National Aeronautics and Space Administration

Technology, Innovation & Engineering Committee
of the
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NASA Headquarters
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December 5, 2017

Meeting Minutes

G. Michael Green, Executive Secretary

William F. Ballhaus, Jr., Chair

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Meeting Report prepared by
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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. He asked the Committee members to sign the sensitive information statement.

Opening Remarks
Dr. William Ballhaus, TI&E Chair, welcomed the Committee members and asked them to think about the messages they wanted to send to the NAC.

Space Technology Mission Directorate Update
Mr. Stephen Jurczyk, Associate Administrator, Space Technology Mission Directorate (STMD), reviewed some of the Directorate's accomplishments for 2017.

Technology Demonstration Missions (TDM) had significant progress toward launching demonstrations in 2018 and 2019, as well as a large-scale, ground-based demonstration project. The Laser Comm Relay Demonstration (LCRD) is doing really well and is on track to launch in early 2019. The next launch is to the International Space Station (ISS) in February, a SpaceX Dragon resupply mission that will include an element of the satellite servicing technology program to demonstrate cryo-fluid transfer and fuel transfer, along with risk reduction elements for the in-space robotic service, Restore-L. There is also a radio frequency mask gauge to measure fluid levels in the zero gravity environment.

The Fiscal Year 2018 (FY18) President's Budget Request (PBR) for satellite servicing has more focus on technology demonstrations with the Defense Advanced Research Projects Agency (DARPA) and other Federal agencies. There is a significant budget challenge to hold the November 2020 launch date. Therefore, STMD is replanning based on the budget, with the assumption that the launch date will move. In response to an industry Request for Information (RFI) to look at satellite servicing partnerships, STMD received two solid responses, which Mr. Jurczyk hoped to discuss more at the next TI&E meeting. Early in 2018, Satellite Servicing will hold its second industry day.

The Green Propellant Infusion Mission (GPIM) that has been in storage for almost a year will launch as a secondary payload on the U.S. Air Force Space Technology Program (STP-2) mission. STMD has overcome the Deep Space Atomic Clock (DSAC) challenges and is now looking at integrating the technology in preparation for a launch also on the STP-2 mission. STMD also leveraged the Neutron star Interior Composition Explorer (NICER) mission for pulsar timing experiments related to navigation. This has been an innovative way of using a science instrument for technology development.

In Game Changing Development (GCD), there has been progress in kilopower, which was on the agenda, and in the High Performance Spaceflight Computer (HPSC), which will replace the current computer used for deep space missions and similar efforts. The Small Business

Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are doing an integrated solicitation across the NASA mission directorates. An SBIR/STTR industry day had good participation, which resulted in improved quality and diversity of proposals. NASA is looking for new and innovative ways to advance small business.

Two small satellites launched on the last Orbital ATK resupply mission, to be deployed after Cygnus comes off of the ISS. Another 14 cubesats will be deployed at that time. The Flight Opportunities program had a good year, with 17 payloads on 15 different flights. STMD continues to partner with balloon and sounding rocket providers and had experiments fly on Zero-G parabolic aircraft. The Space Technology Research Grants (STRGs) continue to be deployed, and a recent Space Technology Research Grants day on Capitol Hill drew 60 to 70 Congressional staff and three members. STMD hopes to do this annually. The Committee meeting had Space Technology Research Institutes (STRIs) on the agenda. STMD will solicit two new STRIs soon, then go to a cadence of solicitations every other year.

The Centennial Challenges program had an active year, with the Space Robotics Challenge as the first virtual challenge. The goal was to develop algorithms to do a series of tasks that the developers did not think anyone could do. However, a single individual completed them and will go to Northwestern University to test them on the Robonaut platform. A third round of the Cube Quest challenge had STMD selecting three teams to build cubesats to fly on EM-1. A second phase of the 3-D Printed Habitat challenge was won by a small engineering firm.

The Technology Transfer program continues to issue licenses and make the software catalogue available.

Commercial transition of the 3-D printing challenge results is likely. The next phase will focus on making the machines more autonomous and NASA has more commercial partners lined up for that. The Agency also wants to look at robotically assembling 3-D printed components. Construction has not taken advantage of 3-D, which is another area for advancement. NASA has a partnership with the Army Corps of Engineers (ACE) to 3-D print with soil and other materials from remote locations.

STMD’s FY18 PBR of $679 million went to Congress in May, and both the House and Senate marked it up over the summer. The House appropriated $686 million and accepted the STMD plan, including restructuring of satellite servicing and elements for Orion. The Senate appropriation is $700 million, but that includes $130 million to be spent on satellite servicing, considerably more than the planned $45 million. There was other directed spending from the Senate, as well. STMD’s biggest challenge is to maintain a balanced portfolio.

STMD continues to expand its public/private partnerships and just released a new Tipping Point solicitation. Instead of three or four specific technology areas, the solicitation identified three thrust areas and stated that STMD would review anything in those categories. This will involve a two-step proposal process. The first step is like a white paper, after which the Directorate will downselect for full proposals.

