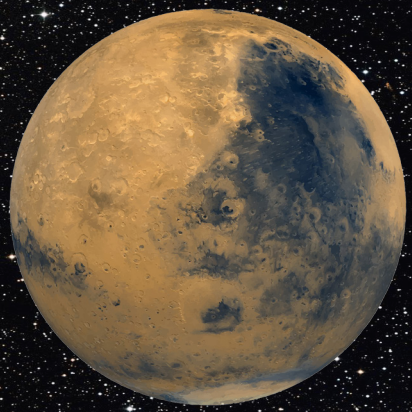
Continuing to Build a Community Consensus on the Future of Human Space Flight

Report of

# The Third Mars Affordability and Sustainability Workshop

December 2-4, 2015
The Space Policy Institute
The George Washington University

**Organized by *Explore Mars, Inc.* and the *American Astronautical Society***




Harley Thronson (American Astronautical Society & NASA GSFC),
Chris Carberry (Explore Mars, Inc.),
& Richard Zucker (Explore Mars, Inc.)
Senior Editors

John Baker (NASA JPL),
Deborah Bass (NASA JPL), Joe Cassady (Aerojet Rocketdyne),
Mark Craig (Science Applications International Corporation),
Mary Lynne Dittmar (Coalition for Deep Space Exploration),
Bret Drake (Aerospace Corporation), Dan Dumbacher (Purdue University),
Lindsay Hays (NASA Mars Program Office), and Jennifer Stern (NASA GSFC),
Breakout Session Chairs and Associate Editors

# OVERVIEW

To continue building community consensus on the future of human space exploration, the Third Mars Affordability and Sustainability Workshop (AM III) was hosted by the Space Policy Institute and held at The George Washington University in Washington, D.C. from December 2 – 4, 2015. Approximately 60 professionals from the industrial and commercial sectors, academia, and NASA, along with European colleagues, participated in the workshop. These individuals were chosen to be representative of the breadth of interests in astronaut and robotic Mars exploration. AM III continued the work that began with the first two Affording Mars Workshops (AM I and AM II) in 2013 and 2014. AM III conducted side-by-side comparisons of potential Mars mission architectures and strategies, discussed potential science goals associated with architectures for human missions to Mars, and examined how to design and advance a humans-to-Mars program that is fiscally and politically sustainable. The output of the workshop consists of observations, findings, and recommendations intended to inform space agency leadership and national policymakers.

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# SUMMARY WORKSHOP FINDINGS & OBSERVATIONS

- A Level 0 requirement for credible human Mars exploration architectures is identification of the sustaining sources of funding and how the architecture will return value commensurate with its costs to stakeholders.

- There is a pressing need to close various strategic knowledge gaps, some of which can be accomplished on Earth, and some on the International Space Station (ISS), but many require measurements or demonstrations that can only be achieved via a Mars flight program. A number of notional robotic missions were identified by the workshop that would be attractive to both the science and human space flight communities.

- The workshop participants agreed with previous recommendations (see, e.g., AM I and AM II reports) that there are capabilities directly related to and on the critical path to the human exploration of Mars that should be tested in cis-lunar space.

- A well-planned and widely vetted set of science objectives for a human landing mission to Mars is essential to help ensure sustained coordination among the human spaceflight and science communities.

- While it is clear how humans on the surface of Mars would significantly accelerate the pace of the search for *past* life, further study must be performed so that humans can play a significant role in (while not serving as a hindrance to) the search for *extant* life.

- The workshop participants were unable to conclude whether human orbital and/or Phobos missions will make sufficient contributions to the subsequent landing of humans on Mars to justify their associated costs and possible risks.

- In order to decide whether to plan a human mission to Phobos, robotic reconnaissance in the early 2020s is critical to scientifically and operationally characterize the moon to properly evaluate costs and benefits.

- Extensive international and in-space economic commercial partnerships yielding a critical mass and broad portfolio of stakeholders are crucial for sustainability. For stability and effective partnership, the members of such an international collaboration must coordinate closely the development of their respective contributions.

- Decisions about choice of architecture must be rational, transparent, consistent with plausible estimates of available funding and be made as they are required. Making decisions in this manner is important to maximize effective participation.

- In discussing the budget for human exploration of Mars, focus should be on annual budgets, rather than the total two-decade cost. At the same time, focus should be on eventual value, pay-off, and goals, rather than annual expectation of major events or discoveries.

