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

NASA Langley Research Center
Hampton, Virginia
July 28-29, 2014

Meeting Minutes

G. Michael Green, Executive Secretary

William F. Ballhaus, Jr., Chair

NASA Advisory Council
Technology, Innovation, and Engineering Committee
NASA Langley Research Center
Hampton, VA
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Meeting Report prepared by
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NASA ADVISORY COUNCIL
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July 28, 2014

Welcome and Overview of Agenda/Logistics

The NASA Advisory Council (NAC) Technology, Innovation, and Engineering (TI&E) Committee meeting was convened by Mr. G. Michael Green, Executive Secretary. Mr. Green introduced Dr. J. M. Oschmann and Mr. Michael Johns as new members. Mr. Green then reviewed the meeting agenda. On the second day of the meeting, TI&E would be joining the NAC Science Committee to discuss a recommendation meant to encourage NASA's Space Technology Mission Directorate (STMD) and the Science Mission Directorate (SMD) to partner on infusing more technology into small and medium-sized science missions. Mr. Green reminded the Committee that the NASA Administrator had charged them to look at knowledge management practices and generate recommendations.

Opening Remarks and Thoughts

Dr. William Ballhaus, TI&E Chair, welcomed the Committee members and explained that he would be providing the meeting recommendations to the full NAC later in the week. He then welcomed Dr. Michael Gazarik, Associate Administrator of STMD.

Space Technology Mission Directorate Update

Dr. Gazarik noted that this has been an exceptional time for STMD, with many test results coming in, as well as a National Research Council (NRC) report that provided 10 technology recommendations for human space exploration. Regarding the proposed STMD budget for Fiscal Year 2015 (FY15), the House and Senate have similar totals but differing priorities.

STMD focuses on eight key thrust areas:
- High power solar electric propulsion
- Space optical communication
- Advanced life support and resource utilization
- Mars entry, descent, and landing systems
- Space robotics systems
- Lightweight space structures
- Deep space navigation
- Space observatory systems

The space optical communications area has been pushing to ready technology for the science community. The Human Exploration and Operations Mission Directorate (HEOMD), SMD, and STMD will conduct a joint Mars entry project. Deep space navigation has projects spanning a range of technology readiness levels (TRLs). The space observatory systems projects are another instance of collaboration with SMD. STMD is also working to help advance the future capabilities and affordability of the Space Launch System (SLS) and Orion launch vehicles. Efforts involve cryogenic propellant, the woven thermal protection system (TPS) for heat shield compression pads, advanced air revitalization, and other projects.

Dr. Ballhaus asked if STMD has any formal accountability to provide technology options for block upgrades to systems like SLS. He mentioned something like a negotiated agreement with the mission directorate that would include decision points at which STMD can feed in technology. Dr. Gazarik replied that once STMD has a body of work, it is formalized. The Directorate then flows down the milestone requirements to those implementing the technologies.

For outer planetary exploration technologies, STMD is getting feedback from the community. Moving the technologies forward involves a multi-step process. The technologies for FY15 include the following:

- Deep Space Optical Communications
- Deep Space Atomic Clock
- High Performance Space Computing
- Small Nuclear Fission/Sterling Power (kilo-power)
- Woven TPS for Aerocapture and Outer Planetary Entry
- Europa Ice Penetration Challenge

Some of these activities are cross-cutting between HEOMD and SMD.

A lengthy list of NASA's space technology partners demonstrates the degree to which the private sector is interested. A Chief Executive Officer (CEO) roundtable is scheduled for September. At the same time, STMD is working with 43 other U.S. government agencies and 14 international organizations. Prominent among these are the U.S. Air Force Research Lab (AFRL) and the Defense Advanced Research Projects Agency (DARPA).

Dr. Gazarik next described some of the recent STMD test flights and demonstrations. Two distinct types of high-powered solar arrays from two different companies were both tested in June and are at TRL 5. STMD is very excited about the results. Both technologies employ off-the-shelf cells but deploy differently. While Dr. Gazarik was limited in what he could say at this time, he did note that this could be a good example of government taking risk at the right time to forward the commercial side. The advantages of the arrays have affected how arrays are now made.

Mr. David Neyland asked if the team has explored the marketplace for terrestrial applications, given the arrays' evident flexibility and ease of use. Dr. Gazarik said that that had not yet come up. There is a smaller terrestrial initiative to lower the cost of the cells, and there are plans to use the International Space Station (ISS) to reach TRL 6. The maximum power is 50 kw per wing.

Another test success was with the Low Density Supersonic Decelerator (LDSD). NASA is looking at supersonic parachutes and recently demonstrated NASA's "flying saucer," which had mixed results due to a shredded parachute. However, the data are incredible. This paves the way for more complex landing abilities on Mars. The larger campaign consisted of a test flight this year, and this was a checkup flight. There may be two more flights in 2015. The cost data are still being evaluated. Dr. Ian Clark, Principal Investigator (PI) for LDSD at the Jet Propulsion Lab (JPL), pointed out that much of what the test used is quite affordable, such as cameras that anyone could buy from a big-box retailer. The Star 48 motor was the greatest expenditure. Dr. Gazarik added that there had been some wind and weather issues in Hawaii, where the test took place, but the team managed to launch on the first day of the second window.

On the composite cryotank technology demonstration project, the tank was pressurized to about 60 psi at cryogenic conditions and the primary test objective of 5,000 micro strain was achieved. The results were undramatic, which is good. This should be repeatable; it is process control. This is the first time that anyone can state definitively that this can be done. Boeing manufactured the tank in partnership with NASA MSFC. The impact will go beyond space into multiple applications.

The green propellant infusion mission test demonstrated the 1N thruster performance and capability. Testing of the 1N thruster continues, and testing of the 22N thruster is about to begin. There have been challenges, such as welding issues, and investigators are looking at the trends. The Cryogenic Propellant Storage and Transfer (CPST) project completed Engineering Development Unit (EDU) testing in order to understand the fluid dynamics. STMD built a test stand at the Marshall Space Flight Center (MSFC) for the initial testing.

It has been interesting to see these tests that have been planned for years finally come to fruition. With all the talk about going to Mars, the Evolvable Mars Campaign with HEOMD and SMD is an exciting project. The approach is to leverage what exists, including ISS, as affordably as possible. STMD is front and center in this. HEOMD is especially interested in the cycling of Mars materials to become consumables. A number of joint projects study that at low TRLs. For Mars 2020, one goal is to convert CO2 to oxygen.

Mr. Gordon Eichhorst asked if the Federal government ever checks to prevent duplication of industry projects. Dr. Gazarik replied that the focus is on a concerted effort to make sure to leverage where possible. It was noted that a recent solicitation seeks near-term technologies for HEOMD, as well as some lower TRL technologies with less emphasis on safety and more on capacity. The focus is on resolving the unique issues.