Dr. Ballhaus observed that program balance seems important to STMD, but balance comes at the expense of focus. That could lead to not moving forward sufficiently in any particular area. Mr. Jurczyk said that “balance” might not be the right way to describe it, as there is an implication of evenly distributed funds, which is not the case. STMD wants to maintain about 10 percent of its investments in early stage technology, excluding SBIR, and this is where he wants to cast a wider net. Moving into technology maturation calls for a transition path to a customer. TDM is STMD’s largest program, implemented in conjunction with other mission directorates and Federal agencies.

Dr. Ballhaus acknowledged the need to justify technology investments and enabling missions that people care about. A good set of charts would be helpful. Mr. Jurczyk agreed, adding that when he goes before Congress, he always starts with TDMs because they show the technologies for future missions. Technology demonstrations are necessary in order to do early stage work, which is hard to promote on its own. He gives it context. Dr. Ballhaus said he also likes the management of SBIR now, and appreciates how STMD has implemented the industry day concept.

Mr. Jurczyk said that one of the STMD success stories will be Deep Space Optical Communications (DSOC). The Directorate is working with the Science Mission Directorate (SMD) to do a joint launch of DSOC and a science mission. Dr. Ballhaus said that TI&E has also been interested in the infusion of technologies onto smaller missions rather than just flagships. There were penalties for proposing risky technologies to smaller SMD missions, and that has been addressed. Mr. Jurczyk agreed, noting that there will be some technology demonstrations on the Mars 2020 lander, which will be NASA’s first non-blind landing. Some of the more interesting science is at dangerous landing sites, so this will enable both precision landing and hazard avoidance near those sites.

The budget is always a challenge, but that is not unique to STMD. By the next TI&E meeting, NASA will have its FY18 appropriation and an FY19 PBR. Mr. David Neyland asked STMD to consider that there is a lot of work in the Department of Defense (DOD) and the commercial sector on the landing of helicopters, which might have some applicability to vertical landers. The last 15 feet are very similar, especially in brown-out conditions. There has been a lot of work on evaluating terrain that cannot be seen. Mr. Jurczyk said that he would pass that along to the team. Regarding center funding compared to SBIR and other elements, that will depend on how the budget comes out. The FY17 final appropriation and report language was significantly constraining to STMD, but they negotiated the operations plan. FY18 looks like it will be less constrained.

Small Spacecraft Technology Program Report Response

Mr. Chris Baker described the Small Spacecraft Technology Program (SSTP). A number of NASA programs have small spacecraft elements, including SSTP, the Flight Opportunities Program, SBIR, Centennial Challenges, and the Small Spacecraft Systems Virtual Institute (S3VI). Mr. Baker is the SSTP program executive and tries to leverage the other four programs. When SSTP was stood up, there was a need for many advances, but the community has evolved so that NASA can now focus its efforts on new mission architectures, new destinations, and augmentation of existing assets and future missions. Upcoming orbital demonstration missions include the Optical Communications and Sensor Demonstration (OCSD), Integrated Solar Array and Reflectarray Antenna (ISARA), and Cubesat Proximity Operations Demonstration (CPOD). In addition, the Pathfinder Technology Demonstrator (PTD) will demonstrate small spacecraft technologies in low Earth orbit (LEO).

The plan is to have two missions per year. Mr. Baker presented a timeline of upcoming missions. He noted that reports from the National Academy of Sciences (NAS) and the Space Technology Policy Institute (STPI) both cite a need for better coordination with the NASA Centers. SSTP has not communicated its role well, and there could be some push on particular small goals. The STPI recommendations address continued support, the communication issue, the need to manage small spacecraft technology from NASA headquarters, and transition partners.

The SSTP mission is to expand the U.S. small spacecraft capability to achieve science and exploration missions in unique and more affordable ways. A 5-year strategic plan emphasizes need to be opportunistic and push on a small number of important goals. The goals include affordable and distributed spacecraft missions, and deep space small spacecraft. There are some technology gaps, but affordability is the main issue. The affordable distributed spacecraft missions include timing architectures and relative and absolute position knowledge, both without GPS. There is also a need for autonomy and constellation management, and the Program hopes to demonstrate "swarm" technologies. SSTP has a series of proposed missions in the swarm area.

SSTP is also looking at deep space small spacecraft in areas of high delta-V deep space propulsion; affordable radiation tolerance for small spacecraft missions; and deep space navigation and attitude determination for small spacecraft. This area is applicable to both planetary science and heliophysics. Dr. Ballhaus asked about the key capabilities needed for the science missions, which have greatly increased their use of smallsats. Mr. Baker gave the heliophysics space weather effort as an example of science that could be enabled with much less cost by using small spacecraft and smallsats.