- Younger scientists and engineers should be actively engaged. This should include internships, competitions, early opportunities to work on key scientific and technical programs, as well as involvement in the development of strategy, and welcoming them as essential advocates for the future of space exploration.

# SUMMARY WORKSHOP RECOMMENDATIONS

- Continue to focus on those human space flight scenarios that are most plausibly affordable and sustainable. Encourage government and private financing for those components, technologies, and capabilities that provide cost savings for initial human missions to the Mars system and that broaden and deepen the partnership base.

- During the process of defining the science and instrumentation development needs for the human exploration of Mars, efforts should be made to engage stakeholders from a broad range of scientific communities (heliophysics, astrophysics, Earth science, etc.)

- The value of sending humans to the Mars system for orbital and/or Phobos landing missions, prior to the initial Mars human landing, should be assessed, perhaps by The National Academies.

- Sustained formal collaboration among Mars scientists, engineers, technologists, and teams developing scenarios for Mars exploration should be supported.

- High-priority human-scale technologies for martian entry, descent, and landing must be pursued immediately. Such capabilities were also found to be relevant to a precursor robotic "heavy" sample return mission. Such an essential capability is an excellent example of highly visible progress toward human Mars exploration.

- Strategy, narrative, and messaging should be shaped by the NASA Authorization Act of 2010's long-term goal. Section 202 of that Act mandates that "The long term goal of the human space flight and exploration efforts of NASA shall be to expand permanent human presence beyond low-Earth orbit". An enduring strategic campaign of engagement should be developed by relevant professionals after a thorough assessment of successful strategies executed in other fields. This could include independent review of the progress of the community's messaging strategy and a clearinghouse for reliable information on that progress.

- Scenarios for initial human missions to Mars should be jointly developed by government, industry, academic, and international partners; that is, the scenarios should be the product of community development, discussion, and debate.

- Stakeholders, as represented by workshop participants, should be advocates for efficient acquisition methods, improved insight/oversight models, acceptance of appropriate risk, and transparent funding processes and priorities that contribute to improved coordination among the NASA HQ Mission Directorates.

- NASA should evaluate a substantial cross-directorate administrative structure that reflects an integrated human space flight/science/technology program.

# Table of Contents

# I. Background, Goals, and Structure

Planning for the third in our continuing series of community Mars Affordability and Sustainability workshops (AM III) began shortly after AM II concluded in October 2014. These workshops, organized jointly by Explore Mars, Inc. and the American Astronautical Society, bring together stakeholders from industry and commerce, academia, government, and the space communities and participants are intended to be representative experts in their respective fields.

AM I, which was held in Washington, D.C. in December 2013, concentrated on industry and government policies and practices that limit cost and seek schedule savings for initial human missions to Mars. Building upon the findings and recommendations from this first workshop, AM II, which was held at the Keck Institute in Pasadena in October 2014, compared and contrasted scenarios, architectures, and sample strategies developed by industry, academia, and NASA that are intended to significantly reduce costs for human space flight (HSF) beyond low-Earth orbit (LEO), especially to Mars. In addition, at that second workshop a team of experienced Mars scientists was included in a breakout session to assess the role of human-enabled science exploration of Mars within the context of current and proposed future HSF architectures. Formal reports from both workshops were widely circulated, briefed to senior NASA leaders, and presented at numerous professional conferences. [More information about both workshops and their deliverables may be found at http://www.exploremars.org/affording-mars ]. Following AM II, however, and based on discussions held there, the organizing team decided to change the name of that workshop from the Affording Mars Workshop to the Mars Affordability and Sustainability Workshop to more accurately capture our intent.

As with our previous pair of workshops, the essential principle in AM III was that it would be of little value to human exploration stakeholders to consider scenarios for human exploration that are not justifiably both affordable and sustainable.

Our previous pair of community workshops concentrated on affordability, management and leadership philosophies to achieve affordable human exploration, and comparison of a recent generation of concepts for HSF missions to the vicinity of Mars. For AM III, the organizers, who had been impressed with the effective participation of a modest number of Mars scientists, decided to integrate more fully representatives of the science community with colleagues who have been working credible scenarios for human exploration. In addition, a team was also established to assess the issue of a sustained program of human Mars exploration and the policies and practices necessary to make this possible.

