Presentation to

NRC Committee for Astrobiology and Planetary Science (CAPS)

23 May 2012

MPPG

Mars Program Planning Group

Agenda Topics

1. Charter
2. Process
3. Pathways
4. Considerations for Early Missions
5. Summary Discussions

Guiding Principles

Mars Program Re-Planning 2012

- Provide options for program architectures
  - Sequences of strategically selected and interconnected spaceflight and ground based investigations
- Responsive to the NRC Decadal Survey, and synergistic with progress toward human exploration of Mars
- Demonstrate a strategic collaboration between the Science Mission Directorate (SMD), Human Exploration and Operations Mission Directorate (HEOMD), Office of Chief Technologist (OCT), and Office of Chief Scientist (OCS) to leverage capabilities for maximum return on science, technology, infrastructure, and exploration support capability
- Responsive to the President's challenge of human travel to Mars orbit in the decade of the 2030s
- Consistent with the FY2013 President's budget
- Maximize opportunities for engaging the public

Process

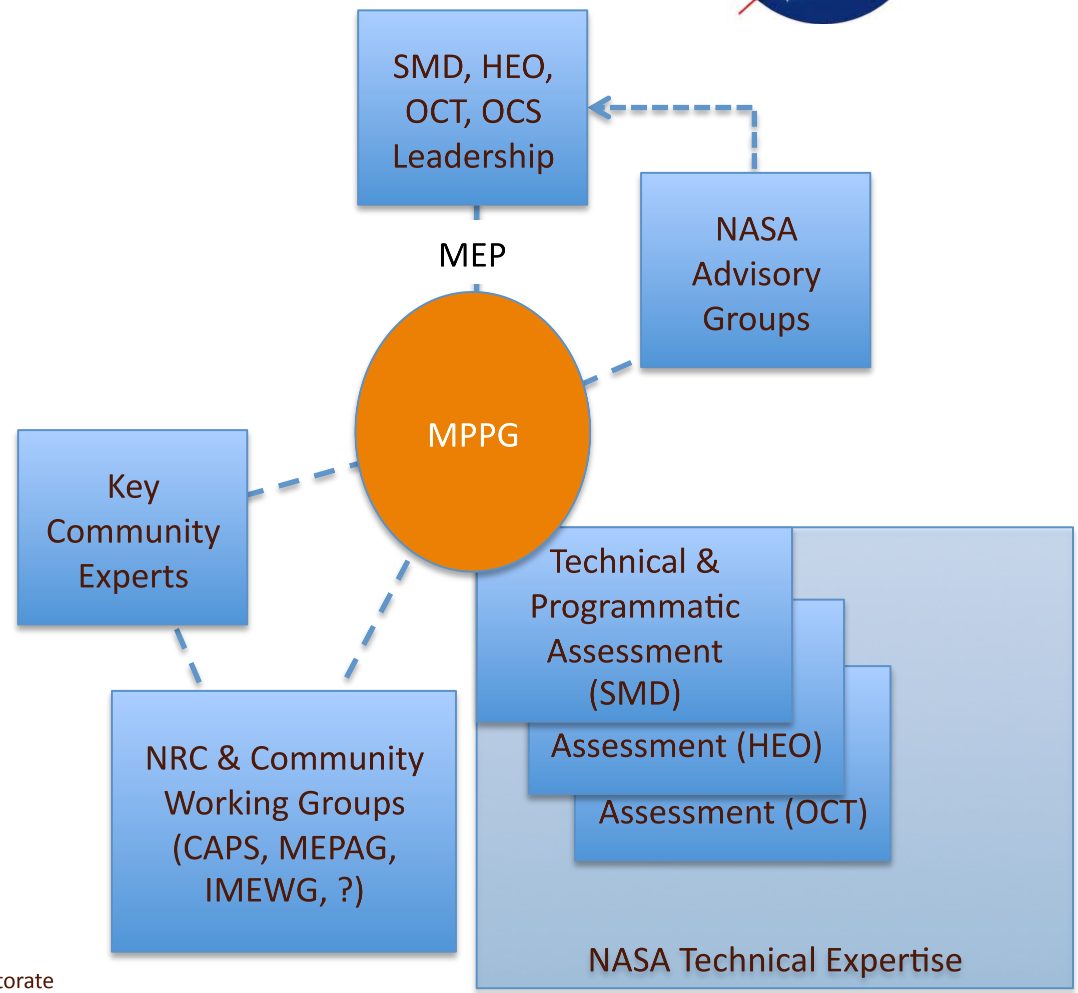
Core Team & Approach

Mars Program Re-Planning 2012

- O. Figueroa (Chair)
- J. Garvin (SMD/GSFC)
- M. Gates (HEOMD)
- M. Gazarik (OCT)
- D. McCleese (JPL)
- J. Mustard (Brown Univ.)
- F. Naderi (JPL)
- L. Pratt (Indiana Univ.)
- J. Shannon (HEOMD)
- G. Tahu (Exec Officer, HQ)

Ex-Officio

- R. DePaula (SMD/Intl Liaison)
- M. Wargo (HEOMD/Science)



GSFC = Goddard Space Flight Center
HEOMD = Human Exploration and Operations Mission Directorate
JPL = Jet Propulsion Laboratory