Dr. Ballhaus cited the centralization that has resulted from substantial personnel reductions at NASA. Increasing the number of people that have to coordinate can slow things down. He wondered how that worked in this area. Mr. Baker agreed that there is a need to cut through some of the processes. Small spacecraft are more affordable but the processes are set up for larger missions. This is where much of his effort has been. STPI advised centralization in order to avoid duplication, but that requires some thought.

Dr. Ballhaus then cited the approach of putting early career people on small missions in order to give them more responsibility, versus putting them on large missions to learn the system well before running their own missions. He advocates the latter, as there is value in teaching people how to do mission assurance. Mr. Baker replied that he likes a high probability of getting data back. The mission to him is conducting the test. The process outlines success criteria. If NASA does not allow for failure, the costs go up.

Regarding the technology development pipeline, NASA is trying to solicit through multiple avenues, such as university partnerships, small business, public/private partnerships and demonstration missions. NASA will buy from commercial sources when possible. The commercial sector could be moving faster for LEO. NASA should focus on things the commercial side is not investing in, like deep space.

SSVI is sponsored by SMD and STMD, as is the Small Spacecraft Virtual Institute (SSVI). The latter engages small spacecraft stakeholders in industry and academia. The Industrial

Commons is a university ground network for optical communications. Finally, the Small Spacecraft Coordination Group (SSCG) is where many NASA units share knowledge, work on issues, and coordinate investments. Dr. Ballhaus described the Space Quality Improvement Council, which has a database on quality issues from suppliers. Mr. Baker said he would follow up on that. He explained that SSVI interacts with existing working groups, while SSCG formalizes some of the communications channels. The goal is to innovate, harness the fast pace of innovation, and leverage small spacecraft capabilities in industry and academia to enable unique and more affordable science and exploration missions.

Dr. Ballhaus said that this area seems ripe for investment and disruption. NASA should interact with the chief technology officers at companies that could buy the disrupters. Mr. Baker said that while his interactions are more with the disrupters, he has also talked with some of the larger companies, which still innovate. NASA's investments are informed in part by what they are not doing, like autonomy from ground stations, in order to fill gaps.

The launch cadence is creating a bottleneck that affects innovation. Part of the solution is to try to stay ahead with flight operations and leverage investments in small launch capabilities. The Agency is working with several small launch companies. It was noted that one of the government limitations is the rideshare policy, which SSTP tries to leverage with other government agency launches. U.S. transportation policy is an area that has always lagged innovation. NASA can currently seek waivers, but the workload involved is not worth it. Dr. Ballhaus said that this might warrant more study by TI&E. The Committee would need a presentation to help characterize the bottleneck and identify the delay, identify the mechanisms, and get a better understanding of the problem. Any solutions or thoughts for course of action that TI&E could evaluate would also be helpful. Mr. Baker noted that while NASA has restrictions, industry can use foreign launch vehicles.

Kilopower Project Update

Dr. Lanetra Tate, GCD Program Executive, explained that the kilopower project extends beyond NASA, and identified some of the other government agencies and industry groups involved. An animation showed the history of nuclear power in space. The Department of Energy (DOE) and NASA are developing a new reactor, to be tested in Nevada. In working with the Evolvable Mars campaign, STMD has identified a need for 40 kWe of continuous power around the clock. It will take reactor units, plus redundancy, to have power in extreme environments and in high-power-need missions. There are many potential future applications for space nuclear power, as well as terrestrial applications.

The Kilopower project involves a compact, low-cost, fission reactor. One of the demonstration goals is the full-scale test of a prototype core coupled to Stirling converters. Dr. Mary Ellen Weber asked about the liquid sodium used to cool the reactors, citing concerns about safety and waste. Liquid sodium reactors have a long history of incidents, and she wanted to understand why it was considered safer than other systems. Mr. Lee Mason said that the previous work was in the 1960s, with pumped fluid systems; the current system is passive, without pumps. Larger reactors would require pumps, however. The waste is not an issue, as the reactor would burn less than 1 percent of the fuel over 12 years. The reactor can be abandoned in place if necessary. The half-life of the radiation hazard is months, and the system is designed to be turned on or off. The team has designed for failures, so there is redundancy. The entire assembly is 5 feet tall and weighs 400 kg. It is meant to provide power to thrusters. Mr. Neyland said he would like to see a curve that shows nuclear, thermal, and electric power converted to propulsion, and the tradeoff of the physics, just to see the trade space. It was noted that trip time is a major factor in manned flights. The trip time savings of chemical versus nuclear propulsion is only 20 percent, which is not a big advantage.

Dr. Tate showed the major development milestones. The reactor prototype test with a highly enriched uranium core is under way, and the actual demonstration has been done for all of the subsystems. Pending tests include a cold-critical test of the entire system, a fission test at 400C, and another fission test at 800C. The goal is to have a full-power test in March. There has never been a reactor of this size developed in the United States for these purposes. This will be scalable for surface power. Mr. Mason added that the Evolvable Mars campaign needs could be met with four 10 kWe reactors, which provides more flexibility than a single 40 kWe reactor. Dr. Tate said that once the testing is done, her team will assess continuing investments and scaling up. Mr. Mason said that they prefer to design pipes that do not depend on gravity. A pump system would start at 40 kWe and larger.

