National Aeronautics and Space Administration

Technology, Innovation, & Engineering Committee
of the
NASA Advisory Council

NASA Headquarters
Washington, DC
November 10, 2015

Meeting Minutes

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G. Michael Green, Executive Secretary **William F. Ballhaus, Jr., Chair**

NASA Advisory Council
Technology, Innovation, and Engineering Committee
NASA Headquarters
Washington, DC
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Meeting Minutes

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Meeting Report prepared by
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NASA Advisory Council
Technology, Innovation, and Engineering Committee Meeting
NASA Headquarters
Washington, DC

Public Meeting
November 10, 2015

Welcome and Overview of Agenda/Logistics

Mr. G. Michael Green, Executive Secretary of the NASA Advisory Council (NAC) Technology, Innovation, and Engineering (TI&E) Committee welcomed the members and asked them to review and sign their Sensitive Information Statements.

Opening Remarks

Dr. William Ballhaus, TI&E Chair, explained that the NAC had asked TI&E to review the technology risks and challenges matrix for the human spaceflight to Mars. The agenda reflected this charge.

Space Technology Mission Directorate Update

Mr. Stephen Jurczyk, Associate Administrator of NASA's Space Technology Mission Directorate (STMD), stated that STMD has a strong program that is going well. Among the recent activities were a space technology industry roundtable, selections of early career faculty, and proposals for early stage innovation. Under the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, STMD launched a new activity called the Commercialization Readiness Program, which advances projects to Phase 3. In the Centennial Challenges area, Phase 1 of the 3D Printed Habitat Challenge brought in 160 responses, resulting in 30 selections to proceed further and funding for five projects in Phase 2.

The Flight Opportunities program issued a solicitation for service providers, as well as another for suborbital payloads. There have been recent launches in the Small Spacecraft Technology program. One had an operations challenge precluding communications, and there will be lessons learned from that. Another suffered an unsuccessful launch from the U.S. Airforce Super Strypi rocket, but should have another opportunity soon.

Mr. Jurczyk provided examples of some of the game-changing technologies that are moving forward, such as the Deep Space Atomic Clock project, which ran into some challenges that have since been addressed. The Solar Electric Propulsion demonstration is proceeding well, and issues with the Laser Communications Relay Demonstration are being resolved and the project is moving toward its 2019 test flight date. There was additional discussion of strategic planning, and Mr. Jurczyk noted that the principal technologists are developing an investment strategy that should provide more structure.

The Fiscal Year 2017 (FY17) proposed budget has been sent to the Office of Management and Budget (OMB), which responded favorably. An ongoing issue is the parachute for the Low Density Supersonic Decelerator (LDSD). The modeling is difficult and will take time. STMD is looking at a range of testing options in order to generate data.

STMD also released two solicitations seeking collaboration with NASA centers or technologies with significant investments for reaching Technology Readiness Level (TRL) 6.

The response regarding these tipping point technologies was good and STMD plans on making awards in four areas.

Budget
Regarding the FY16 budget, Mr. Jurczyk had previously told TI&E that there was a large mark-up on the Senate side for satellite servicing.. He has talked to appropriators to make sure they understand the impact of such a requirement. During these discussions, he learned that they had already heard that from multiple external stakeholders.

The appropriators seem to be gaining an appreciation the technology development and accompanying investments needed to enable programs. STMD changed its message to focus on mission enabling. STMD recently held a "Lunch and Learn" activity on Capitol Hill, which discussed four projects and was well-attended by appropriations staff.

Journey to Mars
Dr. Mary Ellen Weber asked if the NASA Administrator and other top Agency officials were communicating the same message. Mr. Jurczyk replied that there is now a single message across NASA about the Journey to Mars and the critical technologies that must be developed. Dr. Weber noted that the press has stated that NASA has the technology to reach Mars, which is not the case. However, with this kind of press out there, a layperson might assume that NASA is ready to launch. Mr. Jurczyk agreed that the message must be make clear that there are still technologies to be developed.

