National Aeronautics and Space Administration

Technology, Innovation & Engineering Committee
of the
NASA Advisory Council

Ohio Aerospace Institute
Cleveland, Ohio
July 26, 2016

Meeting Minutes

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

NASA Advisory Council
Technology, Innovation and Engineering Committee
Ohio Aerospace Institute
Cleveland, Ohio
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Meeting Minutes

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Meeting Report prepared by
Elizabeth Sheley

NASA Advisory Council
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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 reviewed the meeting agenda.

Opening Remarks

Dr. William Ballhaus, TI&E Chair, introduced Dr. Kathleen Howell, a new Committee member. Dr. Howell is a professor at Purdue University, specializing in guidance and navigation. Dr. Ballhaus explained that the Committee had been asked to compile two briefing slides, one on observations and one on concerns, to share with the NAC. This would be in addition to any findings and recommendations. He reported that Dr. Steve Squyres resigned as NAC Chair due to his workload. Mr. Kenneth Bowersox is the interim chair; the next NAC Chair will be appointed by the incoming president.

Welcome to Glenn Research Center (GRC) and Remarks

Dr. Marla Perez-Davis, GRC Deputy Director, welcomed the Committee and presented a video celebrating the 75th anniversary of GRC. She noted that GRC has a number of activities centered on innovation and has created enabling environments, with less emphasis on the labs.

One of the biggest challenges in reaching the next breakthrough is funding for research. In addition, history shows that major technologies take about 20 years to develop. NASA needs to think in that timeline. Paper studies can only go so far. Beyond that, there must be environments that allow some trial and error. The Agency needs to enable movement forward to the next stages. Future technologies require investment, given the long timeline. NASA should make innovators feel welcomed, supported, and acknowledged, especially the new generation, which has a different way of thinking.

Dr. Ballhaus asked if there are still opportunities for entering engineers and scientists to pursue good ideas based on center funding. Dr. Perez-Davis said that that is a challenge. Everything is based on competition, which involves proposals. At the same time, division directors are supporting internal ideas and internal competitions. The end goal is to align with NASA missions but still have proposals. There are opportunities outside of that to support the exploration of ideas. The advantage of proposals is to gather input from multiple sources – academia, industry, etc.

Mr. Stephen Jurczyk, Space Technology Mission Directorate (STMD) Associate Administrator (AA), said that senior managers will be discussing how to engage the NASA workforce in research and technology, especially in low Technology Readiness Levels (TRLs). They need to think in terms of competition for ideas rather than funding.

In answer to a question, Dr. Perez-Davis said that the GRC workforce includes over 1,000 civil servants and about the same number of contractors. While the workforce has been stable for a few years, GRC is facing a wave of retirements, with 50 percent of the workforce eligible in the next 5 years. Therefore, GRC has been hiring. The Center has a program to train candidates internally as a prelude to employment. The goal is to keep the numbers stable. GRC is also doing succession planning to transfer knowledge, which will be critical. This needs to be done right, while accelerating the learning curve. GRC is also working with the Office of Personnel Management (OPM) to identify areas of need. Every manager is charged with looking at his or her staff to see what skills are needed. This effort is in the early stages.

Space Technology Mission Directorate Update

Mr. Jurczyk provided an update on STMD activities. There are seven strategic thrust areas:

1. Space power and propulsion, which is being worked on across the Agency;
2. High band communication;
3. Life support and in-situ resource utilization (ISRU);
4. Entry, Descent, and Landing (EDL) systems;
5. Autonomy and space robotics technologies;
6. Structures, materials, and advanced technologies; and
7. Space observatory systems, which mostly relate to the Science Mission Directorate (SMD) and do not enable space exploration beyond robotic assembly.

Each area has a principal technologist who develops long-term investment strategies and quantifiable technology objectives. Mr. Jurczyk described one of the technologies as an example.

Dr. Ballhaus said that the meeting would generate suggestions on observations and concerns that STMD would like brought forward. There is the lack-of-urgency argument vis-a-vis human exploration. The Human Exploration and Operations Mission Directorate (HEOMD) has gone through flight test objectives to form precursor missions for human exploration. TI&E wants to evaluate the technologies against those objectives. There is current concern about assessment of risk reduction on technology investment, but the Committee does not have the needed information. Regarding human exploration, the expectation 25 years ago is that it would be way ahead of where it is now. In addition, no one knows what a new administration will promote and support.

