the absolute ages of Phobos' and Deimos' materials

C. Constrain the conditions (P, T, redox, petrology) of formation of Phobos and Deimos

- B and C require analysis of returned samples in Earth's laboratories
- Includes searching for presolar grains, measure D/H ratio, Oxygen thermometry, etc.

Dr. Dimitri Papanastassiou preparing a mineral separate of an extraterrestrial sample to determine its age. This kind of science can only be done in Earth laboratories.

<u>Objective #1</u>: Origin and Evolution of Phobos/Deimos (cont.)

<u>Potential Investigations</u>

D. Characterize the regolith on Phobos / Deimos, and interpret the processes that have formed and modified it.

- Study of the nature, structure, and degree of maturation of the regolith
- Needed as small scale resolutions as well as global. Particle size frequency distributions will be important to understand regolith processes and micro-gravity geology (i.e. nature of cohesion, etc.).
- Also investigations into the mobility and thermal responses of regolith materials will be desired.

The lunar surface drill, used for the first time on Apollo 15, provided a means for one crewman to emplace the Heat Flow Experiment probes below the lunar surface and collect a subsurface core.

Objective #1: Origin and Evolution of Phobos/Deimos (cont.)

Potential Investigations

E. Identify and characterize the presence and distribution of any potential volatile or organic species

- To be performed at or near the surface and at depth if possible. Also relevant to astrobiology and for ISRU on the samples to be returned.

F. Determine the near surface and interior structure at global and regional scales

- Seismic surveys and geodetic tracking for extended periods to complement radio science and radar tomography achieved during precursor mission(s)

G. Quantify Phobos' and Deimos' energy budgets

- This includes measuring the heat flow in several locations and the secular acceleration (Phobos only, not detectable at Deimos)

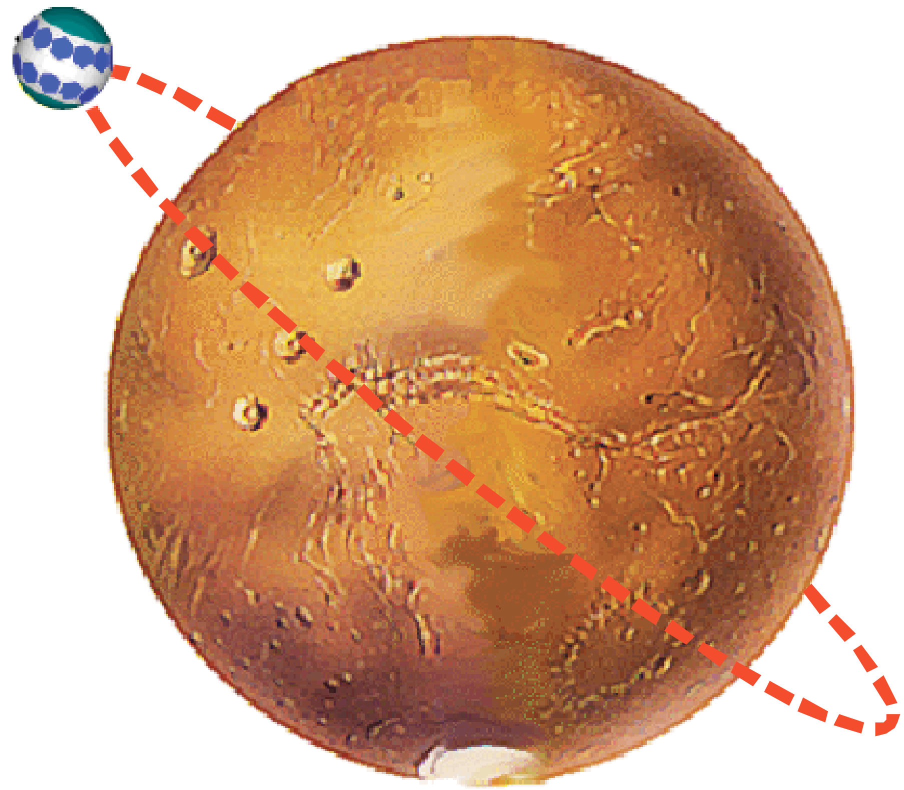
Objective #2: Origin and Evolution of Mars

Potential Investigations (listed in approximate priority order)

A. Complete the MSR Campaign by capturing and returning to Earth the orbiting cache of samples.

- Would achieve multiple high-priority scientific objectives, especially those related to the life question.

