National Aeronautics and Space Administration

Technology & Innovation Committee

of the

NASA Advisory Council

Kennedy Space Center

Cape Canaveral, FL

December 10, 2013

Meeting Minutes

Kathleen Gallagher, Executive Secretary

William F. Ballhaus, Jr., Chair

NASA Advisory Council
Technology and Innovation Committee
NASA Kennedy Space Center
Cape Canaveral, FL
December 10, 2013

Meeting Minutes

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Meeting Report prepared by

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NASA ADVISORY COUNCIL
TECHNOLOGY AND INNOVATION COMMITTEE
Kennedy Space Center
Room 3210
Cape Canaveral, Florida

PUBLIC MEETING
DECEMBER 10, 2013

Welcome and Overview of Agenda/Logistics (FACA Session, Public Meeting)

The NASA Advisory Council (NAC) Technology and Innovation (T&I) Committee meeting was convened by Dr. Kathleen Gallagher, Executive Secretary. She welcomed everyone and announced that the meeting was a Federal Advisory Committee Act (FACA) meeting open to the public. Meeting minutes will be taken by Ms. Bergit Uhran and will be published.

Welcome to Kennedy Space Center

Dr. Gallagher introduced the Committee chair, Dr. William Ballhaus, who introduced Mr. Robert Cabana, Director, Kennedy Space Center (KSC).

Mr. Cabana welcomed everyone to KSC. He described KSC as the world's preeminent launch complex for government and commercial space access. It is transitioning away from the Space Shuttle days and is enabling the world to explore and work in space.

NASA's three main priorities are developing the Space Launch System (SLS) and the crew capsule Orion, the International Space Station (ISS), and the James Webb Space Telescope (JWST). The Johnson Space Center (JSC) has responsibility for the Orion, but KSC is responsible for the launch complex, the Launch Services Program (LSP), and for providing expendable launch vehicles. There is great public interest in the space program; over 10,000 people watched the Mars Atmosphere and Volatile EvolutioN (MAVEN) launch to Mars. The Commercial Crew Program (CCP) is working to send crew to the ISS. The Asteroid Redirect Mission (ARM) is very important because it ties science with human exploration. It will help develop solar electric propulsion (SEP) capability for the agency and enable scientific research on an asteroid.

Many areas at KSC are being renovated or repurposed. Crawler Transporter 2 is being refurbished. New rocket platforms are adjustable to work with different rockets and change as the rockets change. Mr. Cabana would like to see at least one launch at KSC per year.

The "clean pad" concept is a new mobile launcher with everything necessary for launching a rocket. It is able to support commercial operations and will be used for SLS rockets. This will be done using Pad B. The area under the pad has been refurbished with fiber optics and a state-of-the-art, lightening-protection system. The Launch Control Center (LCC) is also seeing changes.

Firing Room 1 has been redone, and Firing Room 4 will be available to Commercial Space. Facilities that are not dedicated for NASA use, joint use, or purely commercial, will be demolished. This will save over six million dollars a year in operating costs. Commercial Crew partners include SpaceX, Blue Origin, Boeing, and Sierra Nevada. The goal is to have one of those companies fly crew to the ISS by 2017.

KSC is working to make human spaceflight more efficient and affordable. It is transitioning from a government center to a multi-user spaceport. NASA has gone from 4.5 percent of the Federal budget to less than 0.5 percent. There are approximately 8,000 employees at KSC, but there may be closer to 10,000 in the future with new development. The goal is to have an "industrial scientific research park."

Dr. Ballhaus advised that it is necessary to understand the human physiology better in order to do more extended space flight. Dr. Weber inquired into the nature of the financial investment from the state of Florida. Mr. Cabana explained that Florida has invested five million dollars into specific projects such as horizontal launch, labs on ISS, and targeted investments to help grow commercial space. Space Florida is a private-public partnership that received developmental funding from the state.

Dr. Gallagher thanked Mr. Cabana for his remarks.

Space Technology Mission Directorate Update

Dr. Gallagher introduced Dr. Michael Gazarik, Associate Administrator, Space Technology Mission Directorate (STMD).

Dr. Gazarik noted that there are seven launches planned by STMD in the next two years. Several projects are in phases C and D, so there will be flight integration challenges. The Green Propellant Infusion Mission project, Solar Sail, and Deep SpaceAtomic Clock project are moving forward.