OCS = Office of Chief Scietist
OCT = Office of Chief Technologist
SMD = Science Mission Directorate

Figures of Merit for Evaluation

Mars Program Re-Planning 2012

- **FOM-1**: Degree to which the program ***advances overarching scientific goals/objectives of Mars exploration*** as stated in NRC Decadal Survey and within the Mars Exploration Program Analysis Group (MEPAG) Goals document, including provision of surface samples from Mars to Earth laboratories
- **FOM-2**: Degree to which the program ***advances knowledge and capabilities required to enable eventual human exploration of the Mars*** "system" (orbit, moons, surface), on a time-frame consistent with the President's challenge (2030's)
- **FOM-3**: Degree to which the program ***infuses technology*** developed via Agency-level investments to reduce risk and increase capabilities for robotic scientific and eventual human-based exploration
- **FOM-4**: Degree to which the program maximizes opportunities for synergies and ***interconnections between robotic and human spaceflight programs*** to increase science yield and to accelerate capability developments (and production of critical knowledge) that support long-term goals
- **FOM-5**: Degree to which each mission and the program as a whole is ***cost credible***, and provides flexibility to mitigate programmatic, technical, and scientific risks.
- **FOM-6**: Degree to which the program ***provides opportunities for participation***, and leveraging other organization's (including international) activities, to lowers risks and to enhance and/or accelerate the longer-term goals