Orbiting Sample (OS) in Mars Orbit



Objective #2: Origin and Evolution of Mars

Potential Investigations (listed in approximate priority order)

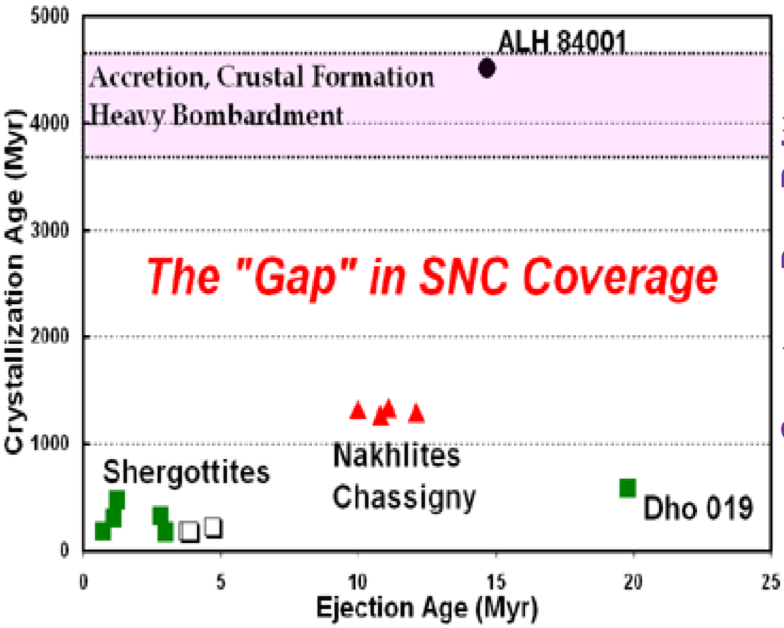
B. Collect Mars meteorites from the surface of Phobos/Deimos, and return to Earth for detailed study

Objectives potentially achievable using P/D meteorites but not Antarctic meteorites

a) Search for organic carbon in Martian meteorites on Martian moons (avoid terrestrial contamination).

b) Investigate Mars meteorites that have not spent a lot of time in inter-planetary space

c) Collect information on igneous petrology through time (fill in the meteorite gap)