Mr. Jurczyk replied that there is a plan to lay out seven missions in the proving ground of cis-lunar space. His current concern is when, which is a key in setting investment priorities and needs. Certain things need to be done in the near term, and NASA needs to make the right decisions at the right time to move forward. He worries that it is becoming harder to move technologies into insertion into the system. There is also a need to begin work early on some of the Mars systems, like infrastructure for crew support.

Dr. Mary Ellen Weber asked what has been dropped. Mr. Jurczyk replied that Environmental Control and Life Support System (ECLSS) technology is an area of discussion. The plan is to retire the International Space Station (ISS) in 2024. It takes time to develop systems for ISS, and the systems should be on ISS for a minimum of two years, which means there is little time. That has brought near-term development of ECLSS technologies into question.

STMD has done some selections in the NASA Innovative Advanced Concepts (NIAC) early-TRL program. Mr. Jurczyk noted that it is eight percent of STMD's investment and high percentage of its press coverage. There is also a solicitation for virtual Space Technology Research Institutes (STRIs). These must be led by universities, which can have outside partners. The focus areas are biomanufacturing and digital materials. STMD received more than 40 Notices of Intent (NOIs). STMD will screen the white papers, then ask some candidates to submit for proposals. The funding is $3 million per year for five years, and the goal is to have these solicitations every two years. The focus is on research and technology development for specific technologies that will end up with NASA. The first two STRIs are essentially pilots.

STMD is trying to expand its partnerships with small business. The Directorate held a solicitation development workshop with the other mission directorates, and the expectation is that solicitations will now be clearer and more focused. There are also regional events to engage small business, and a virtual pre-solicitation conference. This approach was recommended by both TI&E and the small businesses themselves. STMD provides points of contact to the firms, and will also talk to large companies about working with small business; most have a small business strategy already.

The Small Business Innovation Research (SBIR) percentage of the STMD budget went up, so funding is now $230 million. The Agency is helping with the STMD discretionary budget issue, because this takes $30 million from that. Congress rejected a plan to take the funds from the programs, so STMD is working with OMB on an alternative. Outreach in the Flight Opportunities area resulted in higher quality proposals. The Centennial Challenges are close to having a good partner for the 3-D-printed habitat prize. STMD is reviewing the Centennial Challenges, for ways to improve the program. In the area of small spacecraft technology, STMD put out a solicitation on pathfinder cubesats to establish a standard platform with industry. There was a smallsat solicitation and a corresponding SBIR topic. One of the "Tipping Point" solicitations about to come out will ask for an entire mission. There will be an independent assessment of smallsats and cubesats soon, and Mr. Jurczyk expected to be able to brief TI&E on that at the next meeting.

The Office of Science and Technology Policy (OSTP) wants to have a multi-agency smallsat meeting at the White House in September. NASA has put out the technology and policy challenges, and feedback is pending. Dr. Howell said that the cubesat community is concerned about tracking capacities. Mr. Jurczyk said that that and orbital debris mitigation will be discussed at the meeting. There are serious challenges. However, in the area of commercial space, NASA, which is not a regulatory agency, has a good relationship and collaboration with the Federal Aviation Administration (FAA), which does regulation.

The Game Changing Development (GCD) program launched the Inflatable Reentry Vehicle Experiment (IRVE). GCD is looking at a system to help ISS crew identify items internally. Other activities include sounding rocket flight tests and possible next-generation computing

for space communications. Woven Thermal Protection System (TPS) work continues advancing. The Deep Space Optical Communication (DSOC) project is moving closer to demonstration. The Neutron-star Interior Composition Explorer (NICER) will fly on an upcoming SpaceX flight. STMD is looking at basic materials development in the area of Nuclear Thermal Propulsion (NTP).

The Green Propellant Infusion Mission technology demonstration is scheduled to launch in March, 2017. However, the Air Force has asked what another 6-month delay would do, as there are launch challenges. The Deep Space Atomic Clock (DSAC) still has technical challenges, the latest being input light source degradation. This requires rebuilding of the light source but should not interfere with the March launch.