Dr. Gazarik presented the list of 10 technologies recommended by the NRC, along with STMD's interpretation of their development progress. In checking NASA progress against the list, using a green/yellow/red "stoplight" chart, the Directorate found that entry, descent, and landing (EDL) is red, for example, as it is something that the Agency needs to do affordably and is still addressing. Dr. Gazarik presented the capability gaps for each of the 10 recommendations.

One of the issues is that STMD can only afford so many demonstrations. While private investors are sinking hundreds of millions into some projects, NASA considers a "high expense" project to cost upwards of $1 billion. The Agency must consider the private sector activities in all of this.

Discussion
Dr. Ballhaus asked if the Committee should take anything specific taken to the full NAC. Dr. Gazarik noted that there should be an investment to move forward with space exploration. He does not see strong recognition of that. Mr. Eichhorst thought that the Agency ought to make a stronger, more specific argument about the benefits of these efforts. Someone outside of the Agency should delineate the benefits of NASA work, including the non-space benefits, in order to show NASA's contribution.

Dr. Ballhaus observed that recent acquisition budgets have been cut, and there are not a lot of new programs. National Security Space is not developing new systems, but is instead doing production runs, which has to affect the development infrastructure. He asked if there is any national effort to preserve the elements of a development structure. Dr. Gazarik answered that DARPA has done fairly well, and there is a recognized need for development. NASA is not part of that, however. He was recently told that NASA lives off of much that is developed at the Department of Defense (DoD). However, there are limitations to that.

Mr. Neyland noted specific examples, such as rocket engines. That discipline has declined, and the institutional memory is lost, as all those who worked on it previously have retired. The Committee should have a comment that NASA should reexamine its role in technology and innovation development. Dr. Ballhaus added that he no longer sees the movement of engineers that once helped them keep sharp. Mr. Johns pointed out that that resonates on Capitol Hill. Mr. Oschmann said that NASA is in a difficult political position because the Agency needs to keep its civil servants, and a cut affects industry disproportionately. Dr. Ballhaus agreed, adding that many on-site contractors have the specific expertise, an argument that is not often articulated.

Dr. Gazarik explained that impact of the lower budget for FY15 would be flat. One-third of the budget is for Small Business Innovation Research (SBIR), and another significant portion is civil servants. This does not leave much for procurement.

Office of the Chief Engineer Overview/Update

Ms. Dawn Schaible, from NASA's Office of the Chief Engineer (OCE), began her presentation by reviewing the OCE mission. A new element of that mission is to "integrate and provide leadership for the Agency's technical capabilities."

In a time of tight budgets, most focus is on completing near-term projects at the expense of future work. Therefore, the Agency is looking at its workforce and assets. There is a competition model that works well in some situations, but there are also entities that have become self-perpetuating in terms of function. As NASA examines what is being done, it is also looking at consolidation or different ways of deploying a resource. If a capability came forward and needed a new facility, for example, the model would send it to a specific mission directorate. In the absence of an overall integrated strategy, decisions are localized, and the question is how to view this from a higher level.

Ms. Schaible presented the model of capability leadership, which goes across the Agency and facilitates the sharing of resources. This will leverage the NASA Technical Fellows as the pilot leaders, of which there are 15, with four more to be added. The Fellows' main duties are provide a network of experts. They will be discipline stewards, pull together teams, pass along knowledge, and look at the workforce and how it is deployed, including the mix of workforce of civil servants and contractors. The Fellows will look for gap areas that need strategic investment, determine if industry can step in, and so on.

Thus far, no areas have been terminated and no funds have been reprogrammed, but some of this is in the pipeline. There is also the matter of promoting a cultural change to look away from being Center-oriented to becoming Agency-centered. One of the things OCE will do is ensure consistency through metrics or approaches to provide common guidance. The Technical Fellows will probably each need a deputy and a team. While they will stay at their centers, they will be designated as being from Langley. There are funds to pull them together to meet as needed, but much will be done informally. OCE is in the initial steps of codifying this.

Dr. Weber pointed out that only one of the Fellows was a woman, which was surprising and disappointing in light of NASA's role in inspiring young people. Ms. Schaible explained that this was partly because of the lack of diversity in the senior technical leadership area. The pipeline needs to open up. Dr. Weber said that this tells young women not to go into engineering. Dr. Ballhaus said that this situation warrants looking at weaknesses in the pipeline. Ms. Schaible added that most of the Fellows have 20 to 30 years of experience, which is part of the problem. Dr. Dava Newman, participating by teleconference, suggested this as a topic for the next meeting. The Committee should know the proactive plan, not just data about the pipeline. There are excellent people out there, and NASA should go out and find them.

Regarding the Foundational Engineering Sciences (FES), Ms. Schaible said that looking at the overall capabilities will feed into this. Dr. Gazarik added that there may be funding for a pilot program. FES could be a way to fill some gaps. Ms. Schaible summarized her presentation by noting that the Technical Capability Leadership model will leverage the knowledge and leadership of the Technical Fellows, while the Engineering Management Board will provide integration and prioritization across multiple technical capability areas.

Dr. Ballhaus thanked her for her comments.

STMD Knowledge Capture Planning

Dr. Prasun Desai, STMD's Director of Strategic Integration, focused his presentation on two aspects of knowledge capture: the logistics of knowledge capture, and how to pass along institutional memory in order to not to lose knowledge when people retire. The knowledge capture process is a type of branding, while early career knowledge transfer involves providing knowledge to newcomers. The OCE knowledge map support helps prevent repetition of mistakes while promoting efficiency.

Dr. Gazarik wants to make STMD the go-to source for space technology information. The objectives are to make STMD much more visible; develop an information resource for STMD, NASA, and the engineering community; define a comprehensive process to capture the technology knowledge resulting from STMD programs; and minimize the process burdens on the programs.

Dr. Desai listed nine programs with the products they capture, describing each one briefly. STMD is creating a searchable database where users can learn sources for further information. The hope is to have something that is streamlined and cost-effective, without creating a burden for the programs. Metrics for success include the number of visits, feedback in comments, and community feedback. Dr. Charles Mountain said that the intriguing thing is lessons learned, and asked how that was obtained. Dr. Desai gave an example of a technology demonstration, in which lessons learned are part of the close-out process. Depending on how fundamental the lesson is, the Agency has its own lessons learned database into which STMD can feed as well. This is a standard process and does not involve levying new tasks onto programs.

The knowledge capture process assessment concluded that an integrated knowledge capture process would improve access to STMD program results and enhance the Directorate's visibility as a source of technology development information. To that end, STMD intends to increase STMD search visibility and "product branding"; provide centralized access to project results; and enhance current interfaces and processes. It is important that people see STMD's role in NASA as being equivalent to DARPA's role in DoD.