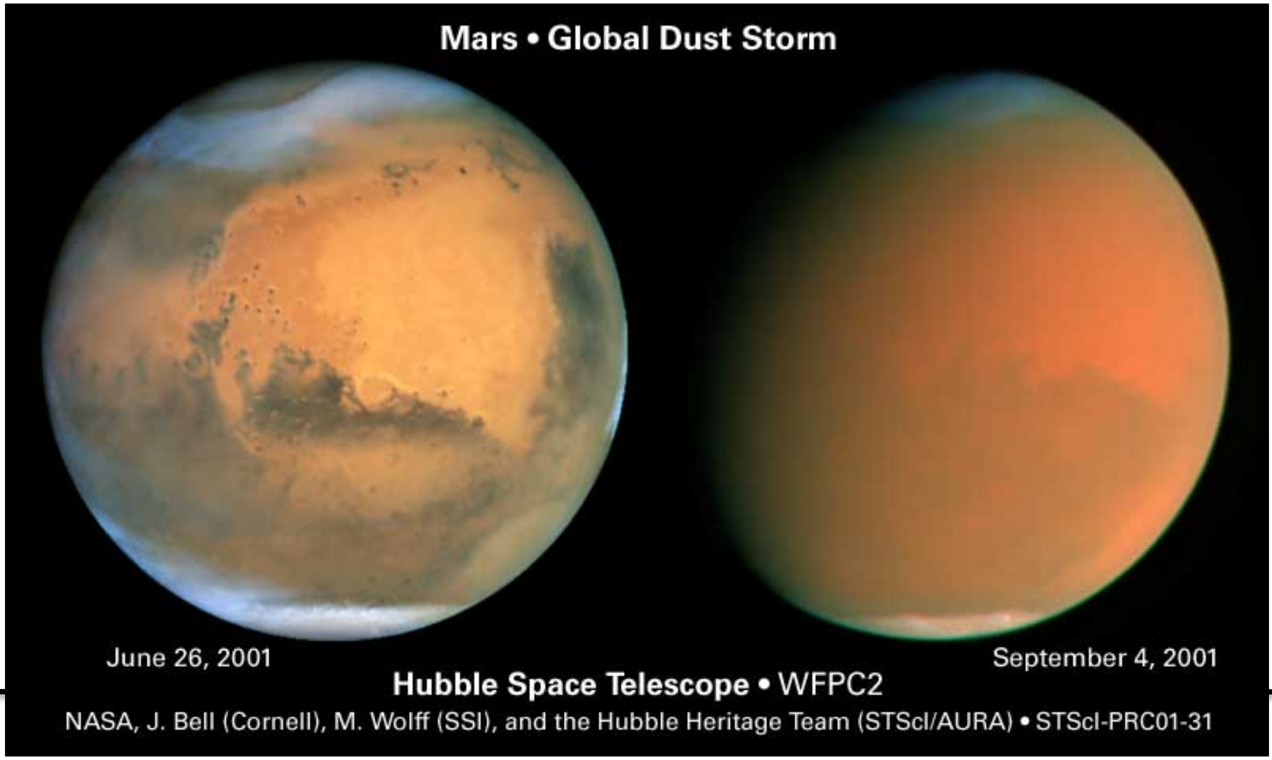
Courtesy Dan Britt

Objective #2: Origin and Evolution of Mars (cont.)

Potential Investigations

C. **Observe the martian weather system from high Mars orbit, allowing collection of simultaneous data from a large sector of Mars.**

   a) Monitoring of dust storm activity (local, regional, global)
   b) Clouds, winds, etc
   c) Would want to set up a met station that operates long after astronauts leave

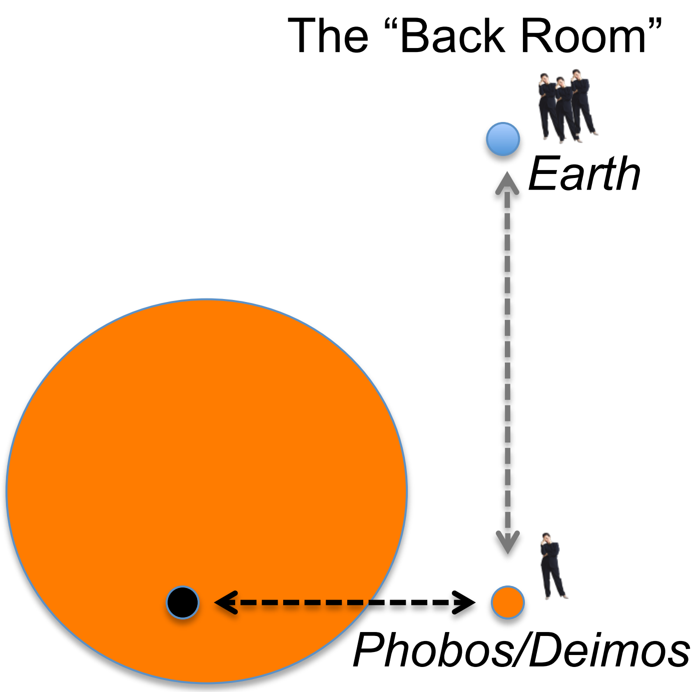


Example (taken from Hubble) showing the benefit of observing what is going on at Mars simultaneously across the full disk.

Objective #2: Origin and Evolution of Mars (cont.)