The technologies are laid out as part of the long-term plans, incorporating how NASA will get them online. That drives the annual investment and sets up a timeline. Dr. Ballhaus recommended creating a single chart with the four or five most important items and the lead time, in order to create a sense of urgency. Dr. Matt Mountain said that there are questions about the existence of certain projects, like CubeSats and the Asteroid Redirect Mission (ARM), that do not appear relevant. Mr. Jurczyk said that some of these, such as CubeSats, are important to the science side of NASA; not everything relates to the Journey to Mars. Less than 10 percent of the STMD portfolio is low TRL, and the rest is technology pull. All of it is now being supported across NASA with the message that STMD can enable key activities and projects with the appropriate resources and investments.

NASA leadership is making these statements to appropriators. As noted, the Senate is hearing from organizations outside the Agency to protest their allocations and suggest alternatives. Industry and university partners have engaged, and this has a greater impact than comments from the Agency seeking changes in the allocations. Dr. Ballhaus pointed out that the NAC always asks what in STMD has to do with the Mars journey and the Science Mission Directorate (SMD). Most of the early stage technology development will not pay off, but it is an investment in the next generation of human capital, which is important. Mr. David Neyland observed that one messaging issue is whether the percentages under discussion are for all of STMD or just the discretionary portion of the budget. It can take as much manpower to run a small project as it does a larger one. This then becomes an issue of allocating the NASA labor force.

Dr. Mountain asked if there had been plans made to transition to the next administration. Mr. Jurczyk replied that this is an uncontrollable unknown, but STMD is setting up a structure and a strategic plan to enable the setting of priorities. Dr. David Miller, NASA Chief Technologist, said that NASA's upper management understands the need for a coherent, high-level strategy that the Agency can carry to the next administration and that can be tailored. He added that the CubeSats mentioned earlier are very important in SMD.

Technology Risk/Challenges Matrix for Humans to Mars and Discussion

Mr. Jason Crusan, Director of Advanced Exploration Systems (AES) within HEOMD, described the Evolvable Mars Campaign (EMC). Instead of relying on design reference missions (DRMs), EMC employs a design philosophy that enables clear decision-making, builds on previous studies and ongoing assessments, and links current investments with future needs. Mr. Crusan reviewed the EMC process, some of which relies on proving ground objectives.

There are similarities and differences in resource utilization on Mars and the Moon. The water bounding effects are probably different and therefore would require different technologies. But both require propellants to go out and return, and both may need to harvest propellants for the return trip. There is a need for a demonstration mission. NASA has one in process, and the Agency's international partners are working in this area as well.

The proving ground space is critical, and the International Space Station (ISS) is already functioning in this capacity for deep space habitat, crew health, and other areas of interest. Once AES has met the proving ground objectives, the program will define system performance levels and their requirements. Each capability will go through development cycles. Mr. Crusan showed a list of 14 capability areas. System Maturation Teams (SMTs) are defining the capabilities needed at the various levels. SMTs also do gap analysis and help drive investment planning. Mr. Crusan provided some examples of SMT activities.

Strategic Priorities and Gaps

Mr. James Reuter, Deputy Associate Administrator for Programs in STMD, noted five strategic themes, which reflect the roadmaps. He also listed some of the crosscutting needs that HEOMD has identified; these are not all STMD priorities. The two mission directorates have three categories of collaboration: deliveries, partnerships, and coordination.

Dr. Ballhaus asked if supersonic parachutes constitute a gap. Mr. Jurczyk said that the Journey to Mars will require delivery of a certain mass to the surface, estimated at up to 27 times the current capacity of 1 ton. A multi-center study team is looking at architectures to enable this; currently, parachutes are not a solution. There are other missions, like those for SMD, where the need is three to five times current capabilities, and parachutes might work in those scenarios. However, they are not considered viable for human descent.