Approximately sixty professionals participated in the workshop, including senior NASA managers, scientists, engineers, technologists, and participants from the U.S. National Academies, as well as international colleagues. The workshop was organized as part of a joint initiative by Explore Mars, Inc. and the American Astronautical Society. Sponsors of the workshop included Boeing, Lockheed Martin, Orbital ATK, Aerojet Rocketdyne, and MDA.

To make progress in a relatively short workshop, even with a number of follow-on tasks, there were a handful of guiding assumptions and ground rules, including:

- Scientific exploration of Mars will be a major activity in the decades ahead, as well as a significant component of human exploration.
- Early and focused technology investment, including precursors and demonstration missions, is essential for the timescale adopted here.
- Technical/engineering solutions exist for landing and long-duration operations on the martian surface.
- Partnerships (international, industrial, commercial, academic . . .) will be an essential component of human Mars exploration.
- Research and development will continue on ISS at least through the mid-2020s.
- The Space Launch System (SLS) and Orion will be available during the time period considered here.
- The budgets for space agencies will be approximately flat at least for the next few years[1]. Budget growth is possible in response to an international commitment to travel to Mars.

Preparation for the workshop included a small team that discussed the importance of sustaining an affordable program, which would be discussed at the workshop. A few top-level observations from this team helped focus discussion during the workshop.

*A Program that is Sustainable is By Definition Affordable.*
*A Program that is Affordable is Not by Definition Sustainable.*

An **affordable program** is an activity that stakeholders are willing to support because it returns value commensurate with its cost. A Level 0 requirement for Mars human exploration architectures is identification of the sustaining sources of funding and how the architecture will return value to stakeholders. A sustainable campaign is one that is affordable with returned value sufficient to ensure stakeholder support over decades. Specifically, what will enable human Mars missions to endure after the first several, unlike the case with the Apollo Program? And what will overcome a "been there, done that" response to initial human missions?

AM III began with a day-long series of prepared presentations on a wide range of activities intended to enable human missions to Mars sometime in the 2030s: technology development, the International Space Station (ISS), multiple scenarios developed recently intended to be affordable and sustainable, and community-developed science priorities for Mars.

The workshop also began with a prepared presentation on the issues and challenges of sustainability, which pointed out that Mars, or any destination, is a "means"...but to what sustainable "end"? A destination as "end" when reached is the end. It was agreed that significant bases for sustainability have been laid in recent years, notably by the bipartisan NASA Authorization Act of 2010, which mandates that the long-term goal of NASA human space flight and exploration is to "expand permanent presence beyond low-Earth orbit . . ." The 2014 National Academies' Pathways to Exploration roadmap and NASA's 2015 Journey to Mars Pioneering Principles build upon the Act's base and, between them, have much in common as to approach.

[1] *It was decided, for purposes of AM III, that essentially flat budgets would be assumed, even though NASA received an increase in the 2016 Omnibus budget and even though there are early indications of a willingness on the part of Congress to continue this trend in the future.*

At the workshop, the participants were divided into two parallel breakout sessions, one concentrating on how science can be enabled by astronaut travel to Mars and the other on how to sustain human exploration of Mars. To focus the work of the disparate participants in the workshop, guiding questions were given to the two teams.

## For the sessions on science enabled by human spaceflight:

For prioritized scientific objectives for the martian system (the planet's surface, in orbit, or on its moons), what are the most enabling capabilities of the exploration architecture(s) and why?

- How might the exploration scenarios be altered to enable better science (connection to higher priority objectives, results more definitive, more objectives pursued, etc.)?
- Which science objectives might be modified to increase science return within the existing exploration scenarios? How might SLS be used to advance the science return?
- Which robotic precursors and instrumentation are necessary to enable initial human Mars exploration?
- How do we best leverage partnerships of all kinds to improve sustainability, including reducing cost?
- How can human and science mission objectives be tailored to more effectively engage the public, which will result in improved program sustainability?
- What are the impacts of planetary protection protocols on an astronaut-enabled science program?

## For the sessions on sustainability and affordability:

What are the strengths/challenges of the Mars exploration scenarios presented in plenary (with solutions to the challenges)?