Potential Investigations

D. Carry out 1 or more scientific investigations via teleoperation of a controllable asset on the martian surface



Issues for future work

- *Every investigation/operation that could be controlled from Earth could also be controlled from P/D.*
- *There are some advantages to in-system telerobotics:*
  - *Activities that benefit from real-time ops (i.e. drilling, brushing, coring, digging)*
  - *Obs. transient phenomena (i.e. dust devils)*
  - *Robotic platforms enabled through real-time ops (i.e. aerial vehicles, cliff climbers)*
- *Cost and risk have yet to be determined. Needs additional study*
- *Not included in draft ConOps as a result*

Objective #3: Science opportunities in Mars-Earth Neighborhood

Potential Investigations (listed in approximate priority order)

A. Pathway-dependent transit science opportunities. Some possibilities:

- Small body flyby observations of comets and near-Earth objects; it is probably given good completeness of the small body catalogues that for any particular Mars mission opportunity the outbound and return trajectories can be shaped without significant penalty to arrange a flyby of a planetary small body by the crew
- Venus flyby observations – this is a feature of the short stay mission opportunities

B. Quantification of the fluxes of material in the Martian system (e.g., sources and sinks of dust)

- Collect data on the dust and micrometeorite population in and around the Mars vicinity; for example, install collectors on the robotic or human spacecraft that could record the fluxes between Earth and Mars and then at Mars orbit

C. Characterize the extra-solar radiation environment in the Earth-Mars neighborhood.

- Important for characterizing the GCRs and their interactions with spacecraft and natural materials of Phobos and Deimos

D. Survey of Mars' Trojan asteroid population

- May give some insight to dynamical relationships and origins with respect to Phobos / Deimos

Objective #3: Science opportunities in Mars-Earth Neighborhood (cont.)

Potential Investigations

E. Heliophysics

- Understanding the fundamental processes that control Mars' space environment
- Maximizing safety and productivity for human explorers
  - **Characterize space environmental variability and extremes**
  - **Understand and characterize space weather effects**