Mr. Crusan said that for a human class mission to Mars in the 2030s, the greatest gaps are reliable life support and communications/navigation. These will require heavy investments. Mr. Neyland compared this to the Apollo missions and wondered if younger engineers might be charged with examining the issues and identifying gaps. It might result in something that differs from current investment strategy. Mr. Gordon Eichhorst said that there should be a goal date from which NASA works backwards in order to identify the needs for technology development and the gaps.

Mr. Crusan explained that the mission will take place in the 2030s and that the team does end-to-end analysis of how to get closure within NASA's constraints. The Agency has found the five most important technologies for each capability, and this drives the investment strategy. Investments are set in three-year windows for a date no later than 2039. Mr. William Gerstenmaier, Associate Administrator of HEOMD, said that this goes beyond technology to include launch vehicles such as the SLS and Orion. He cannot deliver to a date, but the presence or absence of a date is not what is holding him back. He does not have the basic funding across the entire system. Technology is a piece, but the total picture is larger. This is broader than whether or not NASA has a plan.

Dr. Ballhaus said that it sounds like Mars might be too hard, and that there might be a need for another objective. Mr. Crusan replied that there are many milestones, and that the goal of human spaceflight to Mars pushes NASA to find solutions, make good trades, and identify sustainability options. A single missed date is not indicative of failure.

Mr. Reuter showed the eight STMD investment thrust areas, and Mr. Crusan discussed the capabilities progressions, using radiation safety as an example and describing the industry partnerships with the habitation area. The two presenters then provided brief descriptions of each of the capabilities, with special emphasis on Environmental Control and Life Support (ECLSS) and radiation. STMD is moving forward significantly to retire some of these risks, like fire. Ascent vehicles do not constitute a near-term priority, but some analyses and demonstrations are taking place. Mr. Reuter explained that a number of these areas have been delayed deliberately due to relative priorities, levels of technology development, and the potential for industry investment.

A color-coded "stoplight chart" illustrated funding adequacy for each of these areas going forward. A yellow can indicate a combination of difficulties and planned funding. Some areas have significant gaps despite also having a lot of activity. Sometimes impediments are funding, not physics. However, there are areas in which additional funding will not solve the problem. Mr. Crusan identified the areas most in need of additional funding as habitation, ECLSS, radiation, and in-space power and propulsion.

If and when SLS and Orion are ready, presumably in the early 2020s, the program will have its first opportunity to fly a habitation system. ECLSS can use the ISS for now. The program is creating very detailed costing, with the assumption that the rockets will eventually be successful. Long-term budget estimates do not exist. In the area of energy storage, industry is way ahead of NASA, so the Agency is letting that play out. There are other areas, such as avionics, that NASA wants to keep as modular in order to plug in new architectures. It is not possible to predict everything.

When Dr. Ballhaus asked about a finding to present to the full NAC, Mr. Jurczyk said that while there is a physics and time trade, some investments will need to scale up. The area of In Situ Resource Utilization (ISRU) could change the architectures. Mr. Crusan noted that the budget has been relatively stable for over 30 years, and the program is making the best choices it can to reach 2039 in that scenario. Dr. Ballhaus explained that over the last year, TI&E has thought of creating an urgency argument. However, it might make sense to look at it another way, like leadership in space pulling in international partnerships. To maintain U.S. leadership and the soft power partnerships, NASA must show something measurable every two to three years. Mr. Crusan agreed that a constant cadence of missions and continued Low-Earth Orbit (LEO) human spaceflight are important.

Mr. Gerstenmeier added that the Moon missions should be compelling enough to meet the criteria. NASA does not want a single mission to put people on Mars, but rather compelling proving ground missions that fit into a meaningful series of missions that take us out into the solar system.

Mr. Crusan said that another element is to re-use infrastructure and build on performance. To this end, technology demonstrations must have a purpose and set the stage for the next step, leaving behind a capability that can be mission-enhancing. Budget uncertainty is the biggest challenge; it is inefficient. Dr. Ballhaus observed that budget uncertainty and annual appropriations will not change. Mr. Gerstenmeier said that this is the reason NASA does not declare a date.

