

## **Summary of the presentations, discussion, and main outcomes of the 36<sup>th</sup> MEPAG meeting** **April 3<sup>rd</sup>-5<sup>th</sup>, 2018 @ Crystal City, Virginia**

Notes present an overview of discussion as well as presentation materials. This file, the meeting agenda, and presentation files are at <https://mepag.jpl.nasa.gov/meetings.cfm?expand=m36>.

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### **Programmatic MEPAG Announcements**

- *Please send any feedback via the email [MEPAGmeetingOs@jpl.nasa.gov](mailto:MEPAGmeetingOs@jpl.nasa.gov).*
- We welcome Wendy Calvin and Jen Eigenbrode as new additions to the MEPAG Executive Committee. We also welcome Jen Stern to the MEPAG Goals Committee as the new Goal I Representative.
- Past MEPAG Chair Lisa Pratt has been named as the new Planetary Protection Officer at NASA Headquarters.

### **Day 1 – Tuesday, April 3**

#### **Mars Exploration Program Reports**

- Jeff Johnson, MEPAG Chair, [began the meeting](#) with introductory remarks, including an overview of the meeting goals and agenda. This presentation also included an overview of MEPAG, its organizational structure, the MEPAG goals document, and MEPAG analysis activities. MEPAG activities were also reviewed including recent MEPAG meetings, Jeff Johnson's presentation to the new Planetary Science Advisory Committee (PAC), and MEPAG activities at the Lunar and Planetary Science Conference (LPSC). The presentation concluded with an initial summary of MEPAG concerns and reasons for optimism.
- Jim Green, Division Director of the Planetary Science Division (PSD), gave a [status report on the NASA Planetary Science Division](#). [*Announced by NASA [April 10<sup>th</sup>](#): Effective May 1, Jim Green will be the NASA Chief Scientist; Lori Glaze will be the acting PSD Director.*] The presentation included an overview of recent and upcoming significant mission events and a discussion of the PSD budget.
  - Highlights of the budget presentation included a new Lunar Discovery and Exploration Program, a new Planetary Defense Program for near-Earth object detection and mitigation, support for trade studies and technology development for returning Mars samples cached by the Mars 2020 rover, and a Europa Clipper launch as early as FY25. The budget continues to support InSight, Psyche, Lucy, and the next New Frontiers selection in FY19, as well funding all operating missions and completing development of Mars 2020. The Department of Energy will continue production of radioisotope power generators and Pu-238.
  - Brief overviews of plans for the Planetary Defense Program and Lunar Discovery and Exploration Program were presented.
  - Status reports for the Discovery and New Frontiers programs were presented. The release for the draft AO for Discovery is targeted for September, 2018 with the final AO release targeted for February, 2019. Proposers will be able to include the use of up to two Multi-mission Radio-isotope Thermal Generators (MMRTGs) to enable or enhance their mission concept, with the costs to be borne by the proposers. For New

- Frontiers, Phase A concept study reports are due December, 2018 with the down-selection for flight targeted for July, 2019.
- Dr. Green also presented an overview of the timeline of studies leading up to the 3<sup>rd</sup> Planetary Science Decadal survey, which is expected to be tasked before October, 2019 and to be delivered to NASA in the 1<sup>st</sup> quarter of 2022. Missions studies that have already been completed include Mars orbiter, Uranus and Neptune system missions, Europa lander, Venus orbiter and lander, and a Near-Earth Object search and characterization mission study. CAPS has named several candidate priority areas for large or medium class mission studies.
  - Jim Watzin, NASA Mars Exploration Program (MEP) Director, gave a report on the [NASA Mars Exploration Program \(MEP\) Status](#). General MEP News & Status report was good, with all operating missions doing well and all development missions and systems progressing. Other updates included details about MAVEN's orbit adjustment to facilitate telecom relay for Mars 2020. Technology maturation program for key Mars Sample Return technologies is also progressing.
    - The FY18 budget appropriation was favorable for the MEP, which received ~\$75M more than called for in the President's budget request. This will allow MEP to maintain the high pace of development on Mars 2020, continue all operating missions, continue technology maturation activities and fully fund the R&A program.
    - Additional funding was directed to further explore the feasibility and potential of diverse mission technologies for future applications such as Mars Micro Orbiter (MMO) "CubeSat" and Mars Helicopter.
    - The presentation also included brief program and mission highlights for all ongoing missions and technology development projects, as well as an overview of the current status of the notional "lean" Mars Sample Return architecture.