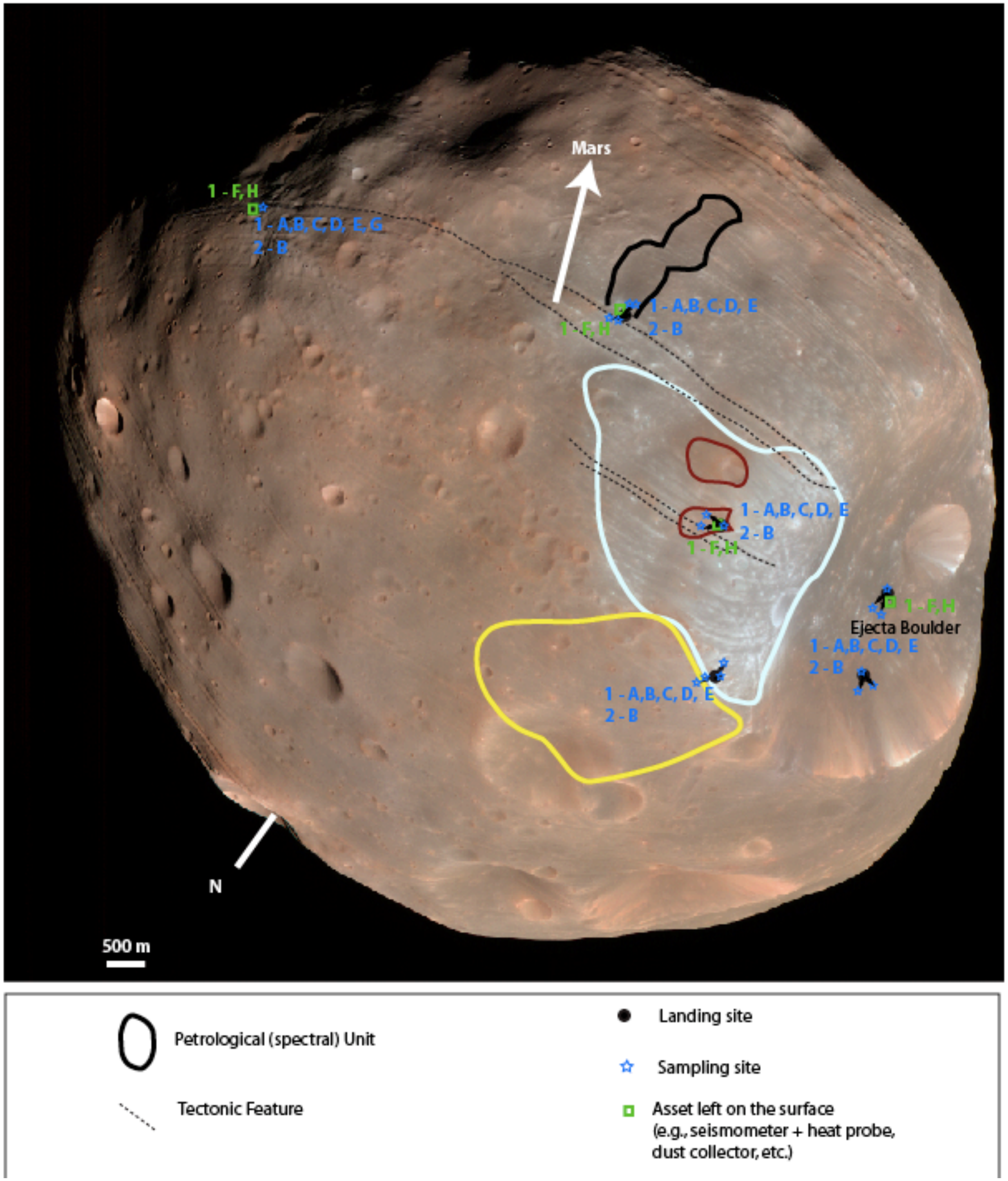
F. Astrophysics

- Characterize the Earth as an exoplanet
- Acquire distance scale measurements via the parallax method
- Compare planetary microlensing events to constrain size

G. TBD science enabled by concurrent observations from different points in the solar system (e.g. from Earth and the crew's spacecraft); for example science that would benefit from very long baseline observations (extra solar system targets are possibilities)