Milestones

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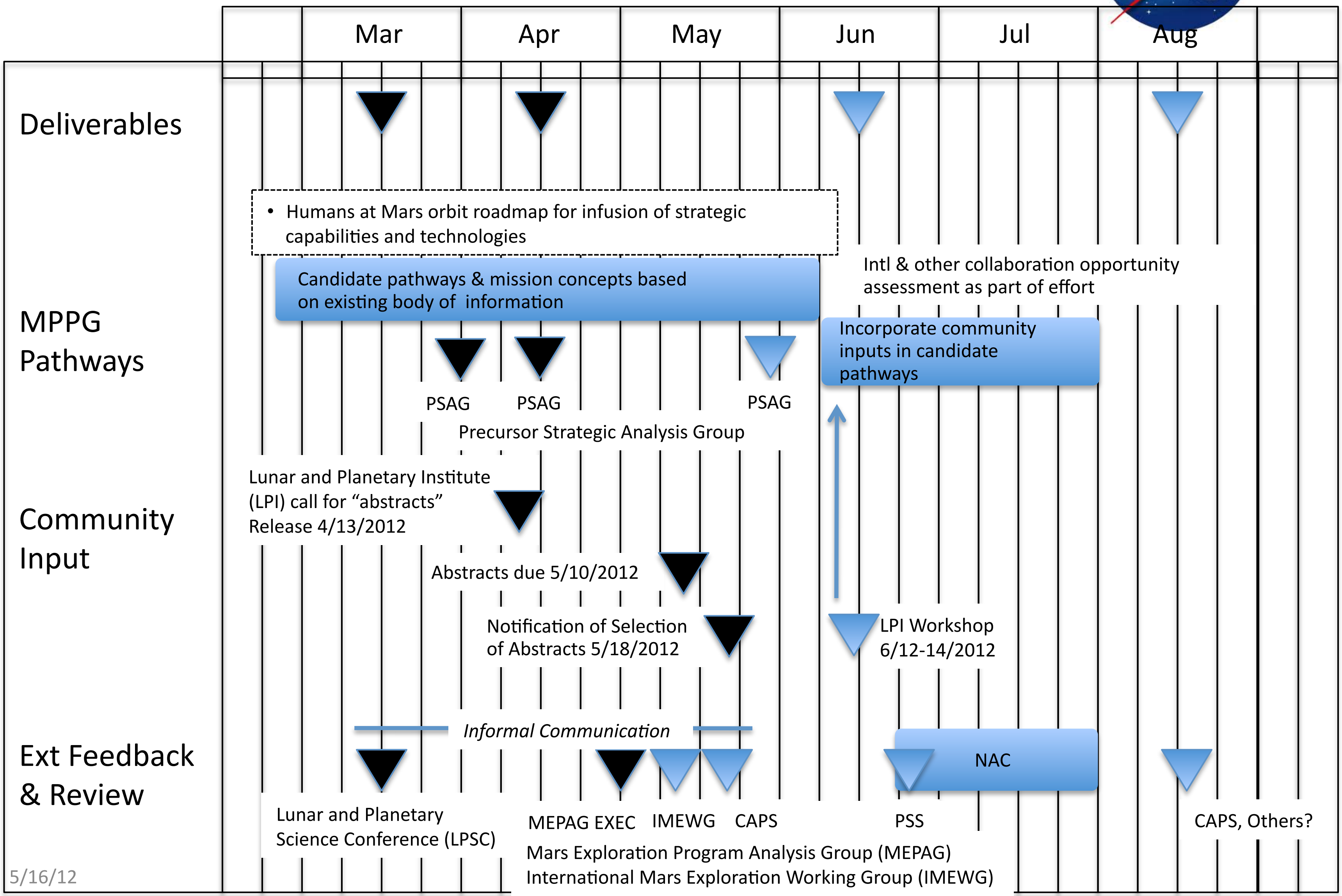

Pathways

Concept of Pathways

- Pathways have been used as a very effective vehicle for strategic planning, analysis, and as a community outreach tool ever since the 2000 Mars Program re-planning efforts

- MPPG is employing them as a vehicle to analyze options with the following boundary conditions:
  - FY2013 budget constraints
  - Foundation for a more strategic collaboration between SMD/HEOMD/OCT/OCS towards a common Agency-level goal
  - New scientific discoveries, ideas, and advances in technology

- Help establish early priorities, common understanding, and intersections

- MPPG using "Samples Orbiting Mars NLT 2033 for return to Earth by humans and/or robotic mission" as a point of possible convergence

Mars Exploration Pathways

Mars Program Re-Planning 2012

- Pathways are a series of interconnected investigations/activities
  - Significant advances in the state of knowledge, and the present experience base allow highly focused scientific interrogation, guided by the highest priority Decadal objectives
  - Responsive to the NRC Planetary Decadal Survey, including Mars Sample Return
  - Pathways must fit within available FY2013 budget without skipping more than one Mars launch opportunity between flight missions
- Missions within a pathway are linked
  - Interconnected scientifically and capability wise; orbiters provide operational support as telecom relay and landing site identification, optimization for selection, and certification;
  - Missions feed-forward technology, capabilities, and knowledge
- Pathways are responsive and driven by discoveries
  - Initiated on the basis of current knowledge
  - Switching between pathways possible, based on new discoveries and drivers