Dr. Ballhaus asked what role STMD has in supporting NASA's Centers in maintaining their franchise technologies. He noted that NASA's role is very different from the past, where NASA maintained capabilities to do everything within the Agency. Dr. Gazarik responded that from an overall Agency perspective NASA has critical technologies to maintain. The Centers rely on the Center Chief Technologists and offer indirect support. STMD is constantly trying to tackle the question "how can we be a more efficient Agency?" and learning to be more efficient with what it has.

Dr. Ballhaus asked Dr. Gazarik for his thoughts on continuing to work with the reconfigured NAC. He replied that he is looking forward to a closer connection with the other committees. He added that there is a need to follow through with projects rather than give in to the desire to change technology every few years. There will be challenges to face, such as how to infuse new technologies into industry. They have begun using Principal Investigators (PIs) to help industry gain awareness about new technologies.

Dr. Ballhaus observed that previous recommendations have been to spend three percent of the Agency budget on technology, but there is no accounting in place to see how much was being used in technology. Another recommendation was to fence funding off from major projects, and that has been implemented successfully. He noted that three of the four bills relating to NASA in Congress have space technology at 3.5 percent of the budget, which ranged from $17.5 billion to $18 billion.

Mr. Gordon Eichhorst inquired into NASA's involvement with universities. Dr. Gazarik answered that there have been 300 fellows through the Space Technology Fellows Program for graduate students. NASA is working with 75 schools, including almost all of the top 25 aerospace schools. The students are producing amazing research.

Dr. Randall Correll asked how STMD is handling budget uncertainty. Dr. Gazarik replied that the Technology Demonstration Missions (TDM) projects have been driving a cost increase. Budget cuts are taken from larger projects that are better able to absorb them, and early stage projects are held at ten percent of the budget.

Update on Solar Electric Propulsion

Dr. Gallagher introduced Mr. Chuck Taylor, PI for In Space Propulsion and Space Power Generation.

Mr. Taylor gave the Committee an update on Solar Electric Propulsion (SEP). He explained that in chemical propulsion the energy is stored in the propellant. It is excellent for getting out of the Earth's gravity well, but it has limited capacity. SEP uses solar energy to ionize a propellant. It has limited thrust and cannot get an object out of the gravity well; however, it has a higher specific impulse and makes launch easier because less fuel has to be lifted.

The theory behind SEP has been around for 100 years, and engineering caught up with the theories in the 1970s and 1980s. SEP was used in space for the first time in 2010 to save an Air Force asset when chemical thrusters failed. Hall SEP thrusters were onboard and used as backup. A trip planned for three months took over a year, but was completed safely to transition the craft from Geosynchronous Transfer Orbit (GTO) to Geosynchronous Earth Orbit (GEO). This mission was so successful that insurance companies now require Hall thrusters on all missions that transition from low-Earth orbit (LEO) to GEO space.

NASA is taking SEP and moving it to the human exploration continuum. It is planned for use in human missions to Mars. SEP reduces the cost of missions ranging from commercial applications in LEO to manned missions to Mars. SEP uses propellant more efficiently than chemical rockets and reduces the mass that needs to be lifted off from Earth.

Dr. Ballhaus asked if SEP could be used to move quickly enough to protect astronauts from space weather. Mr. Taylor answered that it depends on the thrusters' size, and NASA is working to develop larger thrusters. Dr. Gazarik added that one can send cargo ahead using SEP and then send astronauts using chemical propellants.

Mr. Eichhorst inquired into improvements in efficiency. Mr. Taylor replied that the thrusters themselves are typically 30-50 kilowatt thrusters that have been tested terrestrially for 10-15 years, so further increases in efficiency may not be cost effective. It is always possible to improve solar cell efficiency, though this may not be a priority due to cost.