Dr. Weber said she would like to see the products offline. Mr. Mason said that that would be possible. In the past, NASA and DOE have invested in reactor technologies that have proven to be costly and complicated. This is neither, and it proves that cost-effective technology can be developed with simplicity. Mr. William Cirillo added that this is a driving capability for both human exploration of Mars and in situ resource utilization (ISRU). It would provide a lot of flexibility and add resiliency. Mr. Mason said that the key product of the testing is the validated modeling, which will allow the team to design any system in this class. Mr. Greg Sullivan added that there is an effort to match the testing to coding. They are validating the codes and trying to stay within the database of applications that use the same material.

Mr. Mason explained that the work is being done at Los Alamos National Lab rather than Sandia because the project is still in the physics phase rather than the engineering phase. Regarding uranium enrichment, there are existing stockpiles that DOE maintains from dismantling nuclear weapons. The materials were provided free to NASA, which just had to fabricate them into the format. The timeline for the moon or Mars is more a matter of funding, but it is technically possible to do by the mid-2020s for either. Mr. Neyland asked about commercial interest in the kilopower project, and whether there are regulatory issues. Mr. Mason said that these are areas for the next phase. One option might be to go to a low-enriched version that the commercial side could handle and deliver.

Capability Leadership and Engineering Research and Analysis Update

Capability Leadership

Dr. Prasun Desai, STMD Deputy Associate Administrator for Management, discussed the Capability Leadership Team (CLT). The CLT is the Agency's answer to improve integration and coordination, which was previously ad hoc. Some of the CLT teams work on cross-cutting systems capabilities, while others focus on single mission areas. Similarly, some systems capabilities require significant technological advancement to meet mission requirements, while others can rely on evolutionary advancements. Dr. Desai presented the range of team responsibilities, including common responsibilities. The Office of the Chief Engineer (OCE) developed seven Systems CLTs (SCLTs), which report to mission directorates. The Discipline CLTs (DCLTs) will provide matrix support to the SCLTs. The SCLTs will take over the activities of the system maturation teams and STMD's Principal Technologists (PTs). The more cross-cutting SCLTs are in STMD.

Using Entry, Descent, and Landing (EDL) as an example, Dr. Desai presented a graphic representation of how an SCLT would operate. Avionics, robotic systems, lightweight structures and manufacturing, and space observatory systems are STMD areas that will still have dedicated PTs instead of SCLTs. Dr. Desai next described the System Maturation Teams (SMTs). These will move into existing HEOMD teams, some at the Agency level and some merging with CLTs. The staffing process has CLT leads and deputies reporting from different mission directorates in order to balance the perspectives. The leads are staying at their Centers. They will receive guidance and have a budget for operating the function, but not for investing in missions or technologies. Teams will have 5 to 15 members, with each at about a 0.1 Full Time Equivalent (FTE).

Dr. Ballhaus found this to be of concern, as the inability to promote or supervise teams could make it difficult to get people to work with them. The resources and authority should match what they need to do. Dr. Desai replied that this is a NASA model involving influence. Dr. Ballhaus remained concerned that generating real deliverables will be difficult. NASA needs to find ways to strengthen their authority, as they must have some control in order to get things done. Dr. Kathleen Howell asked about deliverables. Dr. Desai said that the CLTs will maintain PT functions like strategic and investment plans, topic selection for solicitations, review panels, etc., as well as activities like state-of-the-discipline assessments. They could do independent assessments as well.

Engineering Research and Analysis (R&A)

Dr. Desai explained that the CLTs have identified many NASA areas needing engineering R&A. The function currently resides in the Agency's various engineering units, and the funding has been ad hoc. STMD funds engineering R&A through GCD at about $9 million per year, the Aeronautics Research Mission Directorate (ARMD) invests about $20 million annually, and HEOMD's Advanced Exploration Systems (AES) has an R&A budget of $1.5 million per year. SMD and HEOMD fund other projects as needed, but some of that is significant, as with the James Webb Space Telescope (JWST) technologies. The scattered and ad hoc nature of the funding makes it difficult to determine if the investments are optimal.

The Agency Strategic Investment Plan (ASIP) called on NASA to develop a funding model that is more systematic and visible. The mission directorates and OCE met to discuss this, determining that while funding will remain where it is for now, there should be a coordination board with mission directorate and OCE membership. The board will set priorities, starting with a list of what the disciplines need. There is no new funding for engineering R&A, however, so the mission directorates have committed to investing more at the cost of other areas.

