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Technology, Innovation, & Engineering Committee
of the
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Meeting Minutes

G. Michael Green, Executive Secretary

William F. Ballhaus, Jr., Chair

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NASA ADVISORY COUNCIL
TECHNOLOGY, INNOVATION, AND ENGINEERING COMMITTEE
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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, opened the meeting with a review of the agenda. Mr. Green reported that Committee member Dr. Dava Newman had been nominated as NASA's Deputy Administrator. The confirmation process was pending, but in the interim, Dr. Newman hoped to hear from the Committee with their thoughts.

Opening Remarks and Thoughts

Dr. William Ballhaus, T,I,&E Chair, welcomed the meeting participants and asked them to think about what specific recommendations he might take to the NAC meeting in January.

Space Technology Mission Directorate Update

Dr. James Reuther, the Space Technology Mission Directorate (STMD) Deputy Associate Administrator for Programs, presented the STMD update. The Directorate budget has stabilized at about $600 million per year with many constraints, rather than becoming the $1 billion portfolio envisioned when STMD was established in 2010. The issue therefore becomes whether the portfolio makes sense under the circumstances. STMD Associate Administrator Dr. Michael Gazarik, participating remotely, observed that STMD was getting feedback to connect more with industry, the primary group of attendees at a recent roundtable held at MIT. Dr. Reuther said that the roundtable was extremely beneficial, with a diverse group of senior representatives of aerospace enterprise, most of whom were very satisfied with STMD's activities and had not previously known of them.

One of biggest technological developments STMD has achieved recently is the successful test flight of the Low Density Supersonic Decelerator in Hawaii, which the Committee heard about at its previous meeting in July. There is parachute work still to do, and the inflatable decelerator is very robust. STMD has also done a lot of work with solar arrays, the newly tested arrays weighing essentially half the mass of a traditional solar array used in communications satellites, with one-third the volume and about half the costs. This is so compelling that commercial satellites are going to begin employing this technology. The fact that NASA pushed these arrays has induced industry to go forward with them.

STMD has also worked on Hall thrusters, which have been tested to show about 60 percent efficiency. They should last for thousands of hours, maybe even years, of continuous operations. The propellant is the limiting factor. Dr. Reuther described how the ceramic exit areas of these thrusters have been redesigned to avoid impingement, resulting in a longer life for the thrusters. This is a massive change backed up by analysis and initial testing. STMD is also issuing procurements for flight arrays for possible use with the Asteroid

Redirect Mission (ARM) or the International Space Station (ISS), as well as for a new thruster.

The Directorate completed testing of a composite cryogenic propellant tank, which worked as expected and appears to be operationally feasible. It is a unique, out-of-autoclave approach that could be used on many applications, not just cryogenic ones. There will be a series of industry days in 2015 at which STMD will discuss the process, the results, and the testing. Backing out the data, STMD has started low technology readiness level (TRL) work on how to bring together Nondestructive Evaluation (NDE) approaches on large composites. A solicitation in this area resulted in one or two proposals that warrant funding. Industry does not have a good solution on this.

Dr. Ballhaus said that different industries approach solar arrays differently. He wondered if there was a sense of where companies are aiming their investments. Dr. Reuther said that STMD does not usually have open conversations about this kind of thing, but there is one group that plans to move forward as a result of the STMD investment; it is part of the company's competitiveness strategy. The arrays have three advantages: a cost drop of 30-50 percent, lower weight, and lower packing volume. NASA invested $13 million, which is quite small compared to the market.

It is hard to get a clear "pull" for technology that might not pan out. Such things can turn into money pits. Working with other government agencies, the issue becomes whether NASA can develop a long-lasting partnership. One factor can be a turnover in leadership, which can cause an unraveling.

Dr. Ballhaus observed that if one competitor believes that an advantage exists, it forces the others to move forward. They move well beyond TRL-6 to make a sale. Dr. Reuther said that an ISS demonstration could function as a competition for the arrays. Mr. David Neyland asked who will take the cryotank to operational status. Dr. Reuther said that that is unlikely to happen all at once. NASA is focused on the upper stage first, before expanding. He expects to see a development start within the next five years. There has not been an investigation of possible applications for a cryotank in a non-aerospace environment.

Dr. Ballhaus thought that small spacecraft technologies might factor into Silicon Valley activities, with potential for small satellites. Dr. Reuther said that the small spacecraft program is doing multiple things at once. One goal is to move beyond existing missions into those that are done in constellations. For example, the Edison Demonstration Mission involves eight cubesats that will crosslink to download data from all the nodes. The only issue is launch delays. NASA is also advancing technologies expanding the capabilities of small satellites. Small satellites run into problems with propulsion and communication, the latter being a power hog. That is where NASA is developing capabilities, with a focus on propulsion during the next year. The Agency has not yet decided whether to focus on micro propulsion, orbital maneuvering, or deep space first, but all three are needed. There will be an incentivized competition in 2015 centered on small satellite capabilities.

Dr. Matt Mountain asked why NASA is in small satellites, since others are as well. He did not see why a constrained program would work on it. Dr. Reuther explained that NASA only looks at areas where the Agency can have a breakthrough and no one else will do development. The micro fluidic propulsion technologies are an example. They are quite challenging and high risk, and it is unlikely that all will make it. These programs will not be funded anywhere else. Sometimes the small spacecraft investments can transition to large spacecraft. Reaction wheels are an example. Without these investments, small spacecraft cannot move forward, and the large ones will not be able to transition.

Dr. Ballhaus said that it would be interesting to see a roadmap with the pull and the enabling technology, cross-listed with who is working on what. Mr. Neyland thought it made sense to have the small spacecraft as an enabler. Dr. Reuther said that there were three ways in which small spacecraft can be enablers: to do something unique, to function as an enabler for large spacecraft, and to engage different communities. For the last situation, small spacecraft constitute the easy entry point for non-traditional communities and partnerships, pulling new players into the business.