Chief Technologist Update

Dr. David Miller, NASA Chief Technologist, explained that in 2010, President Obama said that he wanted humans in the vicinity of Mars in the 2030s, with a landing to follow. This statement included no date for a landing.

When asked about the policy statement behind ARM, Dr. Miller said that he recalled it as relating to development of mission elements other than Entry, Descent, and Landing (EDL) and surface systems. Dr. Ballhaus noted that the NAC questioned this effort. Dr. Miller has heard that people think NASA does not have a plan for Mars, but he thinks the Agency has too many such plans, maybe 20 or more. Ms. Faith Chandler, Director for Strategic Integration in the Office of the Chief Technologist (OCT), is trying to align these. The emphasis is on resilient architectures that adapt and are flexible. Once there is a class of resilient architectures, NASA can set investment priorities, and the goal is to do this in FY16.

A supply and demand chart indicated which missions are in the Agency Mission Planning Model (AMPM), meaning that they have been vetted. The chart also showed what has been studied but not vetted, the number of technology programs in each area. There are some needs with no investments as yet, though this includes technologies for which there are no identified needs. Similarly, other organizations might be developing needed technologies. One can also map engineering and the workforce against the chart.

Dr. Miller noted that another issue is launch vehicle reliability and the fact that flights occasionally fail. This led to a discussion of adaptability analysis and the need to think about mixed methods in some areas. When there seems to be a single answer, the question is whether it was clearly the best answer, people did not think broadly enough, or there was word passed along about what and what not to consider. The common answers might be right, but there should be thought given as to whether they are sufficiently flexible. An example is in landing the Mars crew. Current assumptions have the entire crew landing at once, but is that really necessary? It might make more sense to send crew members to the surface in pairs over time. This could lower the Mars landing vehicle weight to 3 or 4 metric tons, which might also be useful for science.

Ms. Chandler addressed the NASA 2015 Technology Roadmap, which encompasses the entire Agency, including science and aeronautics. External input on the 1,278 candidate technologies informed NASA of areas in which other Federal agencies are already at work or have an interest in collaboration. NASA also sought public and commercial sector feedback. The Roadmap team is now setting priorities among the candidate investment areas and seeking National Research Council (NRC) input on 44 new areas identified in the Roadmap.

Technology Transfer

Mr. Daniel Lockney spoke about technology transfer activities. NASA is in the fourth year of a plan for patent licensing, new software usage, and other efforts. Royalty income has stayed flat because some of the patents expired while new royalties started up, thus masking the success of the initiative. The Agency is not seeking to make money on this, but in order to avoid dilution of patents, NASA has established and is enforcing milestones. The Agency is generous in sharing royalty income with the inventors, investing the remaining funds into NASA Centers.

The Agency has doubled the amount of software released annually. NASA has a standard process and a repository in which to store the code; the process works quickly. In 2012, the program developed a strategy to reduce “defensive patenting,” so that NASA only patents for technology transfer now. The NASA Technology Transfer University partners with business schools where the students evaluate technologies. These students often want to

license the technologies from NASA. Demand for this program is higher than the Agency can meet, and the program is looking at ways to expand it.

An initiative that enables start-ups with licenses carrying no up-front costs has brought in overwhelming results. NASA is also sponsoring the Center of Excellence for Collaborative Innovation and a Future Engineers program. The Asteroid Grand Challenge program has selected two citizen science proposals.

Commercial Space
Dr. Alex MacDonald provided an update on commercial space activities, run through the Emerging Space Office (ESO). There are commercial entities that share some of NASA's goals. ESO has conducted a study of public/private partnerships that might engender growth, and has also investigated opportunities that could generate revenue. For example, a study of microgravity found no single application to justify investment. The business model with the best returns on equity or investment involves displacing an incumbent. Producing results and prototypes before there is revenue can lead to a new business or a buy-out.

ESO also started pre-NASA Research Announcement (NRA) external studies. There is abundant interest in independently identified questions in the social science and economics of space development.