Dr. Ballhaus pointed out that this mechanism does not allow for intellectual leadership from the centers. Dr. Desai said that novel ideas will be brought to the teams. Dr. Ballhaus was concerned about the likelihood of the mission directorates diluting their own programs in order to fund engineering R&A. Dr. Desai replied that the mission directorates know they benefit from this model and are willing to do more of this going forward. There is still a need to figure out FTE and center allocations, leverage of external resources, etc. The effort is in the early stages and the team is committed to making this happen. Each CLT will come up with six areas for investment in order to develop a list of priorities. Dr. Ballhaus cited a need to define the outcomes, which TI&E would like to monitor in order to see the results. Dr. Desai agreed to follow up on that.

Mr. Neyland advised reaching out to academia to identify about 15 R&A questions that NASA has not solved. This would be an opportunity for the universities to address these issues, but first they need to know what matters to NASA. Dr. Ballhaus agreed. He suggested bringing up with the NAC the need for public outreach. He noted that the research centers once relied heavily on a few superstars with supporting teams behind them. Dr. Desai said that this is still the situation at some centers.

Dr. Weber was concerned about the mission directorates decreasing their own budgets for engineering R&A, which she considered a risk. Dr. Ballhaus agreed, noting that their own projects will be the priorities. There must be intellectual leadership in this area. One of the tasks will be to communicate this to the next administrator. NASA should fence off a percentage of the Agency budget for the future and committed outcomes. Dr. Howell thought this should go to the NAC; Dr. Ballhaus agreed.

Space Technology Investment Plan Update

Ms. Vicki Crisp, Acting Deputy Chief Technologist, provided the Space Technology Investment Plan (STIP) update. The STIP provides high-level strategic guidance for investment in technology R&D across NASA, and defines guidelines for the technology portfolio. It complements the internal budget and project selection process. The principles for implementation rely on balance across 15 technology areas, all Technology Readiness Levels (TRLs), and three investment categories. The STIP information will be provided through TechPort, which is being revised. Balance will involve looking at past investments and future needs to ensure progress. The investment areas have goals of 70 percent for Critical, which are definitely needed for mission milestones; 20 percent for Enhancing, which lead to improvements in mission performance; and 10 percent for Transformational, which take a long view into the future. These are not hard percentages, as portfolios shift. All of the mission directorates and offices are involved in these decisions. The NASA Technology Executive Council (NTEC) will monitor the effort, and there is a working group.

Ms. Crisp identified 10 Critical technology investment areas, which were pulled from 15 technology roadmaps. The goal is to have the right division among Critical, Enhancing, and Transformational technologies. The alignment is achieved through the NTEC and working group, responding to action items from the NASA Administrator. Dr. Weber said that she would like to see a matrix of need and risk. In addition, some Critical technologies could also be Transformational and high-risk. Ms. Crisp agreed, noting that there is risk throughout the portfolio. Not everything in the Critical area is easy and low-risk. Dr. Weber advised looking at payoff versus risk as part of the balance, then mapping the investment areas to a matrix that can guide investments.

Mr. Neyland observed that these are umbrella areas rather than technologies. Ms. Crisp said that the actual STIP document provides more detail. The process of moving technologies up or down the ladder based on changing needs, mission requirements, and maturation would happen at the annual assessment. Mr. Neyland was also concerned that reliance on the quarterly NTEC meetings would push the technologies into the next budget cycle, resulting in it taking three years to see actual funding. Ms. Crisp said that it would not work like that. The mission directorates do an annual assessment to make adjustments. What can prove difficult for a mission directorate is an emergent area, however. Dr. Desai pointed out that the mission directorates are in constant communication, and surprises are not common due to that ongoing dialogue.

Dr. Howell pointed out that some Critical needs could also be Transformational, and wondered about the overlap. Ms. Crisp said that NTEC did not want to double-count, and made decisions based on characteristics of the technology. By doing so, they might lose sight of some of the additional challenges, which is why Dr. Weber's recommended matrix would be helpful, as it would help them make sure to include the long-term items.

Mr. Neyland asked why fission was Critical for space power but Transformational for propulsion. Dr. Desai replied that it will be needed regardless of where NASA goes. The transformative portion is the long-term work and the feasibility work. It reflects priorities. Mr. Reuter added that fission for space power is a matter of degree compared to propulsion. Mr. Neyland pointed out that a lot of information is lost when it is simplified for a presentation. He was concerned that Congress would zero in on that and not see the distinctions. He recommended having a cross-walk.

STMD Strategy Framework Update

Mr. Patrick Murphy, STMD Director of Strategic Planning and Integration (SPI), explained that the strategy framework is modeled after that of ARMD, which received a lot of positive feedback from the community and Congress. STMD wanted the framework to be customer-centric, outcome-oriented, and quantifiable. The goal was to focus more on impacts, outcomes, and challenges, then position the technologies accordingly. The overarching trends – or mega-drivers – that affect civilian space research lead to development of strategic thrusts for STMD. Outcomes are measurable goals that are community-based, and the technical challenges represent the technologies STMD plans to deliver.