### **Potential MEPAG Goals Revision: Polar Science**

- Isaac Smith gave a presentation titled [Mars Polar Science: Definition, Activities, and Recommendations](#). This presentation described the polar science objectives & investigations that the polar science community has recommended for consideration in the MEPAG Goals Document. This work began as an output of the 6<sup>th</sup> International Conference on Mars Polar Science and Exploration, which identified 5 primary questions related to polar science. Subsequently the polar science community worked to provide recommendations to the MEPAG Goals Committee for potential revisions to the MEPAG Goals Document to better reflect the current state of polar science.
- Don Banfield, the MEPAG Goals Committee Chair, presented the status of the [MEPAG Goals Committee Evaluation](#) of the polar science recommendations for updates to the MEPAG Goals Document. The presentation included an overview of the MEPAG Goals Document and a review of how and when Goals Document gets updated. The last major MEPAG Goals update took place in 2015 following the 8<sup>th</sup> International Conference on Mars. The MEPAG Goals Committee is currently in the process of reviewing the revision recommended by the polar science community. Proposed edits to Goals I and II are expected to be available for community comment by June 1.

## **Forum: Mission Concepts for the 2020's & Beyond**

- Jeff Johnson gave an introduction to the [Forum: Mission Concepts for the next Decadal Survey](#). This outlined a new concept for this MEPAG meeting. The purpose was to provide the community with opportunities to discuss (1) high-level science objectives or questions, (2) the importance of specific types of observations/measurements/analyses, science or technology strategies, and (3) mission concepts in all classes (small satellite missions, secondary payloads, competed missions, and follow-on flagship capabilities).
  - 31 abstracts were received for the poster session, all of which can be viewed on the [MEPAG meeting website](#).
  - Each forum presenter was asked to provide a 1-slide “lightning talk” before the two-hour poster session. “Synthesizers” took notes and summarized the discussions during the poster session, and a group discussion session immediately followed the poster session.

## **Day 2 – Wednesday, April 4**

### **Decadal Survey Preparations**

- Jeff Johnson began with [a summary of Day 1 activities](#), including a summary of the inputs provided through the Forum. This included discussion regarding (1) the high-priority science questions that could be addressed over the next two decades of Mars exploration; (2) the types of mission classes that could significantly address those questions; and (3) those topics that could be addressed by a MEPAG study or workshop to better enable particular concepts to be considered by the next Decadal Survey committee.
- Lisa Pratt, NASA’s Planetary Protection Officer, gave a talk without slides. Lisa Pratt, a former MEPAG Chair and member of the Executive Committee, was named as the new NASA Planetary Protection officer ~2 months ago. The Planetary Protection office has recently been moved to the Office of Mission Assurance and the integration is still ongoing. The planetary protection research budget is still under the Science & Mission Directorate (SMD). Lisa Pratt emphasized the need for planetary protection to consider both the forward and backward contamination risks and mitigation. There is a strong commitment to following COSPAR policies on all NASA related missions.
- Carolyn Mercer, Manager of the Planetary Exploration Science Technology Office (PESTO), gave a [briefing](#) about the PESTO office. PESTO is a new NASA Headquarters office managed at Glenn Research Center. PESTO recommends technology investment strategy for future planetary science missions, manages PSD technology development through programs such as PICASSO, MatISSE, HOTTech, COLDTech, DALI, etc., coordinates planetary science-relevant technologies within PSD, Science Mission Directorate, and Space Technology Mission Directorate, and promote technology infusion. The presentation also included an overview of how technology items are prioritized, a list of PSD high priority technologies (as of April 2016), and prioritized technologies for Mars and Small Satellites.
- Louise Prockter, co-chair of the Mid-Term Decadal Survey Assessment Committee, delivered a [progress report](#) on the panel’s status. The committee is tasked with review of progress toward implementing the Decadal Survey Vision and Voyages for Planetary

Sciences. The committee will not be developing new mission concepts or priorities, but will deliver some advice to the next Decadal Survey committee. The committee has held five meetings and plans to deliver its report June-July, 2018. The presentation also summarized key issues under review by the committee, including whether the recommendations from the Visions & Voyages Decadal Survey are being followed and what needs to be done to get back on track in certain areas over the next 5 years.