Small Business Innovation Research (SBIR) is a big area. In fiscal year 2014 (FY14), NASA selected 312 SBIR proposals. Space Technology Research Grants (STRGs) were awarded to 86 schools nationwide. Many of these young researchers work in the aerospace business upon graduation.

Dr. Ballhaus asked what message Dr. Reuther would want sent to the NAC. He also wanted to know STMD's major accomplishments in terms of impact. Finally, he wanted to know what will be the likely milestones in the next few years. A lot has been done with a small amount of money. Dr. Reuther said that he would put that together as an action item.

Dr. Reuther added that he did not cover a lot of new work in this presentation. At the next meeting, he hoped to highlight new content in the Game Changing Development (GCD) program. Much of this is in competed areas, like batteries, oxygen recovery, and advanced composite structures. It has been transformational. Dr. Ballhaus said that it would also be good to see SBIR highlights next time.

Update on NASA's Future Workforce: Gender and Diversity

Ms. Sherri McGee, NASA's Deputy Assistant Administrator, Human Capital Management (HCM), spoke at the request of the Committee. Dr. Ballhaus explained that at the previous meeting, TI&E members were concerned when they saw the list of Office of Chief Engineer (OCE) Technology Fellows and saw no gender diversity despite the fact that more women are now in the technology professions. This led the Committee to wonder which pools the Technology Fellows were drawn from and what NASA might be doing to change this in order to have diversity in the senior ranks.

Ms. McGee said that she did not have the data, but the presentation TI&E saw on the Technology Fellows coincided with work her department was doing on executive resources. A subset of the Executive Resources Board (ERB) is addressing the number of women, including the small number of applicants. One thought is to look at external recruitment, specifically where and how NASA recruits. The Agency needs to expand both recruitment resources and the internal pipeline. It could be that women are reticent to apply, and HCM does not know why. A significant factor is that positions do not open very often. One idea is to increase the mentoring of women so that they better understand the pipeline and career paths at NASA, as well as how to advance. The NASA Centers were told to move on this.

The Agency is also looking at data on the hiring of women in science, technology, engineering, and math (STEM) positions and their subsequent experience at NASA. Ms. Jane Datta of HCM pointed out that NASA has a low attrition rate of about 3-5 percent per year, mostly due to retirement. This means that the diversity balance reflects many employees hired decades ago. People move through the system slowly and stay well beyond their retirement eligibility dates. HCM is therefore looking at what has happened over the last 10 years to compare groups and do more qualitative understanding. The department is looking

for patterns, which differ between women scientists and women engineers, for example. HCM is also looking at promotions, awards, etc.

Dr. Mountain explained that the Committee saw the list of Fellows and wanted to know if it was a matter of the pool not having sufficient women, or if it was a hiring issue. The latter is something that NASA can fix more readily. The Agency could have set an example with the Fellows, but people hire people like themselves. Mr. Gordon Eichhorst said that people look to NASA to solve problems. He would like the Committee to state that if there is a problem with the candidate pool, it is important to learn if NASA can do more. He cited a study of eBay, which found that men and women had very different experiences at the company. If NASA wants to solve the problem at the grassroots level, it needs to determine how different groups see the Agency.

Ms. McGee said that HCM is looking at whether women are even applying for these positions, and if not, why not? It is also important to know what the environment is like. There is a federally mandated survey that every agency takes, and NASA has 53 percent participation, which is above average. The Agency takes the survey very seriously and is looking at the experience of women in the Agency. There is also the question of women leaving science jobs; NASA wants to know if this occurs at the Agency. There were focus groups on the Agency environment that led to nothing conclusive. However, one of the themes was that women are not clear about their career paths and how to move up. That was something HCM can use. There was also the perception that women are uncertain in their roles whenever there is a re-organization. That calls for better communication. Another finding was that women felt they did not have the broad networks that they feel men have. There are also supervisors who might be somewhat limited in managing a diverse workforce. Finally, there were issues regarding the need for child care.

Dr. Ballhaus said that most first-line supervisors are not very good at giving people feedback and counseling them on their deficits. At Ball Aerospace, there is now an objective given to each employee on how to improve, either in their current job or in order to move forward. That can be enormously helpful. Also, cultures can be influenced by leadership. His own NASA experience was that technology competence was valued and he had to figure out his own career path. How to fine-tune the culture without destroying the recognition of technical excellence is an issue.

Ms. McGee said that the first-line supervisors are very good, yet they are often given too much in terms of people management. Some are natural leaders and some are not, so the Agency is trying to help provide those skills. The performance management system forces opportunities to engage with employees regarding what they need to do to improve. Theoretically, NASA still has a dual career ladder, but not everyone understands it.

HCM will look at both ends of the bell curve, the employees struggling and those doing very well, for comparison purposes. The engagement study allows HCM to work with center directors where needed. It could be that some supervisors need to be moved because they are not in the right position. Some centers do 360-degree reviews, but this is not yet standard across the Agency. The concern is how to preserve anonymity. Mr. Eichhorst said that there are some great systems that manage that issue. He cautioned them in examining the attitudes of minority groups. Their comfort level in providing their views will vary, and those who have opted to fight through the system will differ from those who did not push.

Dr. Mary Ellen Weber said that the thing that struck her is that NASA seeks to inspire young people. Most STEM education is about making it fun, but students also have to see what their career is going to be. Then a list like the Technology Fellows tells the public that the

technology leadership is virtually all men. Dr. Weber wondered if it would be possible to learn who the other candidates were, not by name but in terms of how many women were considered and if those selected were such outstanding outliers that there was no other choice, and whether there could have been a different answer. She was interested in identifying the process of finding the candidates and the selection criteria. Ms. McGee said that HCM can get the process and try to understand why the applicant pool looked like it did and how it was created. Dr. Weber said that she wanted to know how NASA came to this answer and if a change could have resulted in a different answer. This looks bad for NASA and for STEM efforts. Sometimes the career opportunities do not match the STEM message. There is talk about making concessions for women, but an even playing field would obviate the need for concessions. Women are inherently ambitious, but surveys show a bias from women who do not get a chance to lead. Mr. Eichhorst said that his own career was guided by others. A lot of help occurs indirectly. NASA wants the best people but is leaving a lot of women out of the pool. Academia is increasing the number of women.