Mr. Neyland pointed out that DARPA deliberately does not track what it has done in the past. He also noted that, unlike NASA, DARPA has no problem of the workforce leaving. Dr. Desai explained that at this point, NASA relies on Viking work done 40 years ago. Sometimes, it is even necessary to visit the Library of Congress to access historical information on technologies. This effort is meant to fix that, making STMD information accessible to everyone in the engineering community. The effort will begin with what STMD knows of its activities. There will be archiving. Dr. Gazarik added that the future may lead to some sort of "Wiki" product.

Dr. Ballhaus said that at The Aerospace Corporation (Aerospace), the database is restricted internally, but it covers lessons learned, etc. So there are models. Mr. Eichhorst stressed the need to be relevant. There is a lot of historical data that can be pulled in, but it must be brought to life to make it useful. A data graveyard serves no purpose.

Dr. Gazarik posed the question of whether a person in the technology community who wants to learn about something needs the information or the program director's phone number. Dr. Ballhaus said that if the experts are all retiring, the need is to have the information. Dr. Desai proposed that these are two different things. If people want to know what STMD has done and the results, they need to search so that STMD employees are not fielding calls every 5 minutes. This would argue in favor of providing abstracts along with contact information. It would be more than a Rolodex, but less than an encyclopedia.

Mr. Oschmann said that it seems that they should promote the idea that you can go to STMD for information. Dr. Desai agreed, stating that the Directorate does a lot of forums to tell who they are and what they have done. Dr. Mountain noted that NASA has been storing Hubble Space Telescope (HST) data for years. The issue is how to enable people to look for new things. A lot of work has to occur up front to make it searchable. Mr. Green said that STMD is limited to using the NASA CMS system.

Dr. Weber asked if there was any concern that the STMD name could change some day. Dr. Desai replied that this has been considered, and that there will be a number of ways to reach the data that do not depend on a specific name. The system should be as robust as possible. Mr. Oschmann observed that there can be branding that is not specific to STMD and still sends people to the database. It is important to be the first hit on Google. Dr. Desai said that he wants to be able to give an update in a year or so and tell how the database has succeeded, with lessons learned. It is important to try to standardize without overburdening the programs.

He next spoke about early career knowledge transfer, the effort to disseminate to the younger generation and have them work with mentors. An NRC report found that, as of 2009, more than 60 percent of NASA's workforce was at least 45 years old. This speaks to a need for more opportunities to provide hands-on training and experience with spaceflight development programs. Because timely development of early career employees is needed to maintain NASA core capabilities, STMD has formulated an initiative to engage early career NASA employees in hands-on technology development. The Agency has always been able to hire as needed, so there are pockets of age groups, which is challenging. Dr. Gazarik added that the Centers tend to go for the senior person, and some Centers note problems with hiring mid-career people. Dr. Ballhaus said that industry has the same problem.

Mr. Oschmann suggested leveraging the efforts of the professional engineering societies to pull in young people and possibly establish rotations with industry. The Air Force does this. Perhaps there really should be a healthy turnover. Mr. Neyland wondered if there could be exchanges sending government employees, especially early career workers with 5-10 years of experience, to the private sector for a while. Dr. Gazarik thought it was a great idea for the broader picture.

Dr. Ballhaus suggested that the Committee take an action to see how this is done in industry and if NASA can and should do it.

Regarding the Early Career Initiative, Dr. Desai noted that there is much excitement about this, to the point where the early career people at Langley started talking to each other and their colleagues more than they did previously. For this effort, the Centers will submit proposals, the teams are small, the young people have mentors, and they become innovative and agile. Selections are to be made in September. A written proposal is mandatory, but applicants can also submit a video. This is new and was put in place after a young employee spoke out about the issues the early career people were facing. He is still with the Agency, and Langley has a new lab to get younger people engaged.

Dr. Desai next described the Space Technology Research Grants, which involve a research collaborator, a fellow, and an advisor. Dr. Gazarik explained that STMD invests about $30 million in this program. At this point, which is the program's fourth year, there are over 200 fellows at 75 universities. Since the fellows work with the Centers, they do not just stay and finish school. STMD will start looking more at diversity. It is too early to track the extent to which the fellows go on to work for NASA. Some do, while others go to the broader community, which is good for the aerospace industry. Regarding summer interns, Mr. Green noted that NASA brings in quite a few, along with co-ops. Dr. Gazarik said that this is a route for many younger people to come into the Agency, but NASA cannot hire as many as it once did.

Dr. Desai explained the OCE Knowledge Map support, which involves disseminating information through a linkage of Centers and programs. It includes publications, monthly newsletters, a website, and other outreach efforts such as face-to-face activities. Some of the 19 Technical Fellows are involved with it. Mr. Eichhorst said that this should go out consistently, so that anyone in the field can count on it. That creates awareness. Dr. Mountain suggested doing a TEDx type of activity, and Dr. Weber advised working with the NASA social media people. Other suggestions included having senior people create short videos about their work and experiences, offering "industry days," and setting up a specific YouTube channel for early career people.

Dr. Ballhaus added that it can be difficult to get early career workers interested in lessons learned so that they do not recreate the same mistakes. The mechanism for dissemination of lessons learned is key; young people have not been through failures and they are willing to try things that failed. It can be hard to get them to be sensitive to this. Everyone involved in human exploration should know the lessons from Challenger and Columbia. Entry level personnel ought to read the reports to learn the root causes. This deserves a lot of time and attention. Dr. Gazarik said that this could be a topic for the Chief Engineer, who has made the same comments. Dr. Mountain added that this generation learns visually, through lectures or videos. They want to see faces and emotion.

Dr. David Miller, NASA Chief Technologist, said that young workers need to experience the lessons learned, and one way to do this is through team projects. Mr. Oschmann added that learning requires the experience of some failure. A lot of rules grow out of that, however, resulting in an unwieldy, inefficient system that encompasses all failures. Dr. Desai said that since tailoring projects does not always work, there is now an agreement for additional discussion with the Agency in lieu of tailoring.

Dr. Ballhaus asked Dr. Desai to think about what he would have the Committee take to the Administrator, such as a finding.

<u>Update on Market Studies for Small Spacecraft Activities</u>

Mr. Andrew Petro of STMD began his presentation by noting that he had previously addressed the Committee on the topic of market studies for small spacecraft technology. In this update, he wanted to discuss market pull. NASA has done a state-of-the-art report to see what is possible, and SMD and STMD will soon jointly study how small spacecraft can address the needs outlined in the Decadal Survey. An informal assessment of market pull has come from the annual government cubesat forum, as well as other smallsat and cubesat conferences. These have helped identify the civil and commercial markets, which include Earth remote sensing, space weather and heliophysics, in-space testing of technology, and more. Together, these indicate for small launches and ride shares.