- David H. Smith of the Space Studies Board gave a presentation on [Preparing for the Next Planetary Science Decadal Survey](#). The next Planetary Science Decadal Survey is targeted to be tasked by NASA in October-December, 2019. The statement of task will be finalized and the Decadal Survey (DS) initiated in January, 2020. The Planetary Science Decadal Survey will be released at LPSC in 2022. Several relevant studies have been recently completed or are ongoing or planned for the near future. The DS committee will emphasize getting mission studies going early because these studies are incredibly important at the beginning of the DS process. The DS only prioritizes New Frontiers and Flagship class missions, so these types of studies are most useful. Mars New Frontiers mission studies will be very important if the Mars community hopes to get a New Frontiers candidate mission into the DS. White papers will likely be requested to be submitted prior to the first meeting of the DS committee in June 2020.
- Michael Meyer, Lead Scientist for the Mars Exploration Program, gave a presentation on [Mars Exploration Science Status](#). The presentation included a report on the Joint Workshop on Induced Special Regions. The workshop was sponsored by both the former Planetary Protection Subcommittee and the Planetary Science Subcommittee. At the workshop scientists and planetary protection experts convened to assess the potential of inducing special regions through lander or rover activity. Special regions are defined as places where water activity and temperature are sufficiently high and persist for long enough to plausibly harbor life. “Induced” implies regions that are created by spacecraft operations. The workshop addressed three main questions:
  - What is a safe stand-off distance, or formula to derive a safe distance, to a purported Special Region?
  - Questions about RTGs, other heat sources, and their ability to induce special regions?
  - Is it possible to have an infected area on Mars that does not contaminate the rest of Mars?A general consensus was reached on several points:
  - While a spacecraft on the surface of Mars may not be able to explore a special region during the prime mission, the safe stand-off distance would decrease with time because the sterilizing environment that is the martian surface would progressively clean the exposed surfaces.
  - An RTG at the surface of Mars would not create a Special Region but the result depends on kinetics of melting, freezing, deliquescence, and desiccation.
  - While a buried RTG could induce a Special Region, it would not pose a long-term contamination threat to Mars, with the possible exception of a migrating RTG in an icy deposit.
  - Induced Special Regions can allow microbial replication to occur (by definition), but such replication at the surface is unlikely to globally contaminate Mars. An induced

subsurface Special Region would be isolated and microbial transport away from subsurface site is highly improbable.

Additional research was recommended in several areas. Further details are available in the slides.

- Michael Meyer's presentation also included an overview of the International Mars Sample Return Objectives & Samples Team (iMOST) study. This team is composed of a group of ~70 international scientists, chartered by the International Mars Exploration Working Group (iMEWG), to update the objectives of Mars Sample Return (MSR) and the samples and measurements desired/required to achieve those objectives. The iMOST team will report out at the 2<sup>nd</sup> International Mars Sample Return Conference in Berlin in April, 2018.
- Michael Meyer also introduced the Mars 2020 Return Sample Participating Scientist (RSPS) program. This program seeks individuals whose addition to the Mars 2020 science team will enhance the value of the samples to be selected, characterized, and cached by the Mars 2020 Rover. Selected participants will become members of the Mars 2020 science team and are expected to contribute collaboratively to any and all aspects of the surface science mission. More information about this program will be released soon, including a follow-on, additional PS program for mission scientists.
- Jeff Johnson gave a presentation on [MEPAG Preparations for the Next Decadal Survey](#). There are only ~2 years for the Mars community to come to consensus and to execute pre-DS studies including SAGs and other studies, white paper concepts, and costing studies. This presentation included an overview of the NASEM Committee on Astrobiology and Planetary Science (CAPS) report: Getting Ready for the Next Planetary Science Decadal Survey. That report can be downloaded [here](#). The presentation also briefly reviewed the MEPAG top 7 questions and progress that had been made on those questions through 2009, as well as several discoveries and questions that require follow-up as of 2018. There are also other considerations such as preparations for future human exploration of Mars, and what other aspects of Mars science can and should be pursued in conjunction with Mars Sample Return. More details about MEPAG roles and a summary of these issues can be viewed on the presentation slides.