The four mega-drivers, which are closely related, include increasing access, democratization of space, accelerating the pace of discovery, and growing utilization of space. Mr. Murphy described the major trends within each of these, then presented the six strategic thrusts:

- ST1. Expand Utilization of Space
- ST2. Enable Efficient and Safe Transportation into and through Space
- ST3. Increase Access to Planetary Surfaces
- ST4. Enable the Next Generations of Science Discoveries
- ST5. Enable Humans to Live and Explore in Space and on Planetary Surfaces
- ST6. Grow and Utilize the U.S. Industrial and Academic Base

Mr. Murphy gave the current STMD investments in each strategic thrust area, then turned the presentation over to Dr. Jay Falker, who discussed the outcomes from within the planned framework, along with the technology challenges. STMD was currently convening teams to discuss each strategic thrust. Dr. Falker described the goals for each strategic thrust area for the 2020s, 2030s, and 2040s. Dr. Ballhaus said that in order to communicate the need, STMD should state the impact of a delay or cut, including the metrics. Dr. Falker said that he hopes to do that. If the goals are accepted, they will drill down to increasing level of detail and performance, risk, schedule, and investment. The draft outcomes include many layers of plans and activities that will be broken out into much more detail.

ST2, dealing with transportation, includes activities like lowering costs and providing on-demand small spacecraft launch capabilities. If NASA does these right, industry will be getting involved, allowing NASA to then apply these resources elsewhere. There will be some cross-cutting areas, and some push and pull. Dr. Falker then discussed ST3, which includes EDL. Some of this work will need to be done regardless of where the Agency goes in space. Dr. Ballhaus observed that SMD has strong definitions due in part to the Decadal Surveys. In that mission directorate, the programs know what missions will be done, as well as the mission pull. What is not as well-defined is the supporting research and technology. This program could drive down risks and insert technologies into the SMD baselines. HEOMD is not that much further along than it was 25 years ago. There is no detailed project plan. Selling outcomes to stakeholders in absence of a program plan will be difficult. Dr. Falker agreed, adding that the language must be compelling. ST4, science, tends to decompose into the four divisions, but the SPI replication of that discussion would not add much to the way SMD communicates.

Dr. Falker said that there was some debate about the inclusion of ST6 as a strategic thrust, since it is part of how STMD does business. However, SPI wanted to elevate it in the eyes of NASA's industry partners, and it will provide goals. NASA needs partners, some of which are doing part of the work and some of which NASA watches. NASA should do the part that the partners will not or cannot do. Dr. Ballhaus said that he is not always persuaded that the procurement competitions provide the best results for the government. Both incumbents and challengers have advantages and disadvantages, and the source selection process does not always address them appropriately. Dr. Falker said that he would consider that.

Mr. Michael Johns asked if this can be tied back to the STIP and three levels of technologies. Dr. Falker said that he hoped so, and planned discussions on that issue. Dr. Ballhaus noted that foreign competition could accelerate the timelines, which could help make the case to stakeholders wanting to maintain U.S. leadership. STMD has been lacking the urgency argument. Dr. Falker closed by showing a high-level schedule chart. The projects are being mapped to it in order to enable better discussions among the programs.

Space Technology Research Institutes Update and Future Topics

Dr. Mia Siochi of NASA's Langley Research Center (LARC) explained that the challenge for lightweight structures involves the fact that cost increases in proportion to mass. The lightweight structures effort is using systems analysis to set goals. Increasing material-specific strength by a factor of two could reduce gross lift-off weight by 25 percent, which is necessary due to technology expectations. These expectations are typically inflated at the beginning, before a period of disillusionment leads to a more realistic balance and productivity. Dr. Soichi tracked this cycle of technology expectations against carbon nanotube (CNT) development from powders in 1990 to high-strength yarns in 2015. The CNT composites have evolved due to significant DOD funding. Some of this was used on the Juno mission, launched in 2011. Composite properties still need some work, however. Her team discussed this with the Materials Genome Initiative (MGI), a multi-organization group working to accelerate the materials properties.

The MGI approach spans the entire materials development cycle. NASA is requiring MGI to produce a demonstration material with challenging property targets at the end of the 5-year performance period. The Agency is hoping to provide mission pull to make insertion opportunities plausible. In doing so, NASA is leveraging DOD investments. US COMP is a 22-

member STRI that is doing computational tools, experimental tools, and digital data for design as part of MGI. Dr. Soichi showed the organizational structure, which includes commercial partners. A technology advisory board provides industry input.