The Laser Communications Relay Demonstration (LCRD) mission build is going well at NASA's Goddard Space Flight Center (GSFC), though there are some budgetary challenges. E-cryo work is going well among the centers and Ball Aerospace. For the Mars Oxygen ISRU (MOXIE) project, landing site tracking has been baselined; this will enable landings in interesting but risky areas. This has been a good partnership with SMD to develop pinpoint landing. Some technology challenges and programmatic challenges remain. STMD is talking to the Air Force about demonstrating Solar Electric Propulsion (SEP) jointly.

Dr. Ballhaus said that this sounds positive, but erosion of the discretionary budget remains a concern. Congressional direction and mandates cause this. TI&E has taken this to NAC previously. Mr. Jurczyk said there will be more Congressional direction in Fiscal Year (FY) 2017. Even if they give him more money, he is $40 million short in covering everything they want. The discretionary budget continues to erode. He gave examples of areas of underinvestment. ISRU and Advanced Life Support (ALS) need to be advancing now, and it is a struggle to move areas like EDL, composites, and space robotic systems. He wants 10 percent investment in early TRL. No one else is doing this push technology; even when universities do it, NASA funds them. NASA also should keep raising issues of smallsats and space debris with OSTP and establish a multi-agency group.

Dr. Ballhaus said that STMD should promote its macro-level accomplishments, which have been done despite an eroding discretionary budget. Dr. Charles (Matt) Mountain said that TI&E is really asking what will be robust in this program through any administration change. That will go into the observations list. They also need to highlight the key technologies so that the new Administrator will see STMD as a key player.

Dr. Weber said that Congress will not care about the lower discretionary budget and will continue giving direction, focusing on pet projects. She wanted to know how NASA will handle increasing Congressional direction and mandates. If these items always come out of this directorate, that is a problem. Mr. Jurczyk explained that the challenge is the disconnect between White House and Congressional priorities, which is consistent among all of the mission directorates. The planning and budgeting process is very inefficient and precludes laying out optimal programs. He has focused his Congressional message on the missions enabled by STMD technologies, and that message resonates. The House has a good understanding of the importance of technology development, while the Senate is more of an issue. There is little agreement on technology funding, and the discrepancies result in amounts that unbalance the portfolios. STMD should not be competing with business where business is doing its own development; the other areas are primarily about funding.

Dr. Mountain said that while there is general consensus on Capitol Hill about the NASA science program, there is none on the space exploration. Therefore, technology becomes the next best story after science. He advised that STMD try to encourage technology development stories and stay away from human exploration. Dr. Weber said that NASA as an agency needs to promote technology as important. There should be a strong internal message. Dr. Ballhaus observed that the current Administrator, Charles Bolden, recreated STMD, but faces competing priorities. He needs a reason to give more funds to STMD.

Space Propulsion and Power Overview

Dr. Jeff Sheehy, STMD Chief Engineer, described six investment themes:

- Efficient deep space propulsion, including methane, which is easily stored and has diverse applications;
- Mission enhancing space storable propulsion, including green propellant thruster technology development and demonstration;
- Cubesat/smallsat, including propulsion;
- Advanced solar arrays, including large deployable solar array technology development, which has been infused to industry at a relatively modest investment, and extreme environment solar array technology development;
- Planetary surface power, one of the larger gaps between missions and capabilities; and,
- Revolutionary propulsion research and technology development.

Dr. Sheehy reviewed propulsion technology drivers and the notional schedule of candidate options for crewed Mars exploration. Nuclear Thermal Propulsion (NTP)is among the architectures HEOMD is studying, which could decrease trip time by about 20 percent and broaden the windows for travel. The HEOMD architecture studies have been leading to a 2020 downselect. Dr. Ballhaus said that there is no urgency here, no mandate to get it done by a certain time. Mr. Jurczyk said that there is no consensus about human exploration spaceflight, and there is a challenge, in that it is hard to balance the important with the urgent.

Dr. Sheehy said that they are trying to establish a viable path for NTP, for example. The cost of NTP is the issue, so STMD is trying to show what is real as opposed to estimates based on sparse or outdated data. Mr. Jurczyk said that there is a need to get to hardware and data to prove viability. Dr. Ballhaus said that if they were to lay out a baseline schedule today, they would have metrics to show what needs to work by what time. There are ways to quantify the benefit of the investment in terms of the outcome.