Dr. Ballhaus said that Sally Ride had an initiative for Saturdays at major universities. She asserted that females do as well as males in math until their minds get hijacked in middle school. Ms. McGee thinks NASA supports something like that initiative. She suggested talking with the new head of education at the next meeting to address pipeline development. She and Ms. Datta could present data then as well.

Dr. Reuther described the strong diversity in STMD, noting that four of the nine principal investigators (PIs) are women. There are also women within STMD leadership. Ms. McGee pointed out that those positions are competed. She offered to provide more information about STMD positions as well as the Technology Fellows and other positions within NASA. Dr. Weber said that the OCE presented the Technology Fellows as being the points of contact in each engineering discipline, individuals who are the most expert in those areas. The one woman was in the softest area. Dr. Reuther said that some of the STMD positions are extremely technical and might be more important than the Fellows, since the Directorate is trying to bring the next generation workforce into the Agency.

NASA Response to TIE Recommendation Discussion

Mr. Green explained that TI&E produced a recommendation at the last meeting, in conjunction with the NAC Science Committee. That recommendation is still in the Administrator's office, but the two mission directorates – STMD and the Science Mission Directorate (SMD) – had provided responses already, reflecting different perspectives. Therefore, this meeting invited Mr. Michael Seablom, SMD Chief Technologist, to address the recommendation.

Mr. Seablom read through the recommendation, below:

Recommendation:
The Council recommends that the STMD Associate Administrator & SMD Associate Administrator engage with each other and their communities to determine how policies and procedures could be modified to allow the infusion of new mission-enabling and mission-enhancing technologies developed by Principal Investigators, STMD or others in small to medium class missions.

***Major Reasons for the Recommendation**:*

- *In highly competitive program solicitations, such as Discovery and Explorer, there is a disincentive to propose new technology because of the perceived risk.*
- *As a result, NASA may be missing an opportunity to leverage scientifically beneficial technology through small and medium science missions. In the long-term, this could erode NASA's scientific and technical capabilities.*

- *If the Agency wants to encourage and infuse appropriate new technologies in its small and medium class missions, it must develop a policy that provides a pathway to the inclusion of these technologies in the solicitation release.*

Consequences of No Action on the Recommendation:
Erosion of NASA's science and technical capabilities

Mr. Seablom is the technology point of contact for SMD's four major divisions, and also interacts with STMD, external agencies, SMD senior management, and the centers in what he referred to as the "SMD Technology Federation." The NASA technology investment strategy moves from investments for continuous improvement (low cost, necessary), to operational transformation (improve and leverage core processes to develop new capabilities), to revolutionary improvement (high risk/high cost, far-term payoff). SMD technology investments are almost entirely in the operational transformation area, which is mid-range TRL.

Dr. Mountain said that the central issue is whether SMD is making more technology investments in flagship missions like the James Webb Space Telescope (JWST) versus the smaller missions like the Transiting Exoplanet Survey Satellite (TESS). Dr. Ballhaus added that the flagships carry significant technology risks, but proposing similar risks on a smaller program will keep a proposal from being selected. It looks like the real issue is cost overrun risk, so why not have a reserve to fund overruns, or cancel programs if they go way over?

Mr. Seablom disagreed with that characterization, countering that the current Discovery 14 solicitation embeds a great deal of technology development. Dr. Mountain replied that everyone knows what they have to do to get Explorer funding, but there will then be 10 new technologies on an $8 billion flagship. SMD's Marc Allen said that SMD prefers not to cancel missions. The policy for proposing smaller missions is that the mission either be at or get to TRL6 in a cost-effective manner. There is no aggressive program at the front end for the technology programs. There is a ladder of review. After proposals go through scientific review, they go through Technical, Management, Cost, and Other (TMCO) review. Then the proposals are categorized as 1, 2, 3, or 4, with 1 being a strong approval, and the risks and compelling issues becoming increasingly problematic through 4. There are reserves, but those are limited. The confidence level is 70 percent, and that has improved in the last few years. There is a disincentive to propose something that is not at TRL6 or that will not get there quickly.

These are science programs with science objectives. To the extent a mission can be used to demonstrate technology within that, it will, but the missions are about science. Dr. Reuther said that STMD and SMD have worked hard to get the technology demonstrations done. The perception of risk aversion is understood as being problematic, and SMD understands that it needs future capabilities. The recommendation is already being implemented, in other words, and in a big way. However, the two directorates were struggling with this until a couple of years ago. It is now stronger, in part due to cooperation between the Associate Administrators (AAs), Dr. John Grunsfeld of SMD and Dr. Gazarik of STMD.

Dr. Ballhaus observed that clearly Dr. Grunsfeld has to run the program to be accountable to the Agency. Second, SMD has to be responsible for assessing the technology risk it is willing to take for its missions. It makes sense to take some technology risk in these missions but not push failure. However, there is also a need for mechanisms to get new technology into science missions. He wanted to know why there is a perception that new technology is discouraged. Dr. Reuther said that SMD's TMCO process can be a hard bar to cross. Both JWST and the Mars Science Laboratory (MSL) had high cost growth due to technologies that were not ready for flight. Saying something is at TRL6 does not mean it is

ready to fly. In certain cases, SMD will accept the risk of the technology and bypass the TMCO review, overriding the assessment of risk.