Dr. John Hogan, of NASA's Ames Research Center (ARC), described the Center for the Utilization of Biological Engineering in Space (CUBES). The further humans take space exploration from Earth, the greater the need for resources to address the basic elements of life. Mars exploration will require extended stays, with no resupply, no emergency return, and strict planetary contamination requirements. Elements of future mission stability include ISRU, in situ manufacturing (ISM), closed-loop life support systems, food production, space medicine, and reliability and self-sustainability. Research challenges include minimization of inputs/wastes, genetic stability, and use of unique substrates. STRI has the related goals of microbial media production, production of mission products, and food production, all to be done in situ. These goals align with NASA's technology roadmaps.

CUBES, which includes five universities and an industry partner, will receive up to $3 million per year for 5 years. The kickoff meeting was in October. The vision is to leverage partnerships with NASA, other agencies, industry, and academia to support biomanufacturing in deep space, create an integrated biomanufacturing system for a Mars mission, and demonstrate continuous and semiautonomous biomanufacture of fuel, materials, pharmaceuticals, and food in Mars-like conditions.

There are four integrated research divisions: systems design and integration, microbial media and feedstocks, biofuel and biomaterial manufacturing, and food and pharmaceutical synthesis. NASA expects this to lead to a strong, data-driven, technologically backed platform for space biomanufacturing. The result will be integrated as a system, not just isolated pieces that have to be slotted together.

Dr. Ballhaus said he hoped that STMD will maintain funding for these two institutes. There may be political pressure to do more STRIs, but it is important to have strong funding for the existing institutes. He was assured that the funding is stable.

Discussion and Recommendations

Dr. Ballhaus showed a finding from the Science Committee that discussed having great esteem for the NASA civil servant workforce. He wrote a corresponding finding stating that this offers an opportunity to emphasize the value of the NASA civil servant technologists and research scientists that invent, acquire, and adapt advanced technologies and capabilities (engineering methods) for NASA science and exploration projects. He noted that NASA researchers spend a lot of time writing proposals, which seemed to indicate lack of appreciation. Dr. Desai said that this is being addressed in an SMD effort. Dr. Ballhaus replied that that would not cover the technologists. Dr. Desai explained that it is merit-based in STMD, and not all programs call for proposals. Dr. Ballhaus held that NASA should fund the capabilities it needs. Mr. Reuter said that NASA recognizes the responsibility. One issue is the effort to avoid competition with industry. Dr. Desai added that there is a distinction between internal and external STMD programs. This is also true in HEOMD, where AES is all internal.

Dr. Ballhaus adapted his statement, dropping the sentence about writing proposals. Dr. Howell asked if technology personnel at NASA have sufficient opportunities to move an idea forward. Dr. Ballhaus replied that lab capabilities have eroded significantly over the last 30 years, and Mr. Green added that a lot of facilities have been shut down. Mr. Neyland noted that some NASA capacities have been bypassed by industry. He did not think the scientists take on the additional role of "smart buyers," which NASA needs. It is expensive to keep an educated master base that only does evaluation. Dr. Ballhaus said that they have to do sufficient research to be able to evaluate the contractors.

Dr. Falker said that in the early stage portfolio he used to run, internal experts would complain when NASA competed with outside entities. There are still researchers in the lab who prefer to propose. Dr. Ballhaus said that it is important to have smart technology developers and smart buyers. He was concerned that NASA civil servant scientists and technologists are devalued by competing, and he especially wanted to recognize the technologists. He would recommend that the Chief Technologist look at this across the Agency, clearly define the role of NASA researchers and technologists, and determine the extent to which this work should be competed. One concern is whether they have the incentive to stay at NASA, which could be an action for Mr. Jurczyk as well.

Dr. Ballhaus asked for TI&E observations to share with the NAC. It was agreed to update the near-term milestones chart based on Mr. Jurczyk's presentation. There will be some important milestones in 2018. They could also show a chart indicating progress since the last meeting. Dr. Weber advised showing what shifted and how it affected NASA.

The update on small spacecraft technology had some charts to share on the increased use of smallsats, as well as recommendations. It was agreed that on the launch bottleneck issue, there will be an update at the next TI&E meeting. Dr. Ballhaus planned to tell the NAC that TI&E had been told of a bottleneck and hoped to have more on that in the future. Mr. Neyland suggested commending STMD for its focused approach to smallsats. Dr. Ballhaus thought that would be appropriate to share with Mr. Jurczyk. The concern was that several organizations were all doing small spacecraft development, which led to a request for the Institute of Defense Analysis (IDA) study. At this meeting, TI&E heard that NASA needs to develop these capabilities for the Agency's own mission needs. The finding was to commend STMD for following through to implement the recommendations of the IDA smallsat study, focusing investments on relevant NASA mission areas, and reducing redundancy versus commercial interests. However, there appears to be a lag in gaining launch opportunities. Therefore, the Committee requested more information to understand the impact and potential means to reduce this lag.

Regarding the Kilopower project, Dr. Weber emphasized her concerns about safety, waste, and contamination issues regarding other planets. Therefore, she did not want to present an entirely rosy picture and thought Dr. Ballhaus should note that the Committee wanted more information. Dr. Ballhaus agreed that they did not have sufficient information. He planned to say that there are questions that need to be addressed.