Agency Technical Capability Assessment Outcomes
Mr. Ralph Roe, NASA Chief Engineer, reported that in the past eight months, his team has gathered and analyzed data, and is in the process of developing plans for the various disciplines. This is in addition to their usual work. There are five human spaceflight programs in parallel around the Critical Design Review (CDR) level, so the work level is as high as possible. The decision-makers are now determining how best to move forward. The goal of his team is to have a balanced focus between missions and current capability needs. Standardization is one of the identified challenges.

The NASA Technology Fellows are leading Agency-wide Technology Capability Assessments (TCAs). There is no policy on this, but culturally the centers "own" NASA's talent and have done so for almost 40 years. This ownership of human resources has established a culture that must be addressed in order to integrate and become more efficient. Succession planning is done at the line management level by centers, but the technology assessment has identified gap areas.

There are 19 technology areas and four system capabilities. Dr. Weber asked if there were any women within the new categories. Mr. Roe said that the new fellows were all men. Dr. Weber pointed out that there is only one woman among the 23 technology leaders; Dr. Mountain observed that this is not a good model. He and Dr. Weber agreed that it should be about 20 percent. Mr. Roe said that the selection pool included very few women.

Dr. Weber explained that at TI&E's previous meeting, the data indicated a drop in the percentage of women at each level. This remains a problem. Mr. Roe agreed and said that OCE is trying to address this. NASA's Human Capital department found that many of the women only saw line management as a career path, so OCE is trying to ensure that everyone knows about the technology career path. The Office could use input on how to improve without waiting for another generation.

Each of the Fellows is mentoring at least one woman, as well as members of minority groups. OCE has asked them to consider women and minorities as deputies, which are non-

competitive positions filled by appointment. His own deputy is a woman. Dr. Ballhaus noted that women are competitive on the management side, so there has been some self-selection; this needs to be addressed.

Mr. Roe explained that the TCAs encompassed roughly half the agency, with 16 discipline-level and 3 systems-level TCAs completed at the time of the meeting. The Engineering Management Board (EMB) looked at each of these to identify issues. Teams made 161 recommendations, most of which were consistent and fell into eight strategic themes.

The first strategic theme is that the current operating model is isolating within centers, instead of across centers. NASA must develop drivers to change, and this would be a significant cultural change. There have been some good exchanges between the Jet Propulsion Lab (JPL) and the Goddard Space Flight Center (GSFC), which constitute a model for the Agency. Senior leadership will need to commit to this in order for it to be addressed.

Mr. Neyland told of the Air Force replacing its independent labs with a single, huge lab under one commander. This solution would be revolutionary, but it would also reduce redundancy. Mr. Roe said that NASA is more focused on identifying overlap and duplication, and encouraging centers to borrow skills rather than hire local contractors. Dr. Ballhaus suggested setting up contracts between centers, which Mr. Roe thought was a good idea. At first, everyone wanted to blame funding and the mechanisms, as opposed to an organizational reluctance to collaborate. The budget personnel showed how this could be done, however.

The second strategic theme addresses cutting funds for low TRL research. Dr. Mountain suggested a program in which any savings went into fundamental research. Mr. Roe replied that OCE is considering this kind of incentive. The third strategic theme notes the insufficient in-house development of talent. The workforce age profile shows a large group heading to retirement, which necessitates more hands-on opportunities for leadership for the younger workforce.

The fourth issue is that project teams get mired in documentation and process, which deflects their focus on execution. There needs to be more emphasis on the technology content and less on process. This is a leadership issue. The fifth theme is that the Agency was found to still be risk-averse in technology diffusion and interdependence. The Associate Administrators need to accept this risk.

The next theme is inconsistent funding mechanisms for NASA's critical facilities. For example, the assessments found that the wind tunnels were being starved, which speaks to the need for an Agency funding mechanism to enable this type of research. It would be a pilot program for other large test facilities. Finally, NASA has a wide range of architectures and roadmaps, almost like a menu. The Agency should have a means by which to narrow these down.