Dr. Allen said that the Directorate agrees with the recommendation's objectives, but felt like it articulated a new path. Dr. Reuther added that SMD has a number of different models for technology infusion. STMD is working with the Astrophysics Division (APD) on the Wide-Field Infra-Red Space Telescope/Astrophysics-Focused Telescope Assets (WFIRST/AFTA) by paying for the highest-risk development of a coronagraph. This is not on the critical path, but APD does not believe it could do the coronagraph without STMD funds, which provide for a sustainable program. Dr. Allen noted that SMD has a lot of flexibility through its suborbital program, sounding rockets, balloons, and other programs that operate with modest amounts and a substantial degree of technology development. SMD has a large portfolio of small investments.

Office of the Chief Technologist Update

Ms. Faith Chandler explained that the NASA Technology Roadmaps are part of the foundation of NASA's Strategic Space Technology Investment Plan (SSTIP). The Agency is currently updating the Technology Roadmaps, including that of the Office of the Chief Technologist (OCT). The NASA technology investment emphasizes applied research and development, the budgets for which include some infrastructure. Without the latter, the technology investments come to about $4 billion. OCT is trying to better articulate what is included under technology.

There are four principle guiding elements in NASA's technology investment. The Roadmaps include the technologies needed over the next 20 years. The STIP spells out a strategy to develop those technologies needed to move forward. The NASA Technology Executive Council (NTEC) makes technology policy and decisions for the Agency. Finally, TechPort is a Web-based software system that provides information on technology programs and projects. The Roadmap is updated every 4 years. Work on the next update began in early 2014. NASA will seek public input before having independent review by the NRC. The update will include some areas suggested by the NRC, such as an expanded scope. NASA Administrator Charles Bolden had additional requests for an expanded scope.

OCT has learned that some viewed the first Roadmap as lacking clear starting and ending points, so the update will begin by defining the state of the art (SOA), which will include information brought in through the public comments. The document will also have endpoints. There will be an effort to align the Roadmap across the mission directorates to ensure that the capabilities are cross-cutting and enabled.

The Roadmap will be capability-driven to help align priorities with NASA missions. It will include an introduction and 15 technology areas in a standard format. There will also be technology candidate snapshots. Feedback has indicated that the Roadmap should keep the Technical Area Feedback Structure (TABS) relatively the same, so while there will be new TABSs, none will be removed. There are notes on cross-cutting technologies so those who use this as a tool can find things easily. Each technology area has a similar TABS.

The snapshots include sections on mission linkage, capabilities, and technology description. The Human Exploration and Operations Mission Directorate (HEOMD) content tends to have a higher TRL.

A new introduction and cross-cutting section addresses the fact that people do not search for content beyond where they think it should be. The Roadmap will index every place that

includes an item, as well as every mission. NASA is now reviewing the enabling and the "wish list" technologies, which academic and industry sought. The existing investments will be tied to the Roadmap, then the document will go to the TI&E Committee. Mr. Eichhorst asked how OCT will evaluate the public feedback and whether it will be weighted. Ms. Chandler replied that there will be specific questions, including whether OCT is missing anything. It will help validate the SOA and identify missing technologies that should be included.

Mr. James Adams, NASA's Deputy Chief Technologist, explained that the most important task is the identification of priorities, particularly in terms of investment. Ms. Chandler said that in regard to TechPort, a recent independent review will go to NASA senior leadership and the Office of Management and Budget (OMB) before being released to the public. In 2014 alone, over 3,600 NASA employees have used TechPort, and the goal is to make it available to the public. NASA will do searches and analyses for other federal agencies.

Dr. Reuther asked if the independent review group and its charter had been defined. He thought it was important that NASA be able to show the Roadmap to Congress and other stakeholders. Mr. Adams said that NTEC made the decision to have an external review. The long-term sustainability of STMD depends on external input. His concern is the time it takes to get something from NRC. He hoped to receive validation of prior priorities or any changes. Ms. Chandler added that this Roadmap has the same taxonomy and areas as the previous version, but with a standardized format, added content, and connections to missions. It was released only two years ago, so it is doubtful that much change is needed.

Mr. Eichhorst pointed out that the Roadmap will receive operational input this time. Dr. Reuther added that whoever sets the weights will determine the priorities. There are way too many customer demands. The compromise would be to give NRC the missions and a few ways the solutions could be cut. If NASA only reviews it internally, the Agency will be accused again of doing too much looking at itself, which previously led to the demise of technology at NASA. The roadmap was the first external evaluation.

Ms. Chandler pointed out that Mr. Bolden makes the final decisions, not NRC. OCT wants public input in order to know best how to be smart stewards of the taxpayer dollar. Independent input is important, but there are other factors like partnerships. Mr. Adams added that OCT does not want a rubber stamp from the external evaluators, nor does the Office want to seed the conversation beyond pointing out what was done previously.

Ms. Chandler showed how OCT addressed all of the NRC recommendations. The question remains as to how much has really changed in two years, and whether it really is time to do another large, Decadal Survey (DS) type of study, or instead follow the lead of Aeronautics, which has quarterly roundtables. NRC also wants to know what it could do that is so different from two years ago. Mr. Adams added that this is being negotiated. The likelihood of funding a particular technology is small, but there is utility beyond NASA's own investment priorities, as industry and others, like the European Space Agency (ESA), will pick up some of the technologies. There are nations aligning their activities to this content.

OCT has related activities that beyond this. For example, the Office was invited by the Taskforce on American Innovation to talk about the last part of technology development. Another effort involved crowd-sourcing technology issues across the Agency, with prizes for innovation challenge solutions. This engages the collective intelligence of NASA internally. OCT has hired an economist, Alex Miller, to the staff in order to examine the economic potential of the emerging space environment. There is an effort to look at commercial

space, such as enhanced commercial use of ISS, for example. OCT is trying to move the nation to a more entrepreneurial environment.