Mr. Bowersox joined the meeting, and agreed with what Dr. Ballhaus said. It is possible to show the sensitivity of various architectures, which helps people to understand the numbers. He added that he would be NAC Chair for an indefinite time and looked forward to working with TI&E. Dr. Ballhaus explained to him that TI&E had been working on the fact that the discretionary budget has been eroding due to mandates and Congressional direction. The result has been delayed demonstrations, and they were trying to show why these things are necessary. Mr. Bowersox said that it is sometimes difficult to figure out how to communicate that back to NASA, which is why he wanted to send forward observations and concerns in addition to the usual findings and recommendations.

Dr. Sheehy described STMD drivers and commercial missions. The progression of SEP vehicles over time shows growth in power, as well as broader implementation and research. Dr. Ballhaus asked what they would be looking at in terms of a SEP demonstration in space, should the next administration focus on a Mars mission. He wondered when STMD would need to make technology risk reduction investments. Dr. Sheehy said that SEP has been in the plans since 2010. A space demonstration without the Asteroid Redirect Mission (ARM) would require another means, possibly through a partnership with the Air Force. Mr. Jurczyk added that STMD would have three non-ARM options but would move forward with technology development regardless. There are benefits to commercial space and security, among others.

Dr. Sheehy reviewed the key technologies and the technology risk reduction projects that have been completed. The demonstration project will occur with or without ARM. The integrated demonstration would show that SEP technology can become viable for orbit transfer, defense applications, and deep space exploration. Mr. Jurczyk said that the benefits include efficiency and agility, along with reduced launch costs and greater mission flexibility. Industry would like to go all-electric.

Dr. Sheehy presented the key benefits and near-term focus of NTP development. Dr. Ballhaus told Mr. Bowersox that HEOMD wants to make decisions around 2021 for propulsion, and STMD wants NTP to be considered, as it has quantifiable benefits. He did not know the reasoning behind the 2021 date and was concerned that it might undermine the urgency argument, thereby reducing the pull on the technology. Dr. Sheehy said that there is also a push on this technology. Congressional direction for FY16 had up to $20 million for NTP, and those numbers are larger in both houses of Congress for FY17. There is an effort to determine how to do testing more cost effectively. He presented a timeline with baseline efforts and augmentations. Mr. David Neyland asked how much it would cost to be able to do interplanetary travel if there were no constraints. Dr. Sheehy replied it could be done in 10 years for close to $10 billion. He thought the development would take about $1 billion. Mr. Jurczyk noted that a focus of the current effort is to reduce cost and risk.

Dr. Sheehy said that the limitation in reduction of transit times has to do with the approach. Some think NASA should look at Nuclear Electric Propulsion (NEP). The power would reduce the trip times dramatically. To be on Mars in the 2030s, NASA must downselect propulsion in the early 2020s. Mr. Jurczyk noted that the reactor technology they are developing could provide the power for NEP as well.

Dr. Sheehy described how the SBIR and Small Business Technology Transfer (STTR) programs are being leveraged to address some of these technology challenges. STMD is considering working on the methane engine concept due to HEOMD interest. This concept presents a lot of flexibility and many technology elements that could be advanced. Presently, STMD is looking at what has been done and the remaining technology challenges. He presented a notional timeline.

Dr. Sheehy next described the MON-25/MMH engine, a 100-lbf class engine that would advance efficiency while also bringing flexibility and substantially lower costs. This is now being tested. The engine has significant mission infusion potential and could go onto New Frontiers missions. STMD has a role in moving it from development to utilization.

Hardware is ready to demonstrate "green" propellant. Currently, NASA must obtain the propellant from the Air Force, but the Agency is trying to develop alternative sources. Otherwise, it is easy to handle and performs well. It does require additional materials work, which means cost, and cost is the barrier to infusion. After the Green Propellant Infusion Mission (GPIM), there will be additional activities required. Priorities for technology maturation have been established.

Dr. Sheehy next gave the status of technology maturation projects for cubesats and smallsats. STMD gave awards for development of some tipping point technologies in this area and has worked to advance the iodine hall thruster with a flight demonstration. HEOMD has expressed interest in surface power development for a Mars mission. The project timeline for the small nuclear fission power project has been established.