### **Reports from Mars Missions**

- Bruce Banerdt, PI of the InSight mission, gave a status report (slides not posted yet). The InSight mission is scheduled to launch from Vandenberg Air Force Base during launch windows opening on May 5<sup>th</sup>, 2018. Once launched, InSight is scheduled to land on Mars November 26, 2018. The science payload has completed testing and the spacecraft has been delivered to Vandenberg. The targeted landing site is in Western Elysium Planitia to the north of Gale Crater. The InSight Participating Scientist program received 73 proposals, including 10 from outside the US. The review panel meeting for these proposals is planned for early June and it is hoped that the selections will be announced by the end of July. It is expected that ~18 US and ~6 non-US investigators will be selected.
- Bruce Jakosky, PI of the MAVEN mission, gave a report on [Project Status and Recent Science Results](#) of the mission. MAVEN (Mars Atmosphere and Volatile Evolution Mission) will complete its second Mars year of science observations in August, 2018. The spacecraft and its science instruments are performing nominally, and the mission is planning for

enhanced communications relay operations to support 2-3 relay passes per day in the 2020 era. The presentation included science results relating to the loss of atmosphere to space during the course of the “MAVEN Mars year,” The effects of the largest solar event observed to date by MAVEN, implications of MAVEN results for evolution of habitability of exoplanets, and upcoming observations & plans for an extended mission 3 in FY2019. See the presentation slides for more detail.

- Leslie Tamppari, Deputy Project Scientist for Mars Reconnaissance Orbiter (MRO), gave a presentation on status and results from the [MRO mission](#). MRO launched in 2005 and is currently in Extended Mission #4 and has seven science investigations still returning data. One of the main points of this presentation was that MRO is now regarded as a keystone mission (i.e., absolutely necessary, although there are contingencies) for future Mars missions including Mars 2020. Thus, keeping the spacecraft operational for relay & critical event coverage until 2027 is now MEP’s top priority for the mission. This provides an opportunity for extended science observations. This presentation also summarized several recent discoveries and publications based on MRO data which can be viewed in the accompanying slides.
- Laura Kerber, Deputy Project Scientist for the Mars Odyssey mission, presented an update on Mars Odyssey Results (slides not yet posted). Odyssey spacecraft operations are currently nominal ~17 years after launch. Most redundancy systems remain with the exception of the reaction wheels. Ongoing science work is focused on observing frost, potential surface water and water ice clouds, as well as the thermophysical properties of the surface.
- David Lawrence, PI for the MEGANE instrument, gave a presentation about the Japanese Mars Moons Exploration (MMX) mission & the MEGANE instrument (slides not posted). The MMX mission is scheduled to launch in 2024 and will perform remote sensing of Phobos and Deimos, as well as *in situ* observations of Phobos as it carries out its mission to retrieve >10g of sample from Phobos and return to Earth in 2029. This would represent the 1<sup>st</sup> sample return mission from the martian satellites. The science goals of MMX include determining the origin of Mars’ moon and increasing understanding of planetary system formation.
- Ashwin Vasavada, Project Scientist for Mars Science Laboratory (MSL) Curiosity, presented an update of [mission status and recent results](#). Curiosity has found evidence of late stage diagenesis as well as persistent subsurface habitable conditions. The rover is currently investigating hematite-rich Vera Rubin Ridge with the goals of determining its primary depositional environment and stratigraphic relationship to Mount Sharp. The presentation also included details on current status of attempts to restore drilling operations, which can be viewed in the linked slides.
- Abigail Fraeman, Deputy Project Scientist for the Mars Exploration Rover (MER) Opportunity, presented an update of [MER mission status and results](#). The Opportunity rover hit the milestone of 5000 sols on the martian surface on February 15<sup>th</sup>, 2018 and is currently exploring and investigating formation hypotheses for Perseverance Valley.