The themes covered the bulk of the 161 recommendations, and these actions could help address the technology risks. The OCE demonstrated an enduring capabilities and leadership model for the assessment. The upcoming decisions will reflect all the work done this year and will help NASA move toward a more efficient model.

Discussion and Recommendations

Dr. Ballhaus led the Committee in drafting findings and recommendations. He began with the concept that HEOMD and STMD work together effectively and are making some

progress. He wanted to include the respective budgets available for mission technology risk reduction. After some discussion, the concept was set aside temporarily.

Dr. Ballhaus next proposed a statement about NASA demonstrating measurable progress in going into the solar system at a cadence that maintains U.S. space leadership and public support. The technologies pulled in from the proving ground missions will form the basis for advocating technology investment budgets. Dr. Weber added that NASA is focused on a human presence in space in a progressively increasing manner, not just Mars. Dr. Ballhaus said that the current technology investment assessment relates to the Journey to Mars and the slippage.

The next potential finding addressed NASA's budget limitations and the uncertainties that constitute a significant impediment to a human exploration mission to Mars in the 2030s. Dr. Miller observed that ISS is part of the pathway to Mars. It is deemed to be important for retiring human performance. Although there is a plan to use ISS, the Station is only commissioned through 2024. The important thing is to align needs and funded projects. Dr. Mountain advised that the statement point out that NASA does not have the technologies to get to Mars, and does not even have a maturation plan.

Dr. Dava Newman, NASA Deputy Administrator and former TI&E committee member, joined the meeting. Dr. Ballhaus updated her on the discussion, noting that on the stoplight chart, the red sections did not seem to concern the HEOMD people. However, there were three near-term concerns. Dr. Ballhaus also mentioned Mr. Gerstenmeier's points about budget limitations and uncertainties impeding the Mars mission, the need for SLS development, and the goal of human exploration throughout the solar system. This led to some thoughts about slippage possibly being less important and the need to emphasize U.S. space exploration leadership, in part through a cadence of proving ground missions that advance technologies. This may be where advocacy efforts should focus.

Dr. Ballhaus added that there is no architecture or system concept for getting to Mars; NASA does not have a baseline plan. Dr. Newman said that the architectures are being developed. Dr. Miller added that there are too many goals and dates at this point, and NASA must narrow them down. While another concern is partnering, the budget is always an issue. Architectures need to fit the budget. The budget cannot be an output, it needs to be an input. Dr. Newman said that the technologies should relate to specific causes. NASA tries to allocate funds realistically, and Dr. Miller pointed out that excess funds can be more crippling than helpful, since they cannot be reserved.

Dr. Ballhaus asked what TI&E could do that would help. Dr. Newman replied that the Committee should provide feedback on the Agency's priorities. NASA needs technology development to enable missions. Dr. Ballhaus observed that the NAC hears about what is publicized, and a lot of it is early TRL work that has nothing to do with going to Mars. TI&E was considering a statement that much of this is investment in human capital that will enable the Journey to Mars. Nonetheless, the requirements support the major missions are not publicized. Dr. Newman pointed out that technology development is neither linear nor sequential. Mr. Eichhorst thought that the emphasis on low TRL projects may give those outside of NASA the idea that cutting the technology budget only eliminates "little things." Dr. Newman said that the messaging could address that discrepancy.

After Dr. Newman left, TI&E returned to drafting observation and finding.

Draft Observation and Finding:

HEOMD and STMD working together have identified a range of critical technologies and further capabilities required to support human missions to Mars.

- NASA has a broad range of architectural landscape options and is working to narrow them.
- NASA is defining a common set of technology investment requirements across these architectures.
- They have identified gaps in the areas of: power & in-space propulsion, ECLSS, habitation, ISRU, communications & navigation.