STMD could look at pairing surface and electric propulsion for Restore-L. Mr. James Oschmann noted that Restore-L is very specific and has a very specific timeline. Dr. Sheehy said that STMD wants a sustained, low-level research investment for advanced propulsion technology maturation. Congress is contemplating a 50-year roadmap for an interstellar propulsion technology, which would relate to space travel, not launch technology. Mr. Jurczyk added that for "extremely unusual ideas," like space elevators and sling-shots, it does not hurt to look at them periodically, but the technologies have not moved.

SpaceX Red Dragon Partnership Overview

Mr. Jim Reuter, STMD Deputy AA for Programs, provided some background on the Red Dragon. SpaceX sought NASA support for an uncrewed technology demonstration mission to Mars. NASA agreed to provide additional assistance, and the contract was finalized in April. Mr. Reuter provided the details of the NASA support, as defined in six Technical Exchange Documents (TEDs). In exchange for its support, NASA will obtain critical information for EDL in the Mars environment. While this involves some part-time commitment of members of the NASA workforce, that commitment is small, coming to about $32 million in support over 4 years. The Agency is still discussing some priority areas but has worked out most of the data rights concerns.

The Red Dragon will use a Falcon Heavy launch vehicle, which creates a scheduling issue. SpaceX wants to develop the cargo capability to a high level, as well as some human exploration capabilities. This effort reflects NASA's mandate to help enable the commercial space industry and provides an opportunity to develop and demonstrate EDL technologies, while improving models. This project would be a nice bridge between NASA's current capabilities and goals, and engages the NASA workforce in needed activities in this area. Industry is focusing on an effort that will address the long-term challenge of heavy mass Mars landings. Next steps include a high-level technology feasibility assessment by NASA and a review with SpaceX next April. The flight date will be determined after the system design progresses.

SpaceX is planning to spend roughly 10 times what NASA is spending, though Mr. Reuter did not have the details. The CEO, Mr. Elon Musk, has a vision and says this is the first step. The top SpaceX priority is ISS crew, then other commitments, then this. Mr. Neyland wondered about how to use this to boost NASA. Mr. Jurczyk said that NASA might do less testing and more flying of demonstrations. Mr. Musk is not wedded to the NASA level of risk

reduction, with its testing and analysis. Mr. Reuter added that SpaceX would prefer an 80 percent answer now over a 95 percent answer later.

Mr. Jurczyk noted that SpaceX does not face the same audits as NASA. The company can approach public relations differently as well. SpaceX is not amenable to insertion of NASA personnel onto their side, as the company wants to control the mission. However, it might be possible to detail some new hires or younger workers. SpaceX and other commercial ventures will have failures and will learn from them.

Chief Technologist Update

Dr. David Miller, NASA Chief Technologist, said that his term was to end in one month. The next president will appoint his successor. The Office of the Chief Technologist (OCT) recently participated in an inter-agency technical interchange meeting. There were also two executive councils. The first was to identify activities within OCT and STMD that might be better moved to the other unit, and the second council addressed how to implement that. The criteria are that OCT should handle strategic technology activities, with operational technology activities in STMD. He reviewed the various roles and responsibilities, most of which have remained unchanged.

Dr. Ballhaus said that leadership usually works through the ranks, whereas OCT goes across mission directorates and helps the NASA Administrator examine priorities. The Chief Technologist comes from outside and has a limited term. Dr. Miller agreed. He should not be in a position of protecting programs that might fall under his purview. There is an element of independent assessment in his role.

Dr. Miller reviewed the nine resulting changes, noting first that the technology roadmap and National Research Council (NRC) assessment processes should be streamlined. Right now, the roadmap is revised every 4 years, but these documents are hard to dig through and summarize. Use of the Strategic Space Technology Investment Plan (SSTIP), which sets priorities, will enable more effective communications. The roadmap process has been useful for identifying new ideas, but it still presents issues.

The SSTIP process involves identifying what has changed since the last Plan and how those changes affect technology decisions. New priorities are also determined. Because of the reorganization process, the SSTIP has been delayed. There has been much emphasis on EDL, but there is a need to address ECLSS, CO2 removal, and other issues, which means the balance should be assessed.