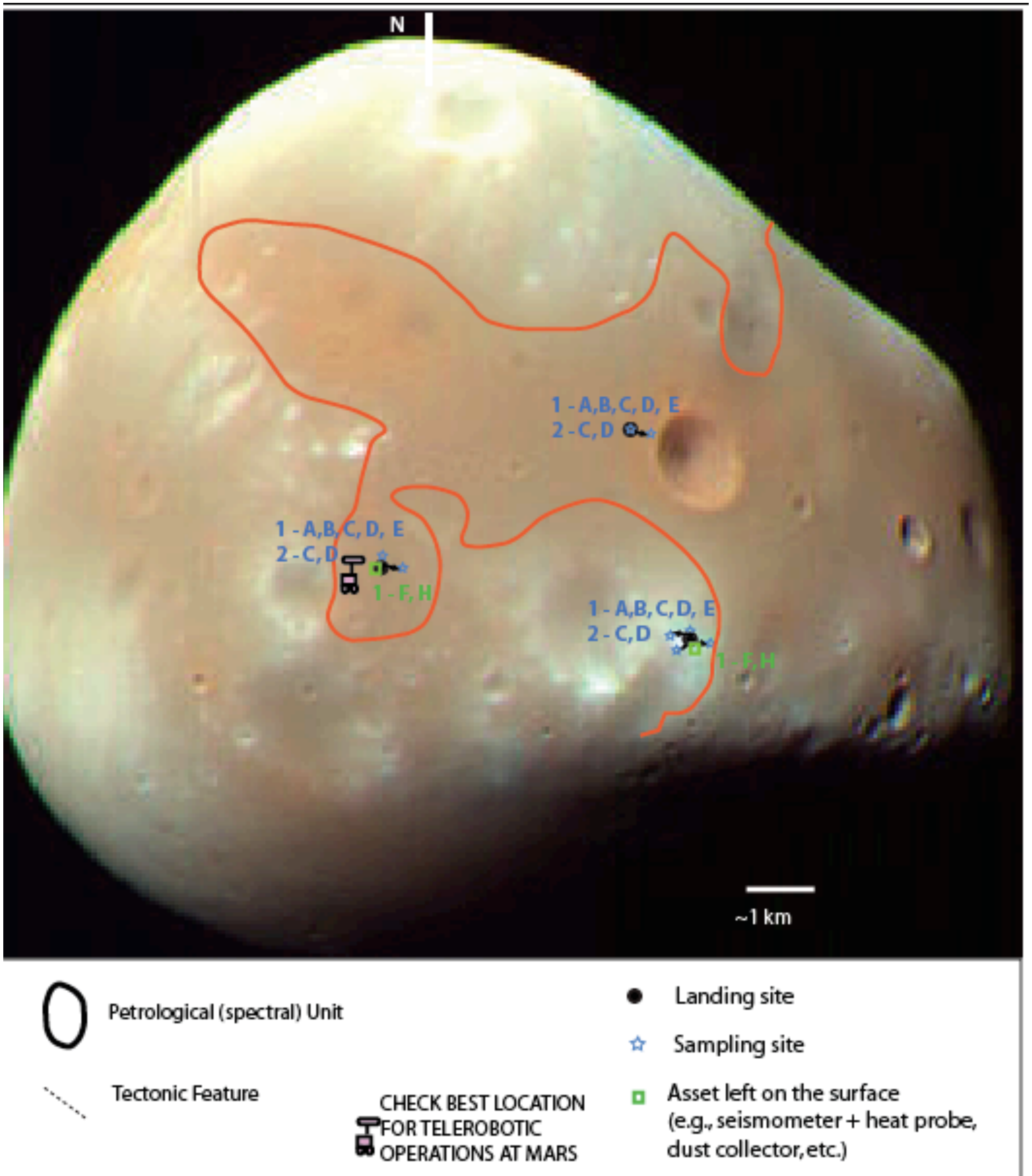
Implementation Implications

SCIENCE PRIORITY	IMPLEMENTATION IMPLICATION
Field science at surface of Phobos/Deimos	EVAs, need for surface mobility, maximize contact time between astronauts and geology
Regolith science	Requires a small drill with depth capacity of ~2-3 m.
Returned sample science	Need field instruments to support sample selection, sample acquisition tools, sample packaging/ containers. Returned sample mass needs to be planned for (mass of samples + containers needs more discussion, but current estimate is ≥ 60 kg).
Leave-behind instruments	A set of monitoring instruments would need to be set up by the astronauts, and left behind on P/D.
Telerobotics to Mars surface	The priority is unclear—needs more study. Also unclear implications for time and position of the astronauts, and necessity for pre-deployment of assets.



Reference Landing Sites and Main Activities - Phobos

Note: suggested landing and sampling sites are notional – Will be refined when high-resolution mapping becomes available (precursor mission)



Reference Landing Sites and Main Activities - Deimos

Note: suggested landing and sampling sites are notional – Will be refined when high-resolution mapping becomes available (precursor mission)

DISCUSSION: Relative scientific interest in Phobos and Deimos – Implications for implementation

- **Both moons need to be visited and subject to similar investigations**
  - Required for system science, i.e., understand the origin and evolution of Mars from multiple perspectives
  - No evidence that the moons share the same origin, difficult to confirm without samples
- **Based on the current state of knowledge, Phobos appears to be of greater science value and is identified as the prime target**
  - Great diversity of the surface physical and petrological properties
  - Likely collection of martian materials (theory, obervations)
- **Depending on timeline constraints, visit both moons but with extended time at Phobos**
  - Descope options remain to be evaluated (e.g., number of landing sites per moon)
- **Precursor data are needed to refine this assessment**
  - Observations recommended by PS-AG for a precursor mission to Phobos and Deimos would also return science data that can inform this decision process