Mr. Taylor described current NASA STMD investments. Advanced next generation solar arrays and higher power electric propulsion technologies will enable 30-50 kilowatt class SEP. Shielding thrusters so that ions do not bombard the walls on their way out helps them last longer. The STMD Solar Array System (SAS) Project creates improvements in stowed volume. New designs are extensible to 300 kilowatt systems. Increasing voltage prevents the need for designs that increase current, which would necessitate greater mass and more copper. One design, the “rolling carpet” or the Deployable Space Systems (DSS) Roll Out Solar Array (ROSA), can be deployed without a motor, saving mass. Another design is the “Chinese fan” or ATK (Alliant Techsystems, Inc.) MegaFlex. He explained that building an array to provide one kilowatt of power costs $1 million, largely due to touch labor. New design concepts must use semi-conductor industry processes and modularized panels to save costs. At present only two companies are producing high-powered solar arrays for NASA. The present industry benchmark thruster is the Aerojet BPT-4000, a 4.5-kilowatt Hall Thruster. Miniature Electrospray Propulsion (MEP) “sugar cubes” have small satellite millinewton thrust applications, but may be stacked for use in larger missions.

Dr. Ballhaus inquired about contamination from the ion stream. Mr. Taylor explained that they were very conservative when they launched Dawn in 2007. The cloud of ions that remain around the spacecraft is supposed to be low energy, while the vast majority exit at high velocity and leave without damaging the spacecraft. The Power Processing Unit (PPU) is a 70-120 Volt Direct Drive Unit (DDU) and provides the high voltages needed to power Hall Thrusters. Future technology goals include higher operating temperatures on PPUs, space-qualified parts for 300 volt operation, bigger thrusters, and better propellants.

Mr. Taylor discussed the Asteroid Redirect Mission (ARM). This is a robotic mission to redirect an asteroid to a trans-lunar orbit. It will use a large, 50-kilowatt glass power system producing acceleration around 10 kilometers per second. The ARM is tentatively planned for 2018.

STMD is seeking an affordable demonstration of a high power, 30-50 kilowatt, light-weight solar array and high power electric propulsion. The electronic propulsion technology under development by STMD is enabling for the ARM. Combining the SEP TDM with the ARM would validate high power, light-weight solar arrays, high power SEP, and asteroid retrieval. In deep space it is possible to use less efficient cells and more arrays because there are no concerns about drag. Other technologies such as thin skin silicone arrays can be used in deep space, but not in LEO. It may also be possible to use solid iodine as a propellant to reduce volume, rather than using gaseous xenon. The effect that these technologies might have on industry was discussed. Mr. Gordon Eichhorst counseled that it is important to get industry involved with the project. Dr. Ballhaus stated that SEP is “one of the most important technologies” for deep space exploration in STMD’s current portfolio.

Dr. Gallagher thanked Mr. Taylor for his presentation.

Update on Cryogenic Propellant Storage and Transfer

Dr. Gallagher introduced Susan Motil, Project Manager, Cryogenic Propellant Storage and Transfer (CPST) Project.

Ms. Motil discussed the difficulties in storing and transferring cryogenic propellants in space. She explained that there is no demonstrated capability to store cryogenic propellants in space for more than a few hours. The state-of-the-art technology is Centary's nine hour storage time with a 30 percent boil off per day. There is no demonstrated, flight-proven method to gauge cryogenic propellant quantities accurately in microgravity and no proven way to guarantee that gas-free, liquid cryogens can be taken from a tank in microgravity. There is no demonstrated ability to move cryogenic liquids from one tank or vehicle to another in space. A flight demonstration with cryogenic propellant storage, expulsion, and transfer can remedy these problems as well as other more subtle problems.

Propellant mass gauging must be tested in microgravity with a range of fuels and fill levels. Microgravity gauging and transferring will become more important with longer missions. NASA is attempting to engage industry in studies on scaling the technology, minimizing heat leak, and gauging liquid levels. A related activity was developing a self-supporting Multi Layer Insulation (MLI), which performed better than traditional MLI in a side-by-side boil off test. This was done in partnership with Quest.

Ms. Motil noted that historically, it has been thought that scientists can only get to Technology Readiness Level (TRL) five on the ground and TRL six on flight because these projects are not developed at scale.

Cyrogenics is a multi-Center program and uses the cryogenics lab at KSC, a test small cell at Glenn Research Center's (GRC) Small Multipurpose Research Facility (SMiRF), and Marshall Space Flight Center's (MSFC) Spray On Foam Insulation (SOFI) Development Center. Chemical composition of SOFI has changed in order to be environmentally friendly.

Dr. Weber asked how cryogenics applies to ground uses. Ms. Motil replied that everything except for the gauging is very applicable, especially insulation and fuel transfer. GE Health Care is very interested in the project's cooling system. The important thing is to get the word out to these companies by using industry workshops and other communication methods.