Dr. Mountain asked if there might not be an issue of implementing activities that should be the responsibility of HEOMD. STMD does not want to implement HEOMD's budget. He mentioned propulsion specifically. Dr. Miller said that the easier work on propulsion has been done, and now it is necessary to focus on the more exotic sensors. He would like to see the new commercial propulsion technologies grafted onto NASA projects. The mission directorates must design their systems to be open.

The second recommended change is for OCT and STMD to use TI&E's advisory role more effectively. He sees multiple models for this. Dr. Miller briefly reviewed the remaining changes, then returned to the TI&E advisory role. Options range from the status quo, to assessment of the SSTIP (which occurred at the last TI&E meeting), coordinating or

merging with the Aeronautics Subcommittee, increasing membership, conducting in-depth studies of technology readiness for specific missions, and conducting annual in-depth review of select technology areas.

Dr. Ballhaus could see adding ad hoc aerospace members for the studies. Dr. Miller noted that there is not much of a budget for studies, but there might be ways to make it work. As long as they were not standing up a new body, it should be manageable. Regarding the in-depth studies of technology readiness, he would look at progress and applicability of the work. Mr. Neyland observed that the two models are almost identical to what the Air Force is doing. He finds portfolio review more valuable than the studies.

Discussion and Recommendations

Mr. Jurczyk reported that the conversations with Congress are now less about the need for STMD and more about what the priorities should be. People are going to Congress and expressing support for STMD, and Congressional staff now understand what the Directorate is doing, just not the priorities. That remains a challenge, but it is a good trajectory. Content is the issue.

Mr. Michael Johns observed that the technology investment priorities have been driven by others, and Dr. Weber said that the Restore-L transfer was not about investing in technology. Mr. Jurczyk pointed out that Restore-L is technology-based. He would argue that there are more cost-effective ways to mature the technology and demonstrate it than spending $720 million on a mission, however. Dr. Weber said that she was still not seeing the urgency argument. Dr. Ballhaus agreed that there has been insufficient success in convincing Congress of STMD's priorities. The urgency argument is hard to address. Dr. Weber noted that the Congressional direction comes from not the American public's will, but rather supports projects without an overarching rationale.

Dr. Ballhaus suggested the Committee note that the issue of investigators being penalized for proposing advanced technology on science missions seems to be a thing of the past and thus belonged on the list.

There was discussion about the budget impact of the SBIR/STTR programs and their placement within NASA. Mr. Johns said that even if STMD were to receive the PBR as a budget, there would be less money due to the SBIR/STTR mandate. Dr. Weber added that this is an important point for the transition team. Dr. Mountain observed that Congress is within its rights to provide direction, and it was NASA that decided to place SBIR/STTR in STMD. Mr. Jurczyk cautioned against being too prescriptive, noting that every mission directorate has budget issues. Mr. Neyland said that he thought they should write as if they were addressing the next administrator. If they thought the placement within STMD was a mistake, they should say so.

Mr. Jurczyk said that there are advantages to a centrally managed program. When TI&E members questioned the sources of funding, he suggested that one option would be to have an SBIR/STTR budget from each mission directorate, but have it managed centrally. The key is to budget it so that it is not the responsibility of a single mission directorate to solve the problem. STMD has done a great job with an integrated program. The problem is that there is no policy to handle the mandated increases. The Agency does not have a way to

deal with it, and there is a need for an Agency solution. Overall, however, he feels STMD gets good support within NASA.

The Committee decided on the following draft observations:

- **NASA needs cutting edge technologies to undertake its missions.**
    - Current missions are based on technologies developed through investments made over several decades.
    - In the timeframe FY2005-FY2009, technology budgets (basic research - $500M; applied research -$900M) were drastically reduced.
- **Current Administrator has established STMD and made an effort to rebuild the crosscutting technology program. OCT/STMD management has done an excellent job of formulating the technology program and executing it, within annual budget constraints.**
    - Example accomplishments: SEP, Green Propellant demo, composite cryotank, small spacecraft technologies, EDL including inflatable decelerator and TPS technologies. And more to come: laser comm, in-space robotic manufacture & assembly, ISRU demo, coronagraph
    - STMD reengaged the academic community in engineering research and technology development and rekindling interest in NASA among students, especially at the graduate level.
    - STMD has effectively used internal and external partnerships to mature and develop technologies, for example, NASA is beginning to incentivize technology demonstrations on competitively selected science missions (e.g. deep space optical communications on Discovery)