Dr. Ballhaus pointed out that of the commercial entities trying to enter the launch business in 1999, almost none have survived. Much commercial activity now depends on the unpredictable interests of billionaires. Five years from now, there could be a totally different environment. Mr. Adams said NASA needs to know the value of these projects because these billionaires tell Congress what they think NASA should do. NASA therefore needs to be able to tell Congress whether those ideas are economically realistic. Mr. Adams offered to bring Mr. Miller to a future TI&E meeting. It is important to continue to use and access ISS. Word still needs to get out that payloads are easier to send. OCT brought on Katie Coleman, a former astronaut who was on ISS, as an advocate for ISS utilization across NASA.

Discussion

Dr. Ballhaus noted that in regard to the recommendation to consider technology investment in SMD, it could be that the impression that technology development was being discouraged is dated, or the SMD representatives could have talked around the issue. Dr. Gazarik said he was wary of letting go of the issue entirely, but he understood not wanting to change a policy when there is no agreement that a problem exists. He would still like there to be an institutionalized practice. Dr. Ballhaus advised tabling the issue for the present, with Dr. Gazarik further evaluating the process. The Committee might also survey some of the proposers for feedback, then possibly re-engage. He wanted to institutionalize the interactions between SMD and STMD so that they are not personality-dependent. Mr. Oschmann noted that institutionalizing something is easier when there is a known answer, and TI&E was working on perceptions. There will be a large fraction of proposers who are unhappy with an outcome, and they may perceive a bias that might not exist.

Mr. Seablom added that SMD has 11 programs to retire risks, which it tries to do in advance of the missions. Mr. Oschmann replied that the system is nonetheless often viewed as one that is scored at more risk. Someone on a losing team is always going to have a built-in bias. But how much review of reviews does an organization do? It slows things down. Mr. Seablom said that TMCO keeps data on how it assesses. Dr. Ballhaus said that TI&E would leave it to Dr. Gazarik to do an assessment with SMD to see if the perception is valid. Dr. Gazarik agreed, noting that he would report out. He would like to see the relationship between SMD and STMD more formalized. Dr. Ballhaus said that he would return to the NAC explaining the action.

Office of Chief Engineer Update

Ms. Dawn Schaible, NASA Deputy Chief Engineer, talked about Technical Capability leadership, which aims to advance capabilities, build a strong foundation, optimize deployment of the workforce across all centers, and determine what NASA no longer needs to do or can purchase elsewhere. To institutionalize this, the Technical Fellows were brought in as the capability leaders. These individuals are deemed the best to determine these technical capability issues. The Engineering Management Board (EMB) reviews the results of the assessments.

Dr. Ballhaus asked who owns the human capital in NASA. In other words, can the Chief Engineer say that an individual should move from one center to another in order to address needs, do the centers keep their people, or is it done some other way? Ms. Schaible said that the workforce belongs to the centers, and OCE can provide advice. However, there is an effort to have an Agency-level capability regardless of where a person works physically.

In this model, the supervisor of record will be at the centers. The model will allow more cross-center movement for an Agency-wide integrated engineering community.

Ms. Schaible presented a list of the 19 Agency Capability Leadership areas, for which 15 Fellows have been hired thus far. A first product will be capability leadership interfacing. EMB will detail the state of the capability from each area. NASA is driven by programs and projects, and OCE is finding that there has not been enough focus on capabilities that have no applicability now but might be needed in the future. There are unintended consequences, like collaboration suffering as a result of competitions. There is also the possibility of duplication. OCE is trying to determine what the Agency needs and does not have.

Dr. Ballhaus observed that there is tremendous budget pressure, but key capabilities and core competencies have been lost. It took NASA decades to build up some of these. The Agency must to look at what it needs and is likely to need. Mr. Eichhorst asked if TechPort helps, and if there is a way to pick up institutional power and track people working on similar projects. Ms. Schaible said that TechPort is instrumental in tracking technology capabilities. It helps build awareness. Mr. Oschmann said that it can be frustrating for industry when it has a firmly entrenched capability that NASA then pursues. Ms. Schaible agreed. Dr. Ballhaus cautioned that NASA must be a smart buyer for its projects, and therefore must have a level of in-house ability. STMD has done a lot to find the right balance. Mr. Oschmann said that in industry, the tendency is to not spend a lot of money maintaining a capability that can be bought more cheaply from a contractor.

Dr. Reuther said that STMD is trying to do three related activities. First is to develop a fundamental engineering science (FES) capability, which has been in the budget request but has not yet been funded. Another effort is the Center Innovation Fund (CIF), which has some latitude to accept proposals for projects that are more science-oriented or constitute a capability or tool, as long as they are still considered innovations. About 30 percent of CIF content is in the FES category. Third is an Early Career Initiative, in which employees at the centers master the skills of technology development and learn to be smart buyers. The question is how to balance those three efforts for FY15 and determine the needs for FY16.

Ms. Schaible reviewed the roles within capability leadership. EMB is relied upon for leadership, and ensures proper alignment across missions and centers consistent with Agency and capability advancement needs. EMB also challenges OCE thinking. The Board is chaired by the Chief Engineer and includes the chief engineers from each center. Any EMB decision is still left to the centers to implement.

The NASA Technical Fellow-led technical assessments are moving forward. The human factors assessment is in implementation. Aeroscience and propulsion are ready for decisions; ascent transportation vehicle/suborbital rockets are about to be briefed. There will be a lessons learned session in January before proceeding with the other areas. The Technical Capability Assessment Team (TCAT) will be complete by the end of 2014.

Technology Demonstration Missions Program Update

Mr. Timothy Chen, a Program Executive within STMD, provided details of the Technology Demonstration Mission (TDM) program. TDM engages in funding breakthrough technologies in eight project areas. Mr. Chen reviewed each of these:

- For the Composite Exploration Upper Stage (CEUS) project, the issue is composites that still need work for the rocket environment. Reducing upper stage weight allows more weight for the payload. NASA needs a viable lightweight heavy-lift vehicle, and

CEUS will start on that with a composite skirt to demonstrate composite structures. This is a new program.