Pathway development is currently underway

Community Inputs to Study Process

- MPPG science members have reviewed relevant recent studies
  - Mars Exploration Planning Analysis Group (MEPAG) SAG reports, White Papers input to Decadal Survey, published papers
  - Discussed with MEPAG Chair and Exec Cmte, and Decadal Mars sub-panel chairs
- Adopted targeted interview approach for key questions
  - Identified community subject-matter experts in remote sensing to aide in understanding measurement of priorities aligned with Decadal priorities (and MEPAG)
  - Conducted discussions with several members of the science community regarding orbital reconnaissance, and surface science
- Expanded outreach via individual polling of community experts on landed science (more complicated than orbital)
  - Polling has touched several subject-matter experts on targeted questions associated with what in situ science is essential
- Engaged MEPAG Executive Committee in general discussion of MPPG science to get their views and suggestions

Science Driven Pathways

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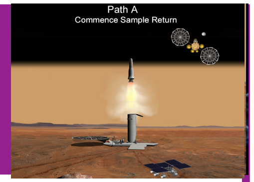
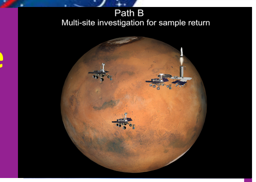
Commence Sample Return using existing data (*A*)



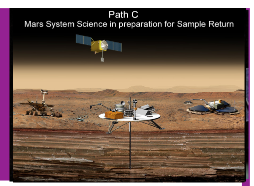
- Search for evidence of past life with samples collected from a site on Mars identified with existing data and returned to Earth for analysis
- The initial step is caching scientifically-selected samples from a site which has been determined from orbit to have astrobiological significance
- Return of samples will depend on funds available
- This is directly responsive to the NRC Decadal Survey recommendations but at a reduced tempo

Multi-site Investigation to Optimize Search for Ancient Life (*B*)



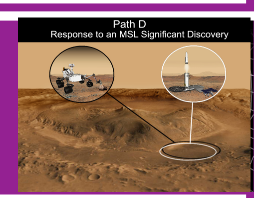
- Search for evidence of past life through *in situ* observations and ultimately analysis of carefully selected samples returned to Earth
- Sample Return commences only after *in situ* measurements and caching of multiple sites (3) and Science Community decision process as to which to return to Earth
- The emphasis of this pathway is searching for samples capable of preserving evidence of past life

Advance Understanding of Mars and Its Evolution/Habitability (*C*)



- Faced with the complex history and physical diversity of Mars, advance Mars System Science in order to fill critical knowledge gaps prior to an undertaking as challenging as human exploration while responding to new discoveries about "active Mars", such as (for example) :
    - Investigate Mars climate, trace gas dynamics, and surficial brine fluid flows, and their potential connection with interior and exterior processes.
    - Investigate the history of interior processes that modulated the near-surface and surface water environments through time.

Response to an MSL significant discovery (*D*)



- *Respond to a breakthrough MSL discovery* to implement the search for evidence of past life through *in situ* observations and earliest possible analysis of carefully selected samples returned to Earth
- Informed by the results of MSL, this pathway is the earliest return possible of samples from the surface of Mars
- Multiple possibilities for response depending on the nature of the discovery (and its degree of alignment with current models)

Science Pathway A

Mars Program Re-Planning 2012

Objective: As quickly as resources permit, return scientifically-selected samples collected from the surface of Mars to Earth for comprehensive analysis.

- Highest priority recommended by the NRC Decadal Survey for Planetary Science in the Decade 2013-2022
- Site for MSR is chosen on the basis of current and continuing Mars orbiter remote sensing observations:
    - *Informed by ground-truth from in situ measurements [Mars Exploration Rovers, Phoenix, Mars Science Lab/Curiosity]*
- Relative to NRC Decadal suggested architecture, missions have reduced cost and are paced on the basis of budget constraints
- Samples are placed in orbit around Mars in late 2020's/early 2030's
    - Retrieval will be accomplished by astronauts if they are at Mars or by robotic mission.

Science Pathway B

Mars Program Re-Planning 2012

Objective: Conduct *in situ* investigations to better understand the habitability and potential for preservation of biosignatures at multiple sites on Mars. Cache samples at each for return from the site with the greatest likelihood of yielding biosignatures.