"Small" can mean affordable, rapid, and transformative. At the same time, cubesats are getting bigger. There are limitations on what one can study in terms of the market for disruptive technologies. Dr. Ballhaus observed that "push" is more than basic research, as it encompasses the concept of benefits if it succeeds. Mr. Petro said that the informal assessments may indicate a benefit, possibly a spectrum of missions. A graph showed the growth in nanosat and microsat deliveries, which together more than tripled between 2012 and 2013. This indicates an emerging and expanding market. Projections are for even greater expansion through the end of the decade.

Mr. Oschmann explained that Ball Aerospace defines "small" as 100kg, which is larger than the 1-50kg range that Mr. Petro described. It is more a complemented, augmented, or increased ability. When it comes to some systems, there are big debates on what could be done with a small satellite. Mr. Petro explained that the forecasts include projects in the pipeline.

A timeline for upcoming flights showed 13 projects in the Smallsat Technology Partnership program, in which NASA collaborates with universities, and five propulsion technology projects. The next launch will be of eight cubesats to be sent up together in November. NASA built two extras that will go to the ISS. NASA is not yet fully utilizing ride share capacity, however. There will be additional launches in February. Mr. Petro thought that if it were possible to receive more data, these missions might be more attractive to others. All of the projects are past critical design review (CDR). The overall effort shows that NASA can perform low-cost missions. One example is a small spacecraft that is like a small Explorer. It has been proposed in SMD for a very low-cost demonstration in 2015.

Dr. Ballhaus observed that this is a step in the direction of the Committee's questions. It could be that the market is not yet well-defined. It will be interesting to see how this could work in terms of the Decadal Survey.

Mr. Petro added that STMD's involvement in small spacecraft goes across the Agency. Dr. Ballhaus wondered if these smaller satellites could replace existing satellites, and asked how this capability might apply to the current set of missions. Mr. Petro said that a portion of the mission portfolio could be replaced with smallsats, but not everything. The technology could open up new areas, however.

Dr. Miller suggested determining which missions can be filled by smallsats. The passive microwave radiometer is an example. It is intended to measure ocean surface vector winds and the like. Dr. Desai added that it is early, but the team expects more adoption of the technology following the demonstration. Dr. Ballhaus explained that marketing a capability should involve identifying what unmet need can be addressed with the key metrics. This would provide a sense of the applications for the capabilities being developed. Dr. Miller replied that some other agencies are reluctant to make any changes in their climate and weather measurement capabilities.

Dr. Ballhaus was concerned that there was no clear vision of what NASA would have if this were implemented. Every effort should be able to answer the question "so what?" What is the benefit? Mr. Petro said that the cubesat effort shows how to operate a constellation while communicating with just one piece of equipment. Mr. Oschmann said that that sounds like an Internet connection in space. It is a low-cost demonstration with other benefits, such as showing how to demonstrate large systems. Dr. Miller added that other possibilities include high spatial and temporal measurement, disaggregation and rapid reconstruction for geolocation, and others. Rapid technology refresh is a capability that flattens costs. This leads to competition, broadening the technology bases and the ability to launch. There are many dimensions to this.

Mr. Petro showed slides on a variety of SMD projects. The Earth Sciences Division (ESD) has a number of projects and small instruments in development, while the Heliophysics Division (HPD) has leapt into this and sees a lot of value in making distributed measurements. The Planetary Science Division (PSD) has also funded some astrobiology work and is developing new project and instruments. The Astrophysics Division (APD) has done the least in this area. HEOMD's biggest involvement has been a launch opportunity of cubesats, and the Directorate is funding some in-space development of cubesats. HEOMD is also planning for multiple 6U secondary payloads on EM-1 and subsequent flights, with deployment beyond low Earth orbit (LEO). A number of HEOMD payloads are in development. Finally, the Asteroid Redirect Mission (ARM) is offering partnerships for secondary payloads.

Adjournment

The meeting was adjourned for the day at 5:13 p.m.

July 29, 2014

Reconvene Technology, Innovation, and Engineering Committee Meeting

Mr. Green opened the meeting. There is a consensus of December 4 for the next meeting, which will be held at NASA headquarters. It is possible that this could change if the December NAC meeting shifts, however.

Game Changing Development Program Update

Dr. Ryan Stephan, the Game-Changing Development (GCD) Program Executive for STMD, provided an update. The GCD Program helps meet the STMD objective of enabling a new class of NASA missions beyond LEO by advancing disruptive mid-TRL technologies from concept to demonstration, usually in the TRL 3-5 range. The Program serves as a technology incubator for STMD and the Agency, and currently has a focus in five areas:

- Lightweight Materials and Advanced Manufacturing (LMAM);
- Revolutionary Robotics and Autonomous Systems (RRAS);
- Advanced Entry, Descent, and Landing (AEDL);
- Future Propulsion and Energy Systems (FPES); and
- Affordable Destination Systems and Instruments (ADSI).

Dr. Stephan briefly described projects under each of these themes.

The flagship project is the Composite Cryotank Technologies and Demonstration (CCTD), which will address the need for an affordable, lightweight vehicle for future exploration. Thus far, GCD has designed and fabricated a 5.5m diameter composite cryotank using automated manufacturing techniques, and demonstrated 30 percent mass savings and a 25 percent cost reduction. Boeing delivered the tank to MSFC in March, and pressure tests were performed in May and July at 45 and 60 psi, respectively. There was a plan to do 80 cryogenic pressure cycles, but excess moisture in the tank has caused concern, so that has been pushed back while other tests are conducted.

Dr. Stephan reviewed some SBIR success stories, including maturation activities. Self-supporting multi-layer insulation was discovered in Phase 1 SBIR and received a GCD award in Phase 3. It has now been matured at NASA to TRL 5, with the goal of infusion to the SLS. The 20 watt, 20 Kelvin cryocooler was matured as components in Phases 1 and 2; GCD made further awards and will move it forward with a successful demonstration. The deep space optical communication project involves the maturation of a deep space photon counting camera and other elements.

Phases 1 and 3 SBIR work on 3D print are leading to flight hardware to be delivered on SpaceX 4 and demonstrated on ISS. The 3D products will be constructed and tested both on ISS and on Earth upon return. Dr. Mountain raised the issue of a report that was critical of this. Dr. Miller replied that the question is whether or not it is easier to continue making tools. If the 3D print machine has too many limitations, it will not be worth the effort to do 3D printing in space. Dr. Stephan described the Phase Change Material Heat Exchanger, which will be infused into Orion's thermal control system for lunar missions if it is first successfully demonstrated on ISS.

STMD and HEOMD are to develop two payloads for infusion into the Mars 2020 mission:

- The In Situ Resource Utilization (ISRU) demonstration to convert the Mars' atmosphere to oxygen for fuel and life support. This will reduce mass and the mission storage burden, as well as decreasing the burden on EDL systems.
- The Mars Entry, Descent, and Landing Instrument (MEDLI-2) is an instrumentation suite to acquire EDL data to benefit future exploration missions. It will provide data to validate the analytical model.