The Agency wants to build the parts internally because cryogenics is a core-competency area. However, industry will probably build the parts for the major missions. NASA is also using senior capstone projects required by many engineering colleges as a resource to get young people excited about technology.

Dr. Weber asked if Ms. Motil has reached out to the oil industry because they are one of the biggest users of hydrogen. Ms. Motil answered that they are doing so through Air Liquid, one of the largest suppliers to the oil industry. Air Liquid is working with NASA on modeling and developing the payload.

CPST now has a foundation for a flight test to validate key capabilities and technologies. This foundation also opens up a more capable architecture for large cryogenic propulsion stages and propellant depots to extend human and robotic presence throughout the solar system.

The project may use SpaceX through the Commercial Resupply Services (CRS) contract to fly a CPST payload to the ISS. This would require cooperation with the Human Explorations and Operations Mission Directorate (HEOMD) and may be too early to discuss with the full NAC. The payload is at 224 kilograms, but may grow. The test-flight mission would not have active cooling because it requires more mass, and active cooling already has been demonstrated on the ground. Radio Frequency (RF) mass gauges will be present in the CPST tank

Dr. Ballhaus and Dr. Gallagher thanked Ms. Motil for the update.

Chief Technologist Update and update on Technology Roadmapping

Dr. Gallagher introduced Dr. Mason Peck, the NASA Chief Technologist, who delivered his presentation through the teleconference network.

Dr. Peck advised the Committee that the goal of the Office of the Chief Technologist (OCT) is to advocate for technology across the Agency in STMD, HEOMD, Aeronautics Research Mission Directorate (ARMD), Science Mission Directorate (SMD), and in the field Centers. STMD is the flagship technology program in the Agency. He explained that basic research is not about a specific application; it is broadly relevant. It only becomes technology when it can be classified through a TRL.

National science and technology priorities come from the White House and other sources. These sources establish top-down, strategic guidelines. There are also bottom-up, driven requirements that are made clear through interactions with the different mission directorates, commercial industry, international agencies, and other Federal agencies. The Technology Portfolio System (TechPort) is a tool to provide access to what NASA is doing in technology and identify opportunities for collaboration. OCT is planning to open this to the public. There is a roadmap created every four years and a Strategic Space Technology and Investment Plan (SSTIP) that is “tweaked” every two years. This will be updated in 2014. The scope will be expanded to address radiation, space weather, avionics, and orbital debris. The roadmap will give a single home to all technologies at NASA.

Mr. Ballhaus inquired as to what extent NASA should establish a technology base for the country. Dr. Peck replied that the NASA Authorization Act requires NASA to work for the national benefit. Accordingly, NASA is meant to invest in technologies that have as broad an impact as possible. The taxpayers should benefit from the work they fund. NASA pursues partnerships to ensure the fullest use of these technologies. Dr. Ballhaus noted that the Committee is not ready to make a recommendation to the NAC on this subject and would like to continue to discuss it over future meetings.

Dr. Peck continued with his presentation and gave an overview of TechPort. Its public user interface should be accessible to the public in January 2014. The program contains restrictions on what information is available to the public. The interface will be searchable and will include some budget data. The information available to the public will not be detailed enough to reproduce technologies; however, contact information is included for those who wish to integrate NASA technology into their business. Between two-thirds and three-quarters of technology projects across the Agency are listed in some way, and OCT is currently asking for employees to add technologies to the database.

Roadmaps are primarily a technical document. The SSTIP provides guidance within the context of a 20-year horizon with a four-year investment approach. This breaks down investments into core (70 percent), adjacent (20 percent), and complementary (10 percent) investments. Mr. Peck asserted that this ratio should be maintained notwithstanding budget changes.

Dr. Peck concluded that he following areas need improvement: inclusion of new technologies, including clear start and end points, standardizing dates, making graphics readable, standardizing definitions, and removing duplications.

Dr. Ballhaus and Dr. Gallagher thanked Dr. Peck for his presentation.

Barriers to Innovation and Innovation Enablers

Dr. Gallagher introduced Ms. Karen Thompson, the KSC Chief Technologist. She introduced Mr. Marty Waszak.