- Thomas Duxbury gave a presentation on the [Mars Exploration Program Geodesy & Cartography Working Group and International Space Agency Phobos/Deimos Working Group](#). The Mars Exploration Program Geodesy & Cartography Working Group (MGCWG) works to develop, evaluate and recommend cartographic standards for Mars and its moons and to produce or validate cartographic map products used for mission design and landing flight operations for Mars landers and rovers. The International Space Agency (representing NASA, ESA, JAXA and Roscosmos) Phobos/Deimos Surface Characterization and Site Selection Working Group (PDWG) works to encourage, support, and produce higher-level derived datasets to support mission design, surface characterization, site selection, mission operation and flight data/sample context.
- Heidi Hammel, JWST Interdisciplinary Scientist, and Stefanie Milam, JWST Deputy Project Scientist for Planetary Science, presented on [Mars Science with the James Webb Space Telescope](#) (JWST). This presentation was focused on observing opportunities for Mars using the James Webb Space Telescope. The first observing window will take place in 2020 in cycle 1 of the mission. Options for Mars include imaging and spectroscopy. There are proposal opportunities for funding both observations and data analysis.

### **Day 3 – Thursday, April 5**

#### **Reports from Mars Missions (con't)**

- Dimitri Titov, Mars Express Project Scientist, gave a presentation on the current [status of Mars Express \(MEx\)](#). The presentation included recent “science nuggets” including new data about the important role of fluvial erosion and middle-low latitude glaciation, evolution of sedimentary deposits, and polar cap morphology. The spacecraft, operations and archiving are currently nominal and the extended mission has been approved by ESA through the end of 2020.
- Jorge Vago, ExoMars Project Scientist, presented an overview and status report of the [ExoMars Project](#), consisting of the Trace Gas Orbiter (TGO) which launched in 2016 and the ExoMars Rover which will launch in 2020. The presentation included the mission objectives and description of all instruments on both missions. TGO finished aerobraking on February 20<sup>th</sup>, 2018 and reached its final orbit on April 7<sup>th</sup>, 2018. The ExoMars Rover is equipped to search for signs of past and present life on Mars and to investigate the water/subsurface environment as a function of depth, with the ability to collect samples down to 2-meters depth. The collected samples will be analyzed with the Pasteur instrument payload, which is described in more detail in the slides.
- Ken Farley, Project Scientist for the Mars 2020 mission, presented a [mission overview and status report](#). The presentation contained an overview of the mission objectives and current status. The project has just completed its System Integration Review and Assembly, Test, and Launch Operations (ATLO) have begun. The presentation also contained videos demonstrating the Fast-Traverse capabilities of the rover as well as an animation of the Adaptive Caching Assembly (ACA) which will be used to collect and cache samples for potential future return to Earth. Dr. Farley also announced that the final Mars 2020 Landing

Site Workshop will take place in October, 2018; the workshop is open to all interested scientists.

### **Human Exploration & Commercial Space**

- Richard Davis, SMD Assistant Director for Science and Exploration at NASA Headquarters, gave a presentation about Looking Ahead to Mars Human Exploration (slides not yet posted). This included a current status report about the Human Landing Sites Study (HLS<sup>2</sup>) and an overview of International Mars Exploration Working Group (iMEWG) draft mars strategic planning.
- Jen Eigenbrode presented on a mission concept for Martian Subsurface Ice Science Investigation (slides not yet posted). This was a look at what types of science could be done with *in situ*, robotic access to pristine subsurface ice before human explorers arrive on Mars. The presentation included a breakdown of baseline and threshold science objectives for this type of mission, as well as recon and investigation strategies to increase the probability of success.
- Nantel Suzuki of Advanced Exploration Systems in the HEOMD at NASA Headquarters, delivered a presentation on [NASA Human Exploration and Operations Mission Directorate \(HEOMD\) Status](#). The presentation included discussion of the HEOMD budget and planning for the future of the Space Launch System and Lunar Orbital Platform-Gateway development to support exploration of the moon and the rest of the solar system.
- John Connolly of NASA Johnson Space Center reported on [The Fifth Community Workshop on Achievability and Sustainability of Human Exploration of Mars \(AM-V\)](#) which took place December 5<sup>th</sup>-7<sup>th</sup>, 2017 in Washington DC. The purpose of the workshop was to determine if there are achievable, affordable, and sustainable scenarios for human exploration of Mars by the mid-2030s that will be supported by the broad community. If so, what are the priority technology investments, major architectural elements, and milestones? More details about the workshop, which considered three different durations for human activities on Mars, can be found in the slides and in the workshop [report](#).