Dr. Stephan next reviewed select STMD projects being conducted in partnership with ISS.

- The Synchronized Position Hold, Engage, Reorient Experimental Satellites (SPHERES)-Slosh experiment uses the SPHERES robots and a simple slosh tank to obtain slosh data for model correlation/validation.
- The Phase Change Material (PCM) heat exchanger tests both a wax-based and a water-based heat exchanger. This effort will retire the risks associated with the microgravity operations of a large-scale PCM heat exchanger for infusion into Orion. It will also allow storage of heat to be used at a later time.
- For the Station Explorer for X-Ray Timing & Navigation Technology (SEXTANT) project, STMD is partnering with SMD's Neutron Star Interior Composition Explorer (NICER) project to demonstrate advanced autonomous navigation technology using Pulsars as beacons.

STMD is also developing critical technologies for Orion and SLS. The 3D Multifunctional Ablative Thermal Protection System (TPS) (3D MAT) matures woven TPS for infusion into Orion. It survives both thermal and structural loads. Dr. Stephan also mentioned the composite cryotank and 20 watt, 20 Kelvin cryocooler.

Dr. Ballhaus asked why this is being done by STMD and not HEOMD. Dr. Stephan explained that if this were a mainline activity, he would send it back. However, a lot of risk is being addressed here. There may also be cost considerations. Dr. Ballhaus noted that there should be some dedicated STMD funds for the technology push, as well as for cross-cutting technologies. That leads to questions about helping Orion and SLS. Dr. Stephan said that the ISRU is obvious to him as cross-cutting. For a minimal investment of about $15 million, GCD can leverage a $1 billion mission to give Mars exploration a confidence that cannot otherwise be obtained.

Dr. Mountain asked if the block upgrade to Orion could happen without the 3D MAT, and whether HEOMD is relying on GCD, or if GCD is offering an alternative. Dr. Stephan said that in many cases, there is an alternative. The block upgrades are longer term, affecting or enabling missions that HEOMD has not yet envisioned. Dr. Ballhaus said that if it is critical, HEOMD should develop it, as they address the near term. Dr. Stephan explained that the cost of the 3D MAT is being split evenly between HEOMD and STMD. Volume is the issue on Mars 2020. Dr. Miller added that it was important to present this to SMD as helping them bringing back samples and enabling future science, which reflects how the scientists think.

Dr. Stephan noted that the Discovery Program is another alignment with SMD. GCD is maturing about six technologies for Discovery 2014.

- The Heat Shield for Extreme Entry Environment Technology (HEEET) is a low mass (40 percent), high performance TPS material for planetary entry missions. On the Announcement of Opportunity (AO), SMD will provide a $10 million incentive.
- The Deep Space Optical Communication project will demonstrate communication technology providing data rates an order of magnitude higher for deep space exploration

Mr. Eichhorst asked if the incentives are available for commercial entities, like SpaceX. Dr. Stephan said that the criteria are those that apply to the Discovery competition. Dr. Miller added that commercial carriers are being used as test platforms for technology. Dr. Ballhaus pointed out that at TI&E's previous meeting, which resulted in the upcoming joint meeting with the Science Committee, TI&E proposed a study, but it was nothing this aggressive with incentives. He wondered if SMD was still discounting the use of new technologies, and he hoped that there would be some rules set on technology demonstration. TI&E's concern is that SMD gives lower scores to proposals using advanced technologies. Dr. Stephan explained that GCD required SMD to include specific language stating that there would be no penalty on advanced technology proposals. It is tough to get anything through the Technical, Management, Cost and Other (TMCO) evaluation process, however.

Mr. Oschmann said that there cannot be an incentive for every new technology. The evaluation process is very conservative, and even if a proposal presents a solid, relevant example and actual costs, the guidelines still require 25 percent reserves, including for existing programs that actually perform. The PIs are concerned that their proposals will not win. Dr. Ballhaus wondered if there might be a way to have a centralized reserve for the mission set rather than requiring each individual mission to have the reserve. Mr. Oschmann said that one issue is whether the PI will stick to the requirements or change the scope.

Dr. Stephan reviewed GCD's recent program accomplishments, many of which he had discussed in the presentation. Dr. Ballhaus said that he would like to see the "so what?" question answered on these. The accomplishments as presented are not what people would generally understand. Dr. Stephan said that of the GCD accomplishments, he is proudest of the work the program is doing in the space technology pipeline. GCD is also working well with SBIR.

<u>Office of the Chief Technologist Overview/Update</u>

Dr. Miller, NASA Chief Technologist, provided an update on OCT activities. The Office has two concentrations: Strategic Integration and Innovation. The NASA Office of International and Inter-Governmental Relations has a mandate to vet all external-facing websites, so it will review OCT's new "techport."

Dr. Katie Gallagher, Executive Officer for OCT, noted that the Innovation office's focus is on challenges and technology transfer. There is a new challenge on the LAUNCH partnership, and a pilot program for Presidential Innovation Fellows. Other challenges include a ballast mass challenge, an ESD challenge, and Centennial Challenges, which is an effort toward engagement with the maker community. The Office of Science and Technology Policy (OSTP) wants all technology agencies to have Centennial Challenges, which offer prototyping and manufacturing for people outside of the usual technology pathways.

Dr. Miller explained that the Asteroid Grant Challenge engages with the public to find asteroids that are threats. There are multiple ways the public can engage. Dr. Ballhaus said that it will take a lot to go through all of these ideas and wondered if they would produce anything than isolating the top people in a room. Dr. Miller explained that a company called Top Coder takes problem statements to the community and gives prizes, having found a business case for doing that with algorithms and software. There are people in other domains who do this kind of thing. They are non-traditional partners. It is not just middle school kids participating; it is also people working on this on weekends. People want to work with NASA, so this benefits both the public and NASA. Dr. Gallagher added that while it is a way to engage the public, it is a challenge to work through.

The LAUNCH Green Chemistry Challenge is being done with Nike and the United States Agency for International Development (USAID). In the past, they brought together experts to solve problems with clean water access, waste management, and energy. Technology transfer partnerships have been set up to put out patents. In addition, a software catalogue with thousands of lines of code is available for people to use. The technology transfer policies are being updated.

Dr. Miller listed five areas of activities:

- Strategic Space Technology Investment Plan (SSTIP) Development Process
- ISS Utilization for Technology
- Agency Investment for Low TRL Research
- Science, Engineering, and Technology Committee
- Achieving a Balanced Portfolio

The SSTIP is updated every two years, and the TI&E Committee will be asked to review the next one. Dr. Miller thinks NASA should have a fundamental knowledge discovery activity that includes both products and processes. This would be the low TRL research, for which he mentioned examples. He sees the Air Force Office of Scientific Research (AFOSR) as a potential model. It has a breadth of disciplines and no strong tie to specific applications. He is still trying to think through the details on how NASA might apply this model.