It was agreed that there was not much to say about the CLT presentation because CLTs lack funding and authority. At this point, they are still establishing an intellectual infrastructure. On engineering R&A, Mr. Neyland recalled that one suggestion was opening up R&A to the public to show the areas of interest to NASA. Dr. Ballhaus said that TI&E had discussed the STIP multiple times. It was agreed to do a brief recap on it, getting more specificity on investments from Dr. Desai. Similarly, Dr. Ballhaus had discussed the Strategic Framework with the NAC at previous meetings. However, the mega-drivers were now more refined and the thrust areas had changed slightly. There was also more information on the end state. The main thing from the STRI update was that the kickoff meeting had occurred.

The following observations and findings were approved by the Committee:

STMD should be commended for following through to implement the recommendations from the IDA Small Satellite study, focusing investments on relevant NASA mission areas and pre-competitive platform technologies. The TI&E Committee is satisfied STMD has met the intent of the July 2016 recommendation.

In executing this plan, there appears to be a bottleneck in acquiring launch opportunities. The Committee is requesting more information to understand the impact and potential means to reduce this delay.

Engineering R&A 25 years ago was funded out of R&T Base account.

- These investments were critical to development of CFD, NASTRAN, etc.
- Due to past R&T budget reductions, R&T Base eliminated.
- For example, FY05 to FY09 – basic research funding declined $500M, applied research declined $900M. NASA technologists increasingly had to write proposals to compete for research funding.

Current plans for funding Engineering R&A is good start, but has potential issues.

- Concern about adequacy of funding level, sustainability of funding, and protection of funds from flight project cost overruns.

Committee notes challenges over past five years in restarting this activity, but hopeful this approach will work.

The Science Committee (SC) wishes to acknowledge the community's great esteem for its civil servant colleagues. NASA civil servants have worked tirelessly in many roles – as project scientists, mission planners, analysts, archivists, project managers, engineers, and more – to enable the breakthrough science of NASA's missions. The TI&E Committee would like to also emphasize the value of NASA civil service technologists and researchers that invent, acquire, and adapt advanced technologies and capabilities (e.g., engineering methods) to the needs of NASA's science and exploration projects.

The commitment, professionalism, and dedication of NASA's civil servants have earned the respect and gratitude of the science and engineering community. The community considers its civil servant colleagues – along with the missions they support – a national treasure.

Dr. Ballhaus planned to work on this with Mr. Green and Ms. Anyah Dembling, then send it out to the Committee for comment before presenting it to the NAC.

Adjournment

The meeting was adjourned at 5:05 p.m.

APPENDIX A

Agenda

NAC Technology, Innovation and Engineering Committee Meeting
December 5, 2017
NASA Headquarters
Washington, DC

Dec. 5, 2017 – 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.	Space Technology Mission Directorate Update Mr. Stephen Jurczyk, Associate Administrator, Space Technology Mission Directorate (STMD)
9:00 a.m.	Small Spacecraft Technology Program Report Response Mr. Chris Baker, Program Executive, STMD
10:00 a.m.	Break
10:15 a.m.	Kilopower Project Update Dr. Lanetra Tate, GCD Program Executive, STMD
11:00 a.m.	Capability Leadership and Engineering Research and Analysis Update Dr. Prasun Desai, Deputy AA for Management, STMD
11:45 a.m.	Lunch Break
12:45 p.m.	Space Technology Investment Plan Update Ms. Vicki Crisp, NASA Deputy Chief Technologist (Acting)
1:45 p.m.	STMD Strategy Framework Update Mr. Patrick Murphy, Director, Strategic Planning and Integration, STMD
2:30 p.m.	Space Technology Research Institutes Update and Future Topics Dr. Mia Siochi, NASA Langley Research Center Dr. John Hogan, NASA Ames Research Center
3:30 p.m.	Break
3:45 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 *(via WebEx)*
Kathleen Howell
Michael Johns
David Neyland
Mary Ellen Weber

NASA Attendees:
Linday Atchison
Christopher Baker
William Cirillo
Vicki Crisp
Prasun Desai
Kevin Earle
Jay Falker
Stephen Jurczyk, *STMD Associate Administrator (via WebEx)*
Lee Mason
Patrick Murphy
Jim Reuter
David Reeves
Dave Steitz
Greg Sullivan
LaNetra Tate
Anyah Dembling

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

APPENDIX D

Presentations

1) STMD Update [Jurczyk]
2) STMD Small Spacecraft Technology [Baker]
3) Fission-Based Space Power [Tate]
4) Systems Capability Leadership Team (CLT) [Desai]
5) Engineering Research & Analysis [Desai]
6) Strategic Technology Investment Plan (STIP) Update [Crisp]
7) STMD's New Strategic Framework Update [Murphy]
8) Space Technology Research Institutes [Siochi]