- What characterizes a campaign that will endure?
- What can be done to minimize the chance of program cancellation after the precursor robotic and initial human Mars missions?
- What specific near-term activities need to be carried out – and by whom – that would enhance sustainability?
- What are key roles played by stakeholders?
- Which of NASA's technology development priorities are most enabling of sustainable and affordable Mars exploration? And on what timescale? (e.g., which must be developed within a constrained budget to permit an affordable initial mission in the 2030s?)
- How do we best leverage partnerships of all kinds to improve sustainability, including reducing cost?
- How can human and science mission objectives be tailored to more effectively engage the public, which will result in improved program sustainability?

# II. Breakout Session One: Scenarios for Priority Science Programs Enabled by Astronauts at Mars

Session Co-Chairs: Deborah Bass (NASA JPL), David Beaty (NASA Mars Program Office ), Joe Cassady (Aerojet Rocketdyne), Bret Drake (Aerospace Corporation), Lindsay Hays (NASA Mars Program Office), and Jennifer Stern (NASA GSFC)

There was general agreement that there are a number of strategic knowledge gaps that need to be closed in the decades before initial human missions to the Red Planet. Some can be accomplished on Earth and others on the ISS or the region of space referred to by NASA as the Proving Ground[2] , generally meaning the vicinity of the Moon. However, many require technology development or measurements that can only be achieved via a flight program to Mars.

More specifically, example high-priority activities identified by this combined science-plus-human-spaceflight session to take place during the time frame of the Proving Ground include:

- **Next Generation Mars Orbiter.** This mission is needed for several strategic purposes: (1) replenishment of the orbital communications infrastructure, (2) provision of surface imaging capabilities for the next several decades for human landing site selection and detailed data necessary to plan crew surface operations, and (3) acquisition of improved data sets for In-Situ Resource Utilization (ISRU) planning. This early 2020s mission could also collect reconnaissance data for Phobos and Deimos, aiding the decision on whether the martian moons should be a target for human exploration.

- **Mars Sample Return.** In addition to the importance of these samples for risk reduction, particularly in the area of planetary protection[3] and dust toxicity, such missions would include the opportunity to demonstrate a launch from the martian surface to orbit and rendezvous. Because the requirements for a science-only Mars Ascent Vehicle (MAV) would be small relative to that which is necessary for a human mission, a "heavy" MAV mission should be promptly evaluated. A heavy MAV would be jointly very attractive to the science communities and relevant to development of capabilities for human exploration.

- **ISRU lander.** The knowledge needed to plan for ISRU can only in part be acquired from orbit. For some key parameters, the necessary spatial and spectral resolution (and in some cases, any data at all) can only be obtained from a mission to the martian surface.

Assessment of such a series of notional priority joint science+human space flight missions should in the near future be supported cooperatively by NASA's Human Exploration and Operations Mission Directorate (HEOMD), Science Mission Directorate (SMD), and Space Technology Mission Dirctorate (STMD). Such an assessment should include a well-planned set of science objectives relevant to a human spaceflight program that eventually lands humans on Mars. An example of a priority for an ongoing assessment activity is the role for astronauts in the search for life on the planet, which would help ensure sustained coordination among the science communities and the human space flight program.

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*[2] This breakout session found it more useful to refer to the Proving Ground as a period of time, generally the decade of the 2020s, rather than a location in the lunar neighborhood, as NASA currently uses it.*

*[3]There was much discussion during the workshop about the need to update and further define planetary protection protocols, not only as they currently apply to robotic missions but also so that they take future human missions into account.*

As in the previous pair of Affording Mars workshops, AM III discussed science opportunities in the event that the initial human missions remained in Mars orbit. A number of such scenarios were discussed at the workshop in the event of insufficient funding or lagging technological development, for example, in high-mass entry, descent, and landing or space propulsion. Should this be the case, it was concluded that missions operating in Mars orbit should be augmented with capabilities to enable priority science goals during the mission, such as surface telerobotic systems. In any case, workshop participants were unable to reach consensus on whether human missions to Mars orbit would make sufficient contributions to subsequent landing of humans to justify their associated costs and possible risks. Therefore, the workshop recommended an in-depth assessment, perhaps carried out by NASA and its partners and reviewed by The National Academies, of sending humans to the Mars system for orbital and/or Phobos landing missions, prior to the initial Mars human landing. This should include an analysis of the costs, benefits, schedule, and risks associated with both the emplacement of the additional robotic assets on Mars and/or Phobos that are necessary to enable higher science return and the option of deployment and support of a Phobos habitation for the human crews.