Dr. Miller next addressed Foundational Engineering Science (FES), which is an area of innovation that includes processes such as design. Many NASA missions are custom designs that require substantial labor costs and time. Design is analogous to a control system. He thinks in terms of models, design, and validation. A control system has actuators, sensors, commands, update rate, model uncertainty, etc. These are engineering concepts. He thinks of the performance as having an output. The old process guaranteed to some confidence level that the efforts would meet a requirement, but he wonders if there is a way to reduce the performance range and get closer to the requirement. Part of the design process is not only varying parameters, it is also developing experimental procedures that make the model more reliable. The goal is to make the design more deterministic.

Dr. Miller next described integrated multi-physics modeling, in which the proposed process would have to ensure that there is not too much extrapolation. Potential benefits include possible identification of detrimental couplings earlier in the design process, solutions that leverage favorable couplings, and broad and rapid trade-space exploration.

Solving the inverse problem is hard to do cost-effectively, given that the simulation times for the complex models are substantial. Some ideas might be worth researching, however, such as reduced order modeling. The team will need to determine the acceptable error. A very large model is the evaluation model, which teams would query in order to identify the best design model. It would also show that only a portion of the model really matters in a given situation, and would specify that part of the model. Teams can start identifying the unique spots in the trade space that they can consider.

Mr. Oschmann said that many of these design tools can determine optimal solutions, but there is the danger of talented engineers going to these automatically and letting everything vary in favor of the coding. Dr. Miller said that it gets into sensitivity analysis of the variables. Teams will want to return to the full model at times.

The Model Based Systems Engineering (MBSE) project captures lessons learned, the history of a design, and the reasoning behind it. Regarding the Integrated Design Environment, the question is whether a preliminary design review (PDR) can be done in a way that incorporates a real-time conversation. Models and tests go hand-in-hand and improve each other. Tests are essential, but they need to be focused on the areas of greatest concern.

The Science, Engineering, & Technology Committee (SETC) is a possible forum for interaction among the three disciplines. Each plays a vital but distinct role, with differing dialogues and concerns, and each discipline furthers the progress of the others. Dr. Miller presented some diagrams illustrating the interactions and examples of dialogues the three disciplines might have. Dr. Ballaus advised thinking about how to simplify this for Congressional staff.

Entry, Descent, and Landing Update

Dr. Clark discussed recent EDL project activities. Thus far at NASA, the Viking lander technologies have been the foundation technologies for EDL. While some progress has been made on entry and landing, there has been nothing substantially new in the area of descent; NASA still uses the Viking parachute design and the 1972 qualification data. Now that the Agency is looking beyond the Mars Science Laboratory (MSL), engineers have run into the square-cube law problem, and deceleration has become increasingly difficult. In mitigating these problems, NASA is looking at three new designs: the inflatable SIAD-R and SIAD-E, and the Advanced Supersonic Parachute (ASP). These all require new testing capabilities, which JPL has developed. Specifically, the project now has two ground-based rockets and a Supersonic Flight Dynamics Test.

Dr. Clark reviewed the design specifications for each of the three designs. For testing, the pieces had to be able to be assembled and reassembled. There were five phases of qualification: initial deployment; inflation dynamics; peak strength; supersonic performance; and subsonic performance. New infrastructure was needed for testing, as the project outgrew existing options. More specifically, the world's largest wind tunnel is at NASA's Ames Research Center (ARC), and it was not big enough. Therefore, the team came up with ground-based tests and high-altitude flight testing.

The ground-based testing was done at the Naval Air Weapons Station in China Lake, California. A rocket sled accelerating to about 300 mph in a few seconds could match the aerodynamic loads seen on Mars. These tests can be repeated. All of the tests were completed successfully for SIAD-R. The powered descent vehicle (PDV) testing was harder and carried larger costs. The team looked at drop testing, which was physically difficult and also expensive. Therefore, they returned to China Lake and asked to have a helicopter take to 40,000 feet a parachute that was tied to a rocket sled on the ground, which then accelerated when the helicopter dropped the parachute. This was a strength test.

A video showed the inflation in slow motion, even though it actually took place in a fraction of a second. There was another shakeout test to pull the parachute out of its container. This was done with a regular parachute, which held despite developing a large tear.

Joint Meeting with Science Committee

Dr. David McComas, Chair of the NAC Science Committee, welcomed the TI&E Committee to the joint session.

Dr. Ballhaus told the combined session participants that recently, an issue arose about the infusion of new technology being disincentivized. When the TI&E Committee expressed its concern, the NAC had advised having a joint meeting with the Science Committee. While TI&E is not recommending a specific policy, the members want the Associate Administrators for SMD and STMD to look at this situation with the idea of seeing what, if anything, can be done. One of most important things NASA does for the country is encourage technology development.

Dr. Mountain said that those who have written proposals know that, in order to be acceptable and selectable, they must minimize the proposed level of risk. There is no incentive for bringing in new technologies, and there is a question of how to incentivize more risk. NASA is now using flagship missions to test technology, not the lower cost missions, which is the reverse of what makes sense to him. TI&E wants a new or revised policy to be considered.

Dr. Ballhaus added that the prevailing concern seems to be to avoid having an overrun, which has also created a situation in which the reserves must be so large as to function as disincentives. He asked if there might be other ways, and wondered if it would be possible to cover the reserve from a large pot of money across all missions. TI&E was not proposing policy, but just wanted to have this examined. Mars 2020 has some financial incentives for risk, but there was still a need to look at the disincentives.

Dr. Mountain asked if it really is the right paradigm to have the flagships test technology and have the lower-cost missions be conservative. Dr. Harlan Spence replied that this does not seem right. He imagines that some "new technologies" are actually attempts to shrink a traditional technology. Dr. Gazarik explained that for the Discovery draft AO, specific technologies are listed; some are incentivized and some are not. This resulted from discussions with SMD and the community. STMD looked at what is ready and what is possible. For example, deep space optical communication was of interest to SMD, high power electric propulsion is ready, the thermal protection system is of interest to the community.

If the two Committees were to make the recommendation to the NAC, he would be willing to talk to the SMD Associate Administrator, Dr. John Grunsfeld, and take on the effort. If they can get technology embedded in the calls, they can change the game. Dr. Grunsfeld was not present, but Dr. Gazarik believed that he would be interested.

Dr. Gazarik noted the problems in getting proposals with new technology past the TMCO process, and Dr. McComas wondered why NASA could not develop new technologies to offer to PIs. Dr. Ballhaus thought that might work with a range of risk and reward. This would include the extended risk reduction of Phase A, maybe funded by STMD. The process mechanisms would have to allow for that. Dr. Carle Pieters, participating by phone, asked for clarification as to whether, for the infusion of new technology, they were suggesting mission critical technology or something descopable with less stringent mission requirements. Dr. Ballhaus said that he was not specifying either. It is possible to drive down the risk with risk reduction investment. It is also possible to baseline existing technology, and have a supporting research and technology line that would be evaluated.