- Acknowledges that preservation of biological signatures is a statistical phenomenon:
  - Well-informed choice of multiple, independent targets improves the probability of identifying biologically-relevant materials to sample
- Multiple sites are investigated to provide detailed understanding of habitability and biosignature potential at different kinds of sites, and to optimize the quality of the cache ultimately returned:
  - Sites chosen on the basis of current and continuing remote sensing observations
  - Samples are returned where *in situ* measurements demonstrate that rock units formed under conditions most favorable for habitability as well as biosignature preservation

Science Pathway C

Mars Program Re-Planning 2012

Objective: Faced with the complex history and physical diversity of Mars, advance Mars System Science in order to fill critical knowledge gaps prior to an undertaking as challenging as human exploration while responding to new discoveries about "active Mars"

- Seeks to improve our fundamental understanding of Mars' surface and interior in order to better inform the search for evidence of life before undertaking Sample Return and/or human exploration
- Would be the path of choice if Mars Science Laboratory/Curiosity revealed significant misinterpretations of orbital observations of the Gale Crater region
- Alternative foci are possible, e.g.:
    - Investigate Mars climate, trace gas dynamics, and surficial brine fluid flows, and their potential connection with interior and exterior processes. (Relevant to extant life.)
    - Investigate the history of interior processes that modulated the near-surface and surface water environments through time. (Relevant to past life.)

Science Pathway D

Objective: Respond to a breakthrough discovery by Mars Science Lab/Curiosity (MSL) by either moving "immediately" to the caching and return of samples from Gale Crater, or switch to Pathway B or C

- This pathway is triggered by an MSL result that strongly suggests the potential of preserved signs of ancient life in materials at Gale Crater, motivating the desire for rapid return of such materials (as samples) to Earth.
  - MSL *in situ* observations *demonstrate* that deposits at Gale Crater formed under conditions favorable for habitability, as well as likely biosignature preservation
- Sample Return commences after validation and caching of the MSL "discovery sample materials" and is accelerated to the greatest extent possible
- First response mission caches a scientifically selected sample at the MSL site for rapid return to Earth for comprehensive laboratory analysis
- Some alternate discovery scenarios could result in a delayed surface response in favor of additional orbital reconnaissance

Humans at Mars Orbit in 2030's

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2014-2020

- Orion Multi Purpose Crew Vehicle (MPCV)
- Space Launch System (SLS) Block 1A (80t), 1B (105t)
- Interim Cryogenic Prop Stage Interim Cryogenic Propulsion Stage (iCPS)-1
- 21st Century Ground Ops

2025

- Large Storable Stage
- iCPS-2
- Deep Space Habitat
- 300kW+ Solar Electric
- Propulsion (SEP) Stage

2030's

- SLS Block 1C (130t)
- 3MW+ Nuclear Electric Propulsion/Nuclear Thermal PropulsionStage (NEP/NTP)

Capability architecture to Mars System requires further study

Building up system capabilities, gaining deep space operational experience and reducing risk as we move further out into the solar system

20xx?

Mars Surface

- Lander
- Ascent Vehicle
- Surface Habitat
- Surface Suit
- Rover
- ISRU Plant

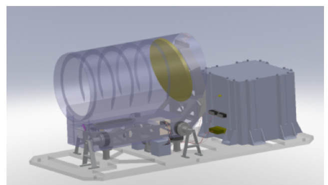
Cross Cutting Technologies - OCT

Mars Program Re-Planning 2012

DEEP SPACE OPTICAL COMM

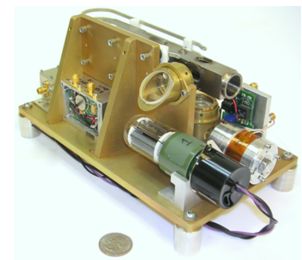
General Technology Description: Develop and demonstrate key technologies for an operational optical deep space communication capability

Benefits:
- Reductions in mass (3X) and power (2X)
- 10X Ka-band data rates for similar mass and power (data rates over 260 Mb/s at 0.4AU)
- Order of Magnitude Improvements
  40X downlink data rate
  1000X uplink data rate



DEEP SPACE ATOMIC CLOCK

General Technology Description: Highly accurate atomic clock (with stability of 1ns/10 days) will enable reduced infrastructure needs on the ground, and help improve navigation and landing ellipse