For concerns, the Committee drafted the following statement:
The Agency has increased external and internal appreciation for the importance of funding crosscutting technologies in STMD. However:

1. **Technology budget priorities have been increasingly driven by factors external to STMD.**
    a. NASA priorities
    b. Congressional direction
    c. Increasing SBIR/STTR mandate
2. **The consequence of this is canceled projects (EDL, CPST, LDSD, CEUS) and an inability to start high priority new activities that would give NASA technology options required for future missions**
3. **If NASA wishes to have a sustainable, crosscutting technology program, it has to find a more effective way of funding STMD working with its stakeholders**
    e.g. NASA could develop an agency-wide policy for accommodating SBIR/STTR mandates and top line increases

Dr. Ballhaus said that he would present a standard introduction at the NAC meeting, with the thrust areas, some of Dr. Sheehy's charts, a description of their GRC facilities tour, and the Red Dragon presentation. Some of Dr. Miller's points were to be presented at the non-FACA all-hands meeting of the NAC. TI&E had no findings or recommendations.

Red Dragon was likely to generate discussion at the NAC meeting. Mr. Jurczyk noted that some NASA Headquarters and centers people are nervous about SpaceX's Mars plans. NASA

is collaborating on Red Dragon for a specific reason: to gain EDL data. The Agency needs international partners and industry. Dr. Ballhaus added that it is good for experienced launch people to have these discussions. The failure rate for initial launches is high outside of government, and it is to NASA's benefit to share its information. Mr. Jurczyk agreed, noting that many early missions die, so collaboration with industry is necessary. He noted that there is a gap in the middle, between DS studies and HEOMD architecture studies. Nuclear propulsion might address the gap.

Dr. Ballhaus said that findings and recommendations will be on the agenda for the next meeting, when they could continue discussing the gap.

Adjournment

The meeting was adjourned at 5:08 p.m.

APPENDIX A

NAC Technology, Innovation, and Engineering Committee Meeting
July 26-27, 2016
Ohio Aerospace Institute (OAI)
22800 Cedar Point Rd, Cleveland, OH 44142
Board Room (Second Floor)

July 26, 2016 – **FACA Open Meeting**

8:00 a.m.	Welcome and Overview of Agenda/Logistics *(FACA Session – public meeting)* Mr. Mike Green, Executive Secretary
8:05 a.m.	Opening Remarks Dr. William Ballhaus, Chair
8:10 a.m.	Welcome to Glenn Research Center (GRC) and remarks Dr. Marla Perez-Davis, GRC Deputy Director
8:30 a.m.	Space Technology Mission Directorate Update Mr. Stephen Jurczyk, Associate Administrator, Space Technology Mission Directorate (STMD)
9:15 a.m.	Space Propulsion and Power Overview Dr. Jeff Sheehy, STMD Chief Engineer
10:15 a.m.	Break
10:30 a.m.	SpaceX Red Dragon Partnership Overview Mr. Jim Reuter, Deputy AA for Programs, STMD
11:15 a.m.	Chief Technologist Update Dr. David Miller, NASA Chief Technologist
12:15 p.m.	Lunch Break
1:00 p.m.	Tours of STMD Projects at GRC *(Non-FACA Fact Finding Session)*

3:15 p.m.	Break
3:30 p.m.	Discussion and Recommendations *(FACA Open Session)*
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
Dr. Kathleen C. Howell, Purdue University
Mr. Michael Johns, Southern Research Institute
Dr. Matt Mountain, Association of Universities for Research in Astronomy
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
Kathleen Howell
Michael Johns
Matt Mountain
David Neyland
Jim Oschmann
Mary Ellen Weber

NASA Attendees:
Stephen Jurczyk, *STMD Associate Administrator*
David W. Miller
Jeffrey Sheehy
Anyah Dembling

Other Attendees:
Ken Bowersox, NASA Advisory Council, Interim Chair
Amy Reis, Zantech
Elizabeth Sheley, Zantech

APPENDIX D

Presentations

1) Propulsion and Power Technology Development Strategy [Sheehy]
2) NASA Collaboration with SpaceX 's Red Dragon Mission [Reuter]
3) Roles and Responsibilities of OCT and STMD [Miller]