### **Conference/Team Reports**

- Carolyn Mercer, Program Officer for Planetary Science Deep Space SmallSat Studies (PSDS3) and Program Executive for Small Innovative Missions for Planetary Exploration (SIMPLEx), delivered a briefing on [Small Spacecraft Programs](#).
- Brandi Carrier and Leslie Tamppari of the Jet Propulsion Laboratory presented a brief overview of [COSPAR Preparations](#) for several Mars related sessions which will take place at the 2018 COSPAR Assembly in Pasadena, CA on July 15-22, 2018.
- Jim Skinner delivered the presentation [Mapping and Spatial Infrastructure Team \(MAPSIT\): Connecting MEPAG Goals](#). The presentation included an overview of MAPSIT and a request for prioritization of MEPAG community needs with respect to spatial data infrastructure.

### **Meeting Conclusions**

- The meeting concluded with discussion of draft findings and suggestions that would be sent to the Planetary Science Advisory Council (PAC) Chair (A. Verbiscer), as well as the current and incoming Division Directors of the Planetary Science Division (J. Green, L. Glaze). Inputs from the community present and on-line were incorporated, and final changes were made through the MEPAG Committees, as shown below and in [the updated Wrap-up meeting presentation package](#).
- Additional discussion was held regarding the potential study groups, including those related to small spacecraft and technological capabilities, and recommendations made by the CAPS committee (see above link). These will be discussed further by the MEPAG Executive Committee.
- The meeting concluded with discussion of potential future virtual and face-to-face meetings and topics. It was expected that one or more virtual meetings would be held during the summer to hear, for example, reports from the 2<sup>nd</sup> International Conference on Mars Sample Return and from the Mid-term Decadal Survey Assessment Committee, as well as the organization of any MEPAG studies in the near term.

**MEPAG Meeting #36 Findings**  
**April 3-5, 2018, Crystal City, VA**

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- 1) Finding.** MEPAG is greatly encouraged that NASA is openly and enthusiastically moving forward on Mars Sample Return, thereby addressing the Decadal Survey's top priority for NASA flagship missions.

*MEPAG encourages the Mars Exploration Program to maintain the goal of completing lean science-driven Mars Sample Return in the next decade and looks forward to receiving regular reports on progress made in technology development and international partnering.*

- 2) Finding.** MEPAG commends the steady progress on the Mars 2020 mission and welcomes the open discussion by NASA of the follow-on elements of Mars Sample Return (MSR). However, the totality of a lean science-driven MSR campaign across multiple missions, including post-landing sample analyses, requires constant and productive long term communication and coordination amongst NASA programs and international partners. It is important that there be designated points of contact and clear lines of communication during technological development of all key components of the complete MSR campaign.

*MEPAG suggests that NASA give strong consideration to integrated management of the entire multi-mission sample return campaign within the Mars Exploration Program, including scientific oversight to ensure that the scientific value of the returned samples is maintained.*

- 3) Finding.** Mars Sample Return (MSR) remains a high priority for planetary science and the Mars Exploration Program, and continuing progress on science-driven MSR is welcome. However, enabling opportunities for the pursuit of other high priority Mars science objectives that can be addressed by the community in the coming decade would augment the science return to be gained from MSR alone.

*MEPAG encourages NASA to explore additional, open-call (competed) opportunities to address high priority planetary science goals in the Mars system during the era of MSR and afterward, in particular, those objectives that have long strategic lead times for the future exploration of Mars.*

- 4) Finding.** The extended Mars spacecraft missions are providing very high science return for a very modest investment. Many extended missions are being counted on to provide critical coverage and relay for the follow-on missions of the "lean" sample return architecture. However, aging relay infrastructures and landed assets will need more, not less, support to meet their engineering requirements. Cuts to mission budgets result in restricted operations of functioning spacecraft and reduced data acquisition, negatively affecting programmatic interdependency and scientific goals. Science opportunities are typically lost disproportionately as a result.

*MEPAG encourages that NASA adhere to the recommendations in the National Academy of Sciences report on Extended Missions and continue to fund extended missions at roughly constant levels, including adjustments for inflation.*

**5) Finding.** MEPAG recognizes the vital role international partners have played and will continue to play during the next decades of Mars exploration, particularly during the era of “lean Mars Sample Return.” However, ongoing and future Mars and planetary science collaborations are contingent on the ability to reconcile international cooperation with the interpretation of security restrictions without hindering needed scientific and technological collaborations on spacecraft missions.