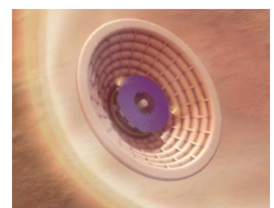


Benefits:
- Enable autonomous radio navigation with a flexible/extensible 1-Way radio navigation
- 2x increase navigation & radio science tracking data
- ~10x improvement in tracking data accuracy (< 20 cm)
- 100x improvement in clock stability over next-gen GPS

EDL INFLATABLES

Technology Description: Develop alternative capabilities to current MSL SoA to land larger payloads on Mars more accurately and to higher elevation landing sites

Benefits:
- Increase the mass to the surface, the landing altitude, and the landing precision of Mars landers
- Begins the path towards human-scale Mars mission lander systems technology development
- Develop a large-scale stratospheric Mach 4 test platform that can be used for other technology developments
- HIAD has the potential to delay chute deployment to a subsonic condition, which reduces risk for supersonic deployment



Considerations for Early Missions

First Robotic Mission Benefits and Considerations

Mars Program Re-Planning 2012

- First mission opportunity is 2018 or 2020
  - 2018 mission in the $700 - $800M class with some adjustments to profile
  - Leverage synergies between SMD, HEOMD and OCT
  - Responsive to the NRC Decadal Survey general Mars priorities
- Concepts and considerations
  - An Orbiter
    - Replenish aging infrastructure (Odyssey, Mars Reconnaissance Orbiter); and provide landing site characterization/selection/certification and telecom relay support and new science
    - Pursue science measurements that are high-value for our understanding of Mars and provide information for future human exploration
    - Platform for technology validation: SMD, HEOMD, OCT
    - "Fits" FY2013 budget for an 2018 Launch Readiness Date
  - A Lander
    - Provide the opportunity to investigate and select samples suitable for return to Earth from a compelling site, chosen based on best available information
    - Pursue high value science, and address knowledge gaps for human exploration
    - Platform for technology validation: SMD, HEOMD, OCT
    - Stationary lander possible in 2018, but first opportunity for a roving mission that meets requirements would likely be 2020 without FY2013 budget augmentation

Definition of a Possible 2018 Orbiter

- Mars science experts consulted by MPPG identified essential “core” orbital remote sensing measurements

- They point to critical need for continuing high resolution imaging and mineralogy mapping for landing site selection, certification, and supporting surface investigations

- New scientific discoveries are inevitable from these orbital measurements
  - e.g. *Surface brine flows described in 2011 peer reviewed papers*

- In addition, a Mars orbiter must provide infrastructure supporting Telecom for landed assets

Potential Early Opportunity Orbiter

Mars Program Re-Planning 2012

Identify/Certify Optimal Landing Sites (Baseline)	Baseline + new science responsive to Decadal goals (Augmentation)

Identify/Certify Optimal Landing Sites (Baseline)

- Expands data and knowledge of compelling landing regions for surface investigations (including for sample return) to increase science value of samples and to refine safety and quantify risks
- Identifies potentially new aqueous environments for preservation of C for habitability (MEPAG/NRC goal)
- Discover new aspects of geologic context for surface sampling sites
- Potential ties to climate cycles via monitoring (MEPAG, NRC Decadal)
- Potential resources inventory such as aqueous minerals [HEO SKG, PSAG]
- Simultaneous measurements with MSL of radiation environments
- Technologies of potential interest: optical comm, ultra-high resolution imaging instruments, atomic clock

Baseline + new science responsive to Decadal goals (Augmentation)

- Possible additional perspective on where to sample and explore (vents, brine flows, ground ice, shallow subsurface?)
- Improve understanding of evolution of atmosphere and of reservoirs over time linked to climate and geology [MEPAG]
- Ties to NRC Decadal as part of Mars (Chapter 6) goals in areas of Climate, Interior processes, and dynamics
- Potential opportunity for new measurements of benefit to both SMD (Decadal) and HEO [PSAG, Goal IV]
- Other technologies of potential interest: atomic clock, new sensors not previously employed at Mars (solar occ. FTS, SAR, sub-mm spect, Lidar, etc.)
- Requires HQ-chartered SDT to refine