Dr. Mark Robinson asked about the possibility of NASA funding technology that feeds specific programs. Investing in technology development makes things cheaper in the long run. Currently, NASA is struggling to get technology development into flight programs while minimizing risk. Dr. Ballhaus explained that the robust flight technology development program of the 1980s was decimated. STMD has been formed to do the technology push, as well as cross-cutting funding and development. He thought the focus was on technologies that have come out of a push effort and cross-cutting initiatives, and are then available for science missions. These are currently difficult to get into small missions.

Dr. McComas said that the idea is to have a better and tighter bond between technology and science. He liked the idea of linking it at the PI-level. There are many smaller technology needs that never rise up to the level of getting attention or funding. They are important, but NASA cannot invest much in them. It is hard for NASA to know what the PIs need. Dr. Spence recommended that Phase A be longer, and Dr. McComas thought that stretching Phases A and B might be an option as long as there are milestones. Dr. Ballhaus pointed out that the idea of an extended Phase B had been considered long ago as a means of driving down risk and firming up the baseline. It would need adequate funding.

Dr. Robinson cautioned that the community might complain that this changes the situation too much. It costs about $1 million to write a proposal. If there were more money in technology development and a PI could see six possible technologies, he or she might be more prone to insert a new technology into the proposal. Mr. Oschmann said that a proposal is currently marked down for a technology that has not yet flown, even if that technology is at TRL6. There needs to be a way to prevent that.

Dr. Pieters expressed concern that an emphasis on new technologies might lead to risking science objectives. The PIs just want the science. It is important that they not be penalized when they submit proposals without the use of new technologies. Dr. Robinson thought that it was more a situation of allowing rather than encouraging use of new technologies.

The draft recommendation reads as follows:

Recommendation:
The Council recommends that the Space Technology Mission Directorate (STMD) Associate Administrator and Science Mission Directorate (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. Once appropriate policies and procedures have been defined, formulate an implementation plan that assures that the selection decision process is consistent with those policies and procedures.

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.

<u>Entry, Descent, and Landing Update continued</u>

After lunch, Dr. Clark resumed his presentation on EDL technologies. In the high altitude space flight dynamics tests (SFDTs), the objectives were to:

- Deploy and collect data on SIAD-R operation and dynamics
- Deploy and collect data on SSDS operation and dynamics
- Fly camera mast assembly and other SIAD and SSDS sensors
- Recover the test vehicle or flight image recorder from the ocean

There were a number of reasons for conducting the SIAD-R STDF-1 in Hawaii, most of which related to weather reliability. STDF-1 was conducted on June 28 and used a large scientific balloon that can take a payload to about 180,000 feet. The parachute inflates and cruises, deploys, and descends. Dr. Clark showed a video of the test. The test vehicle forebody is modeled after one of the Mars vehicles. The fully inflated balloon is the largest ever, about the size of a large football stadium, and consists of several thousand pounds of exceptionally thin plastic. The helium is held by a collar and expands at altitude. The deployment was successful in and of itself. However, the parachute shredded during inflation.

Nonetheless, the test met all of the success criteria and the team recovered all of the equipment. Everything that needed to work did so. NASA now has much more data on supersonic parachutes than ever before. This was the largest ballute ever flown supersonically and the largest supersonic parachute ever deployed. The SIAD-R inflation was rapid, the time from initial emergence to rigid appearance was between 0.3 and 0.4 seconds, and vehicle disturbances during inflation appeared to be negligible to non-existent.

The greatest concern had to do with the ballute deployment, which worked very well. The parachute inflated quickly, and the recording provides strong resolution. In viewing the video, the team noticed previously unseen inflation transients that have apparently been occurring all along. A parachute is a pressure vessel, and there was not a lot of pressure, which affected the stresses. The team had not envisioned this, and now must consider it going forward. After an immediate examination of what happened, they went through all the possible causes and presented a hypothesis. However, it is important to make sure that the root cause has really been developed, and there is no easy way to test this hypothesis.

Parachute testing is full of challenges, and parachutes can be fickle. NASA has had seven successful landings on Mars. This is the best data ever developed, and the lessons learned can now be applied to 1960s for retrospective lessons. The team wants to create a new basis for a similar heritage that will pave the way to grow these technologies.

Discussion

Mr. Neyland suggested that Dr. Clark talk to DARPA, as his team created a cost-effective test methodology that they may be able to exploit. Dr. Clark noted that this effort incorporated many STMD goals. The core technology team is very young by design, but they were all paired with experienced people. Removing the top four positions, the average age is 30. These early career workers have now become desirable and are being recruited by other parts of the Agency, so that other young people are being brought in behind them. One requirement was to document all test data as part of knowledge retention. He spent a lot of time in the 1960s archives, which were well-written. However, it would have been helpful to have more videos to provide greater insight.

When asked about aero capture, Dr. Clark explained that the multi-pass of going in and bouncing out does not help that much, and the difference in velocity is not worth the trade-off. Work has already begun on a new parachute design. The team is strengthening the crown with Kevlar and creating a more robust skeleton. They are also hoping to obtain a higher frame-rate camera. People are presenting him ideas. They want to look at the ballute, and they want to get the shape resolution. Much of the hardware was off-the-shelf, and the team found new ways of using materials.

Mr. Neyland pointed out that part of this is the story of the people, and it used to be that all of NASA was like this. Dr. Clark agreed that a lot of enthusiasm comes from doing technology development. Mr. Eichhorst found it interesting that the team members have come to be in demand. It would be great if these technology programs became a badge of honor and resulted in support from colleagues going forward.

Dr. Weber asked if the team was sure they were getting the best parachutes. Dr. Clark said that for the air space used, he thought they did. Dr. Weber noted that the military might not be testing at the same heights, but the testing and analysis might be helpful nonetheless. She offered to provide some names and suggested having a roundtable to discuss this. Dr. Clark added that he saw good potential for coupling between NASA and the commercial side.

Discussion and Recommendations

Dr. Ballhaus led the Committee in reviewing the day's presentations in order to determine what to send to the NAC. When asked about the highlights of his presentation, Dr. Clark suggested discussing the square-cube law problem and how the team met the challenges. He would also include the graphic of the Supersonic Flight Test Architecture, the technical success summary, the discussion of the value of the SFDT dataset, and the video. He would expect interest in the parachute as well.

It was suggested that the presentation incorporate some of the test result slides from Dr. Gazarik's presentation, and a timeline from a prior meeting to show major events and milestones with their status. Dr. Ballhaus wanted the test results slide to be more specific in answering the "so what?" question. In looking further, it was decided to use the flagship project slide from Dr. Stephan's presentation, and a slide from a previous meeting to explain the green propellant project. The list of NRC recommendations on technology for human spaceflight was to be included with status notations.