# III. Breakout Session 2: Elements of a Sustainable Program of Human Exploration of Mars

Session Co-Chairs: Mark Craig (Science Applications International Corporation), Mary Lynne Dittmar (Coalition for Deep Space Exploration), Dan Dumbacher (Purdue University), and Ann Zulkosky (Lockheed Martin)

This session assessed the characteristics and practices of a program of human Mars exploration that make it sustainable[4]. Previous Affording Mars workshops concentrated on affordability, which per force is a necessary element of sustainability. In AM III we took affordability as a given: scenarios presented at AM III were asserted by their creators as being plausibly affordable.

Thanks to pre-workshop meetings, by the time of AM III, all participants agreed on basic definitions, viz. a "sustainable enterprise" is one that will be continued indefinitely.

Contrast was drawn between the Apollo Program and the International Space Station (ISS), both being affordable – or, at least, afforded – although only the latter has been sustainable. [In previous workshops, the ISS was adopted as a notional model for human exploration of Mars: afforded, international, sustained, and now developing key capabilities necessary for subsequent human missions.]

Primary among the workshop's observations and findings on sustainability was the crucial importance of extensive international and in-space commercial partnerships in producing a critical mass and broad portfolio of stakeholders. For stability and effective partnership, the members of an international collaboration must coordinate the development of their respective contributions. Effective partnerships will have both domestic and international institutions on the "critical path," which makes sense for management, scientific, and budgetary reasons. However, this may also be politically challenging. This is another reason that decisions about choice of architecture must be rational, transparent, consistent with plausible estimates of available funding, and be made as they are required. Making decisions in this manner is important to maximize effective participation. Collaboration will be important among industry of all kinds, as well as government and international partners. As was discussed in the previous section, full involvement of the international scientific communities will be essential. Throughout this discussion, the ISS was used as an example of a successful, multi-decade, international space program.

Also primary among our observations and findings is that strategy, narrative, and messaging should be shaped by the NASA Authorization Act of 2010's mandated long-term goal for NASA human spaceflight to "expand permanent human presence beyond low-Earth orbit". An enduring campaign of engagement should be developed by relevant professionals after a thorough assessment of successful strategies executed in other fields. This could include independent review of the progress of the community's messaging strategy and a clearinghouse for reliable information on that progress.

Demonstrated progress toward a consensus goal was also identified as important; that is, accomplishments that are unambiguous milestones on the path toward humans on the martian surface in the 2030s. Examples of such milestones include the ISS as a test bed, long-duration habitation systems and operations beyond LEO (a priority recommendation from AM I), development of appropriate in-space propulsion, and accomplishing priority science/human space flight robotic precursors (previous section).

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*[4] We note that many of the topics in this section on sustainability apply equally to all programs of human exploration, regardless of destination.*

In discussing the budget for human exploration of Mars, focus should be on annual budgets, rather than the total two-decade cost. At the same time, focus should be on eventual pay-off, value, and goals, rather than annual expectation of major events or discoveries.

As the old saying goes, "demographics is destiny." Thus, younger scientists and engineers should be actively engaged, which should include internships, competitions, early opportunities to work on key scientific and technical programs as well as involvement in development of strategy, and welcoming them as essential advocates for the future of space exploration.

Workshop participants generally observed that sustaining an effective human Mars exploration program will require some evolution in philosophy of human space flight as well as management structures within NASA HQ. [This was a topic in the reports from AM I and II, as well.] Recommendations from the community workshop included continued efficiency in acquisition, as well as improved insight/oversight models. There was an appreciation expressed during the workshop for the realistic risks of human spaceflight, which will have to be incorporated into the strategy adopted for Mars exploration: an international program of this magnitude could be imperiled if the response to a tragedy is stasis, as opposed to renewed vigor.

A major concern at the workshop was the apparent tendency of human space flight advocates to "shoot inward," reflexively to oppose alternative scenarios. Our recommendation of a transparent process that involves multiple stakeholders will significantly mitigate this problem.

Finally, the workshop community again urged NASA to evaluate a cross-directorate administrative structure that reflects an integrated human space flight/science/technology program.