*MEPAG encourages that the Science Mission Directorate review interpretations of security recommendations that may overly restrict the ability of international partners to fully carry out their agreed-upon responsibilities in mission development, operations, and data analysis while maintaining appropriate security.*

**6) Finding.** Over the past two decades of successful Mars exploration, the careful decisions to maintain a portfolio of investments in the scientific analysis of large data sets collected by spacecraft, at analog field sites, and in the laboratory have culminated in an advanced understanding of the planetary evolution of an Earth-like, habitable planet. The Mars Exploration Program and the Science Mission Directorate would benefit greatly by continuing to capitalize on the expertise developed within the planetary science community to enable further discoveries that feed directly back into exploration plans for sample return and remote reconnaissance. However, as decommissioned missions end or deal with reduced funding, researchers previously engaged in data analysis directly via mission resources will rely increasingly on traditional Research and Analysis (R&A) programs to preserve these efforts. MEPAG recognizes that there is debate about whether recent increases in R&A funding have been commensurate with the previous Decadal Survey recommendations. However, the fundamental issue is that the growing base of Mars data and the increasing pool of expertise will require increased R&A funding to best advance knowledge of Mars that is needed to plan for future missions beyond sample return.

*MEPAG recommends that R&A resources be incrementally increased in advance of a next decade of fewer non-MSR missions in order to exploit the rich value of the vast volumes of data already returned, and to ensure a critical core of expertise remains available to carry out associated science investigations and plan future missions to Mars, whether robotic or human.*

**7) Finding.** Recent advances in small spacecraft mission capabilities are certain to continue and will provide additional opportunities for focused science measurements that will address key science questions in the Mars Exploration Program. By clearly linking science objectives with plausible small spacecraft capabilities, MEPAG could create a framework for the definition and evaluation of the science capacity of such missions, as

well as identify significant scientific opportunities. Two major challenges for the success of small spacecraft missions in deep space are: 1) how to get there, and 2) how to get the data back. There is much energy and creativity being devoted to what small spacecraft can do, much of it arising from academic and private sector investments.

*MEPAG encourages NASA to continue to support small spacecraft concept studies to help investigate engineering capabilities/challenges, coupled with science objectives and requirements. MEPAG also encourages identification of specific, near-term opportunities for small spacecraft missions/secondary payloads, and to the development by NASA with the commercial sector of technologies and infrastructure necessary to minimize the burden on individual missions for interplanetary propulsion and back-to-Earth telecommunication.*

**8) Finding.** Long-lived, new, and planned international Mars spacecraft missions such as Mars Express, the ESA-ROSCOSMOS ExoMars Trace Gas Orbiter (TGO) and 2020 rover/surface/platform (RSP), the United Arab Emirates HOPE orbiter, ISRO's Mars Orbiter Mission (MOM), and the JAXA Mars Moons Exploration (MMX) missions have provided--or hold great promise to provide--substantial contributions to Mars science.

*MEPAG congratulates these teams and their sponsors on the progress to date and looks forward to the data acquisition and analysis enabled by these missions and to the discoveries sure to come.*

**9) Finding.** The Committee on Astrobiology and Planetary Science (CAPS) recommended that a suite of studies be prepared in advance of the next Planetary Decadal Survey. Among these were (1) new cost and technical evaluations of the next elements of the sample-return campaign, and (2) analysis of medium-class missions to explore ancient and modern aqueous environments.

*MEPAG agrees with these recommendations and stands ready to work with NASA to provide assistance to complete these studies in a timely and efficient manner.*

**10) Finding.** MEPAG acknowledges the importance of accurate, scientifically compelling, and standardized cartographic and geologic map products in the exploration of solar system bodies.

*MEPAG encourages interaction between the Mapping and Planetary Spatial Infrastructure Team (MAPSIT) and all Analysis/Assessment Groups (AGs) to help prioritize the products in most need of oversight and fabrication to achieve their exploration and analysis goals. MEPAG will strive to do its part, but wishes to understand how priorities can be set consistently across the program.*