- Evolvable Cryogenics (eCryo) will work with the SLS program to define cryogenic fluid management technology development and move forward in modeling. Much of this is being done in conjunction with industry. One goal is to develop a path for a cyrocooler demonstration. Some selections were delayed in order to shift the funding to later years, and some decisions were deferred. The Radio Frequency Mass Gauge is an experiment going to the ISS in 2017. Accomplishments from 2014 include completed engineering design unit development testing, collaboration agreements, workshops, and development of the eCryo base portfolio.
- The Deep Space Atomic Clock (DSAC) has a very low error rate, with a drift of <1 microsecond in 10 years. Benefits apply to navigation, Mars exploration, gravity science, and more. It is now going through testing.
- The Green Propellant Infusion Mission (GPIM) is being worked in partnership with Ball Aerospace, demonstrating a green propellant-based propulsion subsystem that is extremely safe; it is less toxic than caffeine and has negligible vapor toxicity, with about 50 percent improvement in volumetric performance over hydrazine. The hardware is mostly done, aside from the thruster which continues to be in development.
- The Laser Communication Relay Demo (LCRD) is part of an optical communications relay services suite. If the two-year demonstration project is successful, it will change space communications. LCRD has experienced funding issues, however, and the project has a new management team, and is currently replanning. Once the replan has been completed to standards, another assessment will take place. The instability of the project has affected costs.
- The Low Density Supersonic Decelerator (LDSD) was covered extensively at the previous TI&E meeting. Parachute work continues with two vendors and retesting is planned for 2015.
- Solar Electric Propulsion (SEP) uses flexible blanket solar arrays for power generation and electric propulsion. Some of this was discussed earlier in the meeting. Arrays under investigation have been brought to TRL5.
- The Solar Sail demonstration has been very challenging. A contract initiated in 2011 was descoped in June 2014. In October, STMD chose not to extend the contract.

Dr. Reuther added that the LCRD was a relatively large procurement, and if STMD did not descope it, 10 game-changers would have had to be cut. The delays have hurt STMD significantly, but it will launch in 2019. The Space Communications Network (SCaN), which has taken over the program, is concerned, and Congress and OMB know about the problems. Mr. Neyland said that the existence of a new management team makes it look like there were additional issues. He wondered about industry collaboration options. Dr. Reuther said that it has been problematic, and NASA is doing everything it can to bring in partner participation and to talk to industry. There are activities to see what more NASA can do and to develop better strategies for moving forward.

Advanced Exploration Systems Program Update

Mr. Chris Moore, Deputy Director of Advanced Exploration Systems (AES) within HEOMD, presented an update of the program. It is not clear how AES is going to move forward on the path to Mars. Right now, ISS astronauts are close and communication is easy. Mars will be the opposite. The proving ground will be the lunar area. Some of the paths being considered include a human mission to Phobos, which is close to Mars and could be used as a base for sample return and other uses. Near-term objectives for cislunar space include validation of the following:

- SLS and Orion in deep space
- SEP systems
- Long duration, deep space habitation systems
- Mitigation techniques for crew health and performance in a deep space environment
- In-Situ Resource Utilization (ISRU), and
- Operations with reduced logistics capability

To address these validation objectives, NASA will conduct extra-vehicular activity (EVA) in deep space microgravity environments, along with human and robotic mission operations, and capability Pathfinder and strategic knowledge gap (SKG) missions.

AES does rapid development and testing of prototype systems. There are currently 27 projects in five major domains:

- Crew Mobility Systems
- Deep Space Habitation Systems
- Vehicle Systems
- Operations
- Robotic Precursor Activities

AES has established 77 milestones for FY15, more than 60 percent of which include flight demonstration elements. The goal is to achieve at least 80 percent of these milestones. The division relies upon 580 civil servants; most work is done internally.

Mr. Moore listed a number of prominent current activities, such as launching the EFT-1 flight experiment, which will measure radiation inside Orion when it passes through Van Allen Belts. The Bigelow Expandable Activity Module (BEAM) will fly to ISS in September 2015. An idea for extending human duration in space is to launch an exploration augmentation module (EAM) that could extend Orion's mission to 30-60 days. NASA is currently testing the avionics and software, and soliciting partnerships for development.

One of the important things to worry about is fire safety; scientists do not understand how fire behaves in microgravity on a large scale. There are three experiments planned but not scheduled. Another capability is in-space manufacturing, which involves 3-D printers. NASA sent one to the ISS, and it recently printed a wrench. In the area of life support, a lot of systems are high-maintenance, so AES is trying to improve their reliability and life span, with a focus on air revitalization, water recovery, and environmental monitoring. AES has developed a new space suit, the Z-3, which it hopes to demonstrate on the ISS around 2021. AES is also modifying the standard orange suit for potential space walks.

For ground and mission operations, AES is trying to reduce the number of personnel. To that end, the Division is looking at automated propellant loading, as well as autonomous systems and operations on ISS to reduce crew dependence on ground control. In the area of lander technology, AES completed a flight test of the Autonomous Landing Hazard Avoidance Technology (ALHAT). There will be two more flight tests to resolve issues with the laser Doppler velocimeter. The lunar catalyst will stimulate the commercial sector to deliver payloads to the moon. Three companies have been selected, and the goal is to have landers ready by 2017. NASA is working with the Japanese Space Agency (JAXA) on a resource prospector that would go to the polar regions of the moon in order to verify the presence of extractable water. AES will also be launching 11 cubesats.

For the Mars 2020 project, AES has selected a number of payloads, including the Mars Oxygen ISRU Experiment (MOXIE) to demonstrate production of oxygen from the Mars atmosphere. The Mars Environmental Dynamics Analyzer (MEDA) is a surface weather

station being developed by Spain. The Mars Entry, Descent, and Landing Instrumentation (MEDLI-2) involves temperature and pressure sensors on the heat shield to validate aerothermal models.