Dr. Gazarik wanted to convey two messages: 1. STMD is working with SMD and HEOMD; and, 2. STMD is making investments and gathering data on the technologies for the future. Dr. Weber recommended reframing that to say that STMD is working on projects that matter to science and human exploration, then giving examples. In order to show why STMD is needed and has value, a second chart should show that SMD and HEOMD would not have the things they need without STMD. Dr. Mountain added that the parachute deployment situation provides a good starting point for the narrative. The last time NASA thought about this was 40 years ago, so the Agency had to all but start over with this. STMD is needed for continuity. Dr. Weber said that this also ties to the long-term vision. HEOMD would not have done this work. STMD is trying to develop the capability so that there is not a need to invent technology on a critical path for a program.

The discussion moved on to Ms. Schaible's presentation. Regarding the lack of diversity among the Technical Fellows, Dr. Ballhaus wanted more information about why this happened before taking it to the NAC. Dr. Gazarik took it as an action item. Dr. Ballhaus also thought it was important to point out that FES is currently unfunded. He wanted to keep the first chart, remove the Air Force references, and add a benefits chart about why this matters. Dr. Ballhaus also wanted to highlight the benefits described in Dr. Miller's presentation, as well as the need to ensure that the meetings among the Directorate leaders continue. The "smiley face" chart showed that interaction well.

From the presentation on small satellites, Dr. Ballhaus thought the mission pull and small space pathways were important. Dr. Gazarik cautioned that it is not yet clear what the customers need in the way of cubesats. Regarding the knowledge capture discussion, Dr. Ballhaus observed that this was a very active area. Mr. Green said that he would focus on defining the task and the implementation chart.

Finally, Dr. Ballhaus read the recommendation to the NAC, as revised alongside the Science Committee that morning.

Administrator Remarks

Dr. Ballhaus greeted NASA Administrator Charles Bolden and told him that the NAC had asked for a recommendation from TI&E and the Science Committee. Mr. Bolden explained that he had just come from visiting the Science Committee. One of his concerns has been conflicting technology and science interests. It is very clear that the committee members have a broader reach into the community than ever before. He gave the James Webb Space Telescope (JWST) as an example of a flagship science mission into which NASA infused technology, while the small and medium-class missions do not take such risks. Dr. Mountain observed that NASA takes risks among its most expensive programs rather than the other way around. Mr. Bolden explained that the less expensive programs need to fly more frequently and on some cadence. But the budget should follow the strategy instead of vice versa, which is what happens. There also has to be a willingness to fail.

Dr. Ballhaus said that the technology program's accomplishments have been impressive, with noteworthy demonstrations and risk reduction. Dr. Mountain mentioned Dr. Clark's excitement and that of his team. Mr. Bolden said that failure leads to learning and improvement. Dr. Ballhaus recalled that in the early days, NASA moved rapidly but took tremendous risks. Mr. Eichhorst asked if the funding had always been such an issue, and whether it might be possible to lock in an amount and make the programs more difficult to cut. Mr. Bolden replied that in the FY16 budget proposal being sent to the White House, he wants to specify what is lost if certain things are cut. Much of what the Agency does is not for NASA. ARM will address some challenges, as three different directorates are involved in it. There is good chemistry among the chiefs and associate administrators. They communicate well with and for each other. He has asked them to look across the entire enterprise.

Adjournment

The meeting was adjourned at 3:12 p.m.

APPENDIX A

Agenda

NAC Technology, Innovation, and Engineering Committee Meeting
July 28-29, 2014
NASA Langley Research Center
Room 205A, Bldg. 2101

July 28, 2014 – FACA Open Meeting

12:30 p.m.	Welcome and overview of agenda/logistics (FACA Session – public meeting) Mike Green, Executive Secretary
12:35 p.m.	Opening Remarks and Thoughts Dr. William Ballhaus, Chair
12:45 p.m.	Space Technology Mission Directorate Update Dr. Michael Gazarik, Associate Administrator, STMD
1:30 p.m.	Office of the Chief Technologist Overview/Update Dr. David Miller, NASA Chief Technologist
2:30 p.m.	Break
2:45 p.m.	STMD Knowledge Capture Planning Dr. Prasun Desai, Director, Strategic Integration, STMD
3:45 p.m.	Update on Market Studies for Small Spacecraft Activities Mr. Andy Petro, Program Executive, STMD
4:30 p.m.	Group Discussion and Wrap-up
5:00 p.m.	Adjournment
5:01 p.m.	Informal Tour

July 29, 2014 – FACA Open Meeting

8:00 a.m.	Reconvene Technology, Innovation, & Engineering Committee Meeting
8:15 a.m.	Office of the Chief Engineer Overview/Update Ms. Dawn Schaible, NASA's Office of the Chief Engineer
9:00 a.m.	Game Changing Development Program Update

	Dr. Ryan Stephan, Program Executive, STMD
10:00 a.m.	Entry, Descent, and Landing Update Ian Clark, Principal Investigator for LDSD, JPL

Recess meeting at ~10:50 a.m. in room 205A and relocate to 105A & 105B for joint meeting discussion with the NAC Science Committee

11:00 a.m.	Joint Meeting with Science Committee (Room 105A & 105B)
12:00 p.m.	Lunch

The Technology, Innovation and Engineering Committee will reconvene after lunch in original meeting room 205A.

1:00 p.m.	Discussion and Recommendations
2:30 p.m.	Adjournment

Non-Public Session - Council and Committees: NAC Annual All-Hands Meeting

3:00 – 3:30 pm	Meet & Greet *(light refreshments)*
3:30 – 5:00 pm	NAC Annual All-Hands Meeting with NASA Administrator Bolden

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, Hubble Space Telescope Institute
Dr. Dava Newman, Massachusetts Institute of Technology
Mr. David Neyland, Office of Naval Research
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
Dava Newman (via teleconference)
David Neyland
Jim Oschmann
Mary Ellen Weber

NASA Attendees:
Ian Clark, NASA JPL
Prasun Desai, NASA Headquarters
Amir Deylami, NASA Headquarters
Katie Gallagher, NASA Headquarters
Michael Gazarik, NASA Headquarters
David W. Miller, NASA Headquarters
Andrew Petro, NASA Headquarters
Dawn Schaible, NASA Headquarters
Ryan Stephan, NASA Headquarters

WebEx Attendees:
Darrel Branscome
Jeffrey Herath
Greg Lee
Michael Moloney
Juergen Nittner II

APPENDIX D

Presentations

1) Space Technology Mission Directorate [Gazarik]
2) Office of the Chief Engineer Update [Schaible]
3) STMD Knowledge Capture Initiatives [Desai]
4) Small Spacecraft Technology Markets and Motivations [Petro]
5) Game Changing Development Program Update [Stephan]
6) Office of the Chief Technologist Overview/Update [Miller]
7) Low Density Supersonic Decelerator Overview [Clark]