Definition of a Possible Early Landed Mission

- Mars science experts consulted by MPPG identified essential “core” measurements consistent with NRC Decadal Survey and MEPAG goals

- They point to the critical need for *in situ* measurements of multi-scale geology and mineralogy to guide sample consideration and ultimately selection, as well as for geologic context:
  - *Such measurements are “in family” with those from MER with specific improvements (sample-scale mineralogy; multi-focus, wide-field imaging)*

- Contact and near-sensing measurements are also essential (on an arm):
  - *Microscopic imaging for texture/morphology, others for elemental chemistry and specific mineralogy (tied to key science issues at the sample scale)*

- Mobility is critical to enable analysis and sampling of the diversity within a site, as well as for optimum sample acquisition

Potential Early Surface Missions

Mars Program Re-Planning 2012

Sample identification, context, selection and preservation (Baseline)

- Identifies high priority materials suitable for sampling, criteria established by community (Decadal, E2E-iSAG, MRR-SAG)
- Requires mast-based multi-scale imaging for geologic context and sample-scale remote mineralogy
- Requires means of examining textures, morphologies, basic composition at sample scale from “arm” at scales as fine as sub-mm
- Understanding mineralogy is essential in sample selection at multiple scales
- Sampling must include interiors of rocks and ideally coring beneath weathering surface
- Requirements must be consistent with current reqt’s from MEPAG SAG’s as input to NRC Decadal
- Rover must be able to traverse a few km to meet sample diversity requirements
- Landing ellipse must be MSL-class (20x10 km) or better as guided by MRO-class reconnaissance
- Assessment of organics is “nice to have”
- Rover mobility and lifetime reqt’s under study

Baseline + Organics Detection Experiments (Augmentation)

- Include means to assess organic content within candidate samples to optimize selection for astrobiology/habitability
- Context remote sensing could include remote elemental analysis with ability to distinguish C-bearing materials
- Sub-mm scale local imaging could include multispectral and UV fluorescence capabilities to extend sample identification
- Geologic context could be improved with widefield panoramic zoom capability (for efficiency) and “mini-CRISM” approach (for mineralogy at cm-scales)
- Technologies of potential interest: new in situ instruments for identification of organics, new instruments for geologic context (ie., “mini-CRISM”, remote laser raman, etc.), and technologies systems for enabling precision/pin-point landing (HIADS/SIADS and others)
- HEO reqt’s and desirements to be folded in (PSAG)
- Requires HQ-chartered SDT to define and refine

Near Term Plans

Mars Program Re-Planning 2012

- Finalize early robotic mission concepts and options
  - Orbiter, lander/rover, and synergies with technology and human exploration requirements

- Finalize initial set of science pathway options, and address human exploration pathway options
  - Integrate Human Exploration and Operations Mission Directorate (HEOMD) and Office of Chief Technologist (OCT) priorities for technology and capabilities
  - Initiate independent assessment for cost realism (Aerospace) for early robotic missions

- Expand community inputs (NAC/PSS, MEPAG, NRC/CAPS) and international engagement, and conduct LPI Mars workshop
  - Findings from LPI Workshop will be integrated into pathways (modify present or lead to new ones), and recommendations for future planning

- Continue communication with stakeholders as work progresses

- Information will be shared for review/assessment as MPPG work matures

Summary/Discussion

- Orbital reconnaissance is valuable if it sustains and extends MRO capabilities with direct relation to MSR-related goals (Decadal). Payload concepts evolving into two tiers:
  - Core competed payload of essential measurements
  - Enhanced science (competed) that could extend capabilities and synergies tied to NRC Decadal Survey priorities
  - New discoveries will influence aspects of the strategy/payload

- Community impression is that early landed science is most highly desired if it can retain path to MSR
  - Details are still in development for early landed missions, but roving is the key desire/need together with access to high priority sites with precision landing

- PSAG analyzing priorities in human exploration strategic knowledge gaps
  - Can be applied to orbiter and/or lander concepts

- Community leaders polled generally pleased with MPPG approach as more details are unveiled