## Participants in *The Third Mars Affordability and Sustainability Workshop*
## December 2 – 4, 2015
## Space Policy Institute
## The George Washington University

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The Space Policy Institute

The George Washington University

| Last | First | Affiliation |
|---|---|---|
| Aldrin | Andy | Florida Tech BASI |
| Antonell | Tony | Lockheed Martin |
| Baker | John | NASA JPL |
| Barbier | Louis | NASA OCS |
| Bass | Deborah | NASA JPL |
| Bearden | David | Aerospace Corp. |
| Beaty | David | NASA Mars Program Office |
| Bingham | Jeff | US Senate Commerce Committee Staff (retired) |
| Bleache | Jacob | NASA GSFC |
| Boston | Penelope | New Mexico Tech |
| Callahan | Jason | The Planetary Society |
| Carberry | Chris | Explore Mars, Inc. **Co. Chair** |
| Cassady | Joe | Aerojet Rocketdyne |
| Conley | Cassie | NASA HQ SMD |
| Conrad | Pamela | NASA GSFC |
| Cooke | Doug | Cooke Concepts |
| Craig | Mark | Science Applications International Corporation |
| Davis | Richard | NASA HQ |
| Dittmar | Mary Lynne | Coalition for Deep Space Exploration |
| Drake | Bret | Aerospace |
| Duggan | Matthew | Boeing |
| Dumbacher | Dan | Purdue University |
| Elsperman | Michael | Boeing |
| Foley | Kevin | Boeing |
| Frassanito | Jack | Jack Frassanito & Associates |
| Fulford | Paul | MDA |
| Garvin | Jim | NASA GSFC |
| Gates | Michele | NASA HQ HEOMD |
| Gatens | Robyn | NASA HEOMD |
| Giacalone | Pietro | Embassy of Italy |

| Last | First | Affiliation |
|---|---|---|
| Guidi | John | NASA HQ HEOMD |
| Hays | Lindsay | NASA Mars Program Office |
| Henning | Garth | NASA HEOMD |
| Hopkins | Josh | Lockheed Martin |
| Jackman | Angela | NASA MSFC |
| Kirkpatrick | Jim | American Astronautical Society |
| Laurini | Kathy | NASA JSC |
| Martin | Thomas | Aerojet Rocketdyne |
| Meyer | Michael | NASA HQ SMD |
| Moloney | Michael | The National Academies |
| Murchie | Scott | Johns Hopkins University |
| Ori | Gian | International Research School of Planetary Science |
| Perino | Maria | Thales Alenia Space |
| Porter | Ron | NASA HQ |
| Pratt | Lisa | Indiana University |
| Price | Hoppy | NASA JPL |
| Radcliffe | Torrey | Aerospace Corp |
| Rafkin | Scot | Southwest Research Institute |
| Raftery | Michael | TerraTrace Corp |
| Rominger | Kent | Orbital ATK |
| Sauvageau | Donald | Orbital ATK |
| Smith | David | The National Academies |
| Stansbery | Eileen | NASA JSC |
| Steele | Andrew | Carnegie Institution of Washington |
| Stern | Jennifer | NASA GSFC |
| Thronson | Harley | AAS & NASA GSFC **Co. Chair** |
| Troutman | Pat | NASA LaRC |
| Turner | Janelle | NASA HQ SMD |
| Watzin | Jim | NASA HQ SMD |
| Zucker | Richard | Explore Mars, Inc. |
| Zulkosky | Ann | Lockheed Martin |

## The Third Mars Affordability and Sustainability Workshop Planning Team

Chris Carberry (Explore Mars, Inc.) & Harley Thronson (NASA GSFC)
Co-Chairs

John Baker (NASA JPL)
Louis Barbier (NASA HQ)
David Beaty (NASA Mars Program Office)
Joseph Cassady (Aerojet Rocketdyne)
Doug Cooke (Cooke Concepts and Solutions)
Mark Craig (Science Applications International Corporation)
Richard M Davis (NASA HQ)
Bret Drake (Aerospace Corp.)
Matthew Duggan (Boeing)
Kevin Foley (Boeing)
Paul Fulford (MDA)
Lindsay Hays (NASA Mars Program Office)
Scott Hubbard (Stanford University)
Jim Kirkpatrick (American Astronautical Society)
Kathy Laurini (NASA JSC)
Michael Meyer (NASA HQ)
Maria Perino (Thales Alenia Space)
Michael Raftery (TerraTrace Corp)
Donald Sauvageau (Orbital ATK)
Sam Scimemi (NASA HQ)
Jennifer Stern (NASA GSFC)
Charles Whetsel (NASA JPL)
Richard Zucker (Explore Mars, Inc.)

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