Asteroid capture systems fall into two categories: bag capture and boulder pick-up. AES has awarded four studies, which will soon be narrowed down to two. Advanced in-space propulsion is being worked on in conjunction with the Department of Energy (DOE). An independent review panel will make a fuel element down selection recommendation in February and is advising AES on how to proceed. The decision will be followed by a broad agency announcement (BAA) soliciting commercial partnerships for development and ground testing of high-power electric propulsion systems (> 100 kW).

Mr. Moore listed the 27 FY15 projects and 77 project milestones. The vision for 2020 is to extend Orion capabilities, demonstrate an advanced space suit on ISS, and do SKG Robotic Precursor Missions. There will also be Evolvable Mars Campaign precursor missions to test and place key systems on Mars, such as entry, descent, and landing (EDL) systems for heavy payloads, an in-situ propellant production plant, and a surface power system aligned with SMD needs such as Mars sample return. AES will also work on development and testing of advanced in-space propulsion systems, including high-power electric propulsion for the efficient transport of cargo, and nuclear thermal propulsion to reduce the trip time for crewed missions.

Dr. Weber questioned the use of the orange space garment, which is not flexible and lacks impact protection. Mr. Moore said that that will be a modification as a compromise. In terms of technology push, sometimes there is so much collaboration that the lines between the programs become blurred. AES meets with STMD at least once a week.

Dr. Ballhaus observed that NASA is presumably slipping every year in terms of getting to Mars by a certain date. He wondered how much more of a budget is needed, or if the current budgets persist, how much the date slips each year. Mr. Moore said that progress is incremental, and there is no exact timeline for Mars, though notionally it is the 2030s. A lot of the technologies have other capabilities as well.

Discussion and Recommendations

Dr. Ballhaus asked if there were any recommendations for STMD. He thought there should be a finding that significant progress has been made with a limited budget over just a few years. Greater re-engagement with academia and industry seems to be working, as does the increased communication with other NASA divisions and mission directorates.

Dr. Reuther said that when the Agency stood up OCT and STMD, some stakeholders asked why the technology was not being developed within HEOMD or SMD. The cross-cutting appeal with NASA and other agencies, as well as industry, is strengthened by having a dedicated organization. The fact that SMD is looking at technology demonstration in Discovery calls, coronagraph development in STMD, and more, indicates that this works. The issue never goes away, however. He likes to say that the benefits are apparent, and that technology development is more vibrant in the mission directorates as a result. Dr. Ballhaus agreed, adding that if the funds are not set aside, they are used for risk reduction and support of other missions. STMD keeps the focus. The next administrator may need to hear the argument again, however, as will new stakeholders.

Dr. Ballhaus said that while the FES activity case was made, the recommendation should be reinforced because it has yet to be implemented. However, while it was suggested that this

should be a core competency through the OCE. Dr. Reuther said that FES has a different direction from what it was doing a number of years ago. It can analyze the structural capabilities of 3-D printed parts before they are printed, for example. NASA has to be part of the leading edge here.

Regarding the diversity issue, the plan was to have further discussion with Ms. McGee once she provided additional information. One option was to show the full NAC the chart that initially caught the Committee's attention, note that it indicates some issues, and explain that the HR representatives were to return with more information. However, the Chief Engineer ought to know before any further action is taken by the Committee. Dr. Mountain advised noting that the Fellows are almost all white males. Dr. Weber cautioned against assuming a single process behind this issue. There might be pockets of processes, and she did not want the Committee to jump to conclusions. She preferred to wait for more information rather than risk having the matter dismissed.

Regarding the NASA education budget and the effort to restructure education within the Agency, it was agreed that after hearing from Ms. McGee and Ms. Datta again, the Committee would determine what additional information might be needed from the Education Office. Dr. Weber noted that taking on STEM education could cause NASA personnel to do a lot of work on a topic that TI&E cannot actually influence at a significant level. Dr. Ballhaus agreed to defer it to a future meeting.

Dr. Mountain asked if it was really necessary to go to NRC every 2 years with the Roadmap. The NRC process takes 16 months. Dr. Reuther said that the cycle is really 4 years, though it has been 2 years since the last full report. He noted that technology changes so quickly that this can be a problem. Regardless of the cadence, it is important to make sure that external stakeholders buy into the process. Otherwise, the value of an update is meaningless.

Mr. Neyland said that his concern is that there are national imperatives to have a new engine, and this process is so slow that it will put NASA further behind. Dr. Reuther saw that more as an engineering problem than a technology problem, and Dr. Ballhaus thought it was a political problem. Mr. Neyland maintained that only projects on the Roadmap receive funding. NASA has not developed a new engine in 40 years; the need has emerged in the last 12 months. He wondered about the Committee's role, or whether there was one.

Dr. Ballhaus thought that there was little TI&E could do. No one on NAC will be surprised at this development. The Air Force (USAF) and the National Reconnaissance Organization (NRO) will have to figure this out to get their payloads launched. NASA is less worried about it. Mr. Neyland pointed out that the number of engines is finite. He suggested asking a question about the long-term viability of the engines. Dr. Reuther said that inclusion on the Roadmap would not affect engines. If HEOMD AA William Gerstenmaier wants an engine, he will go after one. USAF wants to pursue a domestic engine. NASA could be a partner in paying for that, but the Roadmap does not matter.

Dr. Ballhaus expressed concern that the country lacks the metallurgic expertise needed to design an engine. The question is how to develop it. Mr. Neyland pointed out that there is a lot of precursor technology work to be done by STMD en route to a new engine, but it has to be done under a mandate. Dr. Reuther noted that Blue Orbit says it has been working on engines, as have ULA and Aerojet, but it is unclear how far they have gone. Dr. Ballhaus said that the question is important. If the country needs a new engine, someone will have to do the specifications. Dr. Reuther said that the science is there, the issue is the skills and the people. STMD does not want to develop an engine, but the Directorate could have a

robust group work on the materials side of it for $5-10 million a year. The expense is in testing flight-size hardware. Precursor technology component and materials research are in STMD's realm. There are 16 engines left in the inventory.