In order to assess the technology investment matrix, the TI&E committee would need the following:

- A mission definition
- A plan that includes technology risk burn down lead times and tech demo completion dates
- Budget commitments and authority to proceed dates
- An assessment of technologies that could be effectively evaluated on extant ISS environment

In the absence of these items, the committee offers the following:

- The committee has been told that NASA budget limitations and uncertainties are a significant impediment to a human exploration mission to Mars in the 2030s with SLS, Orion, and other system developments as the current near term pacing items in human exploration.
- NASA has defined what budget it needs in STMD, but the discretionary portion has diminished over time, and has forced many of the planned technology investments and demo risk reduction missions to be significantly delayed, de-scoped, or eliminated.

To effectively advocate to correct this situation, in the absence of a defined mission plan to go to Mars, this committee believes the preferred approach is to develop the technology pull from the proving ground missions

- The committee believes the current HEOMD efforts must demonstrate measurable progress in most of the essential areas enabling future HE missions
- At a cadence that maintains US human space leadership and US public support
- Must address major technology gaps (power & in-space propulsion, ECLSS, habitation, ISRU, communications & navigation) with timeline for need dates and appropriate investment

After some discussion about the ISS retirement, currently set for 2024, it was determined that setting the priorities for the Station would be a worthwhile exercise.

In addition, the Committee made a statement that Mr. Roe's capabilities study appears to be worthwhile. It remains to be seen what results in terms of management, budget, and culture changes.

Adjournment

The meeting was adjourned at 5 p.m.

APPENDIX A

NAC Technology, Innovation, and Engineering Committee Meeting
November 10, 2015
NASA Headquarters
MIC 7A (7H41)

November 10, 2015 – FACA Open Meeting

8:00 a.m.	Welcome and Overview of Agenda/Logistics (FACA Session – public meeting) Mike Green, Executive Secretary
8:05 a.m.	Opening Remarks Dr. William Ballhaus, Chair
8:10 a.m.	Space Technology Mission Directorate Update Mr. Stephen Jurczyk, Assoc. Admin, STMD
9:00 a.m.	Technology Risk/Challenges Matrix for Humans to Mars and Discussion Mr. Jason Crusan, Director, Advance Exploration Systems, HEO Mr. Jim Reuter, Deputy AA for Programs, STMD Mr. William Gerstenmaier, Assoc. Admin, HEOMD
11:00 a.m.	Break
11:15 a.m.	Chief Technologist Update Dr. David Miller, NASA Chief Technologist
12:30 p.m.	Lunch
1:15 p.m.	Agency Technical Capability Assessment Outcomes Mr. Ralph Roe, NASA Chief Engineer
3:00 p.m.	Break
3:15 p.m.	Discussion and Recommendations
5:00 p.m.	Adjournment

APPENDIX B

Committee Membership

Dr. William Ballhaus, *Chair*
Mr. G. Michael Green, *Executive Secretary*
Mr. Gordon Eichhorst, Aperios Partners, LLC
Mr. Michael Johns, Southern Research Institute
Dr. Matt Mountain, Space Telescope Science Institute
Mr. David Neyland
Mr. Jim Oschmann, Ball Aerospace
Dr. Mary Ellen Weber, Stellar Strategies, LLC

APPENDIX C

Meeting Attendees

Committee Attendees:
William Ballhaus, Jr., *Chair*
G. Michael Green, *Executive Secretary*
Gordon Eichhorst
Matt Mountain
David Neyland
Jim Oschmann
Mary Ellen Weber

NASA Attendees:
Gina Anderson
Dennis Andrucyk
Katie Boggs
Faith Chandler
Jason Crusan
Anyah Dembling
William Gerstenmeier, *HEOMD Associate Administrator*
Stephen Jurczyk, *STMD Associate Administrator*
David W. Miller
Chris Moore
Dava Newman, *NASA Deputy Administrator*
James Reuter
Ralph Roe
Dawn Schaible
Jeffrey Sheehy

Other Attendees:
David Gump, Deep Space Industries
Amy Reis, Zantech
Elizabeth Sheley, Zantech

APPENDIX D

Presentations

1) Capability Development Risks for Human Mars Exploration [Crusan, Reuter]
2) Update on OCT Activities [Miller]
3) Office of the Chief Engineer Update [Roe]