Dr. Ballhaus said that he would frame the issue in terms of there being limitations on engines in the future. That is new. The issue of a kerosene engine is an open question. It is more of a national security question, in that the country does not want to be held hostage by a foreign supplier. Dr. Reuther said that there is a need to facilitate NASA development of an engine, which the NASA workforce can support. NASA should have that internal capability. At the very least, having the internal capability would provide NASA with "smart buyers" who know the engines inside and out. Dr. Jeffrey Sheehy of STMD said that the National Reconnaissance Office has been looking at a hydrocarbon engine for a while and might be a good partner. He did not think that USAF could complete an engine on its own. R&D spending at the Department of Defense (DOD) has dropped significantly. Dr. Reuther added that STMD needs to put the technology backdrop in place so the nation can set up the partnerships to get this done. There cannot be a reliance on "rogue billionaires."

The Committee agreed to the following key finding to take before the full NAC:
Committee believes it is important for NASA and the Nation to develop a new domestic alternative to the current suite of foreign hydrocarbon rocket main engines.

Committee also believes NASA plays a key role in this activity especially in the development and understanding of advanced materials and metallurgy technologies for a future domestic hydrocarbon rocket main engine.

Mr. Neyland said that he appreciated the talk of small satellites and the technologies they are bringing to bear; this is a different perspective on why NASA should do them. They are a commodity, but to say they will advance the next generation of technology demonstration is great. He suggested that Dr. Reuther talk about technology development in terms of the work to be done on small satellites. Dr. Mountain agreed, saying that this was the first time some of the Committee members heard a compelling reason behind the work on small satellites.

Dr. Weber pointed out that a couple of projects within the Technology Demonstration Missions had been descoped. TI&E had requested but did not see a comparison of the 2012 projections and the reality of how they fared. The Committee wanted to see why things did not happen or got delayed, changed, or cancelled, with the rationale.

Dr. Reuther explained that there is a new effort in doing TDMs, which cannot be done retroactively. The solar sail is an example. STMD realized that TDMs marry the people who know the technology and the spacecraft people. Often with a TDM, one or the other is weaker or missing. It would be better to have proposals for technology hardware; when the technology is far enough along, NASA could then find spacecraft partners. An alternative is that those who want to propose an entire package should show that they have both teams. Often, the flight team is not needed until later. Some technology will not get that far. STMD has learned lessons that it is putting into the process. A phased process with re-proposal is an easier termination.

Adjournment

Dr. Ballhaus thanked the Committee members and asked that they send him any assignments by December 12. The next meeting will be held in early April, in Washington, DC. He adjourned the meeting at 4:54 p.m.

APPENDIX A

Agenda

NAC Technology, Innovation, and Engineering Committee Meeting
December, 2014
NASA Headquarters

December 4, 2014 – 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 and Thoughts Dr. William Ballhaus, Chair
8:15 a.m.	Space Technology Mission Directorate Update Dr. James Reuther, Deputy Associate Administrator for Programs, STMD
9:00 a.m.	Update on NASA's Future Workforce: Gender and Diversity Ms. Sherri McGee, Deputy Assistant Administrator, Human Capital Management
10:00 a.m.	Break
10:15 a.m.	NASA Response to TI&E Recommendation Discussion Dr. Ryan Stephan, Program Executive, STMD Mr. Michael Seablom, Chief Technologist, SMD
11:00 a.m.	Office of the Chief Technologist Update Mr. Jim Adams, NASA Deputy Chief Technologist
12:00 p.m.	Lunch
1:00 p.m.	Office of Chief Engineer Update Ms. Dawn Schaible, NASA Deputy Chief Engineer
1:45 p.m.	Technology Demonstration Missions Program Update Mr. Timothy Chen, Program Executive, STMD
2:45 p.m.	Advanced Exploration Systems Program Update Mr. Chris Moore, Deputy Director, Advance Exploration Systems, HEO
3:30 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
Dr. Dava Newman, Massachusetts Institute of Technology
Mr. David Neyland, The Charles Stark Draper Lab
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
Michael Johns
Matt Mountain
David Neyland
Jim Oschmann (via teleconference)
Mary Ellen Weber

NASA Attendees:
W. James Adams, NASA HQ
Marc Allen, NASA HQ
Rob Anderson, NASA HQ
Timothy Chen, NASA HQ
Jane Datta, NASA HQ
Elaine Denning, NASA HQ
Katie Gallagher, NASA HQ
Teresa Kline, NASA HQ
Sherri McGee, NASA HQ
Chris Moore, NASA HQ
Jacqueline de Morgne, NASA Goddard
Don Parker, NASA HQ
James Reuther, NASA HQ
Dawn Schaible, NASA HQ
Michael Seablom, NASA HQ
Jeffrey Sheehy, NASA HQ
Natalie Simms, NASA HQ
Ryan Stephan, NASA HQ
Ryan Stillwater, NASA HQ
Harley Thronson, NASA Goddard

Other Attendees:
Ben Keller, Lewis Burke Associates
Amy Reis, Zantech
Elizabeth Sheley, Zantech

WebEx Attendees:
Darrel Branscome
Michael Gazarik
Jim Oschmann

APPENDIX D

Presentations

1) Space Technology Mission Directorate [Reuther]
2) NASA Technology Roadmap Update Overview [Chandler]
3) Office of the Chief Technologist Update [Adams]
4) Office of the Chief Engineer Update [Schaible]
5) Technology Demonstration Missions Program [Chen]
6) Advanced Exploration Systems Program Update [Moore]