Mr. Waszak explained that Barriers to Innovation (B2I) is a study conducted from 2011 to early 2012 that assesses barriers to a culture of trust and innovation at NASA. It aims to define what innovation means for NASA, identify common barriers to innovation, recommend actionable steps to reduce and eliminate barriers, and enable innovation. The study sought diverse perspectives across the Centers, the disciplines, and at all levels of expertise. NASA is considered to be the most innovative Federal agency and the best at adopting commercial practices, but there is room for improvement. For example, only 61 percent of NASA employees believe creativity and innovation are rewarded.

Potential problems identified by the study include a risk adverse culture, a focus on short-term projects, communication challenges, process overload, instability, lack of opportunity, and organizational inertia.

Dr. Ballhaus observed that it is sometimes best to stay with a proven system for developing technology. Mr. Waszak asserted that it is acceptable to take risks on small projects. Ms. Thompson noted that there are Center Innovation Funds available from STMD for low-TRL projects and for collaborations with industry and universities. She explained that if the funds are not spent they are lost. There are three funds for innovation: the STMD Center Innovation Fund, the ARMD Seedling Fund, and the Science Innovation Fund.

The top five solutions generated from B2I are: to use corporate time for creative thinking; create innovation labs and creative spaces; provide innovation funding and protect investments in innovation; streamline processes; and use the “skunkworks” model. Some of these solutions were originally present at NASA, but have eroded over time as the work culture changed and the budget shrank.

Dr. Ballhaus expressed concern that if everyone is given flexibility to work on innovation projects, some people will not be able to produce results. He cautioned against skunkworks and recommended putting boundaries around them because they do not work well in all areas.

The Administrator issued two memoranda based on this study: "NASA and the Importance of Risk" and "Preparing our Workforce for the Future." His messages conveyed that failure is acceptable for low-TRL projects, but should be avoided for high-level projects. Dr. Ballhaus requested a future telecom with Mr. Waszak to discuss this topic further before making a recommendation to the NAC.

Dr. Gallagher thanked Mr. Waszak and Ms. Thompson for their presentation.

The public meeting was adjourned at 1 p.m.

Appendix A

Agenda

NAC Technology and Innovation Committee Meeting

December 10, 2013

Kennedy Space Center

Headquarters Building, Room 3210

December 10, 2013 – FACA Open Meeting

8:00 a.m. Welcome and overview of agenda/logistics (FACA Session – Public meeting)

Dr. Kathleen Gallagher, Executive Secretary

8:05 a.m. Opening Remarks and Thoughts

Dr. William Ballhaus, Chair

8:10 a.m.	Welcome to KSC Robert Cabana, Director, Kennedy Space Center
8:30 a.m.	Chief Technologist Update and update on Technology Roadmapping Dr. Mason Peck, NASA Chief Technologist
9:30 a.m.	Space Technology Mission Directorate Update Dr. Michael Gazarik, Associate Administrator, STMD
10:00 a.m.	Update on Solar Electric Propulsion (SEP) Chuck Taylor, Principal Investigator for In Space Propulsion and Space Power Generation
10:45 a.m.	Update on Cryogenic Propellant Storage and Transfer Susan Motil, Project Manager, Cryogenic Propellant Storage and Transfer Project
11:30 a.m.	Barriers to Innovation and Innovation Enablers Karen Thompson, KSC Chief Technologist
12:00 p.m.	Lunch Break – box lunches available

Public Meeting Adjourned at 1:00 p.m.

Appendix B

NAC Technology and Innovation Committee

NASA Kennedy Space Center

Cape Canaveral, Fl

December 10, 2013

Committee Membership

Dr. William Ballhaus, Chair

Dr. Kathleen Gallagher, *Executive Secretary*

Dr. Erik Antonsson, Northrop Grumman

Mr. Gordon Eichhorst, Aperios Partners, LLC

Dr. Randall Correll, Consultant

Dr. Matt Mountain, Hubble Space Telescope Institute

Dr. Dava Newman, Massachusetts Institute of Technology

Mr. David Neyland, Office of Naval Research

Dr. Mary Ellen Weber, Stellar Strategies, LLC

Appendix C

NAC Technology and Innovation Committee

NASA Kennedy Space Center

Cape Canaveral, FL

December 10, 2013

Meeting Attendees

Committee Attendees:

William Ballhaus, Jr., *Chair*

Kathleen Gallagher, *Executive Secretary*

Randall Correll

Gordon Eichhorst

Mary Ellen Weber

David Neyland

NASA Attendees:

Ivette R. Aponte, NASA KSC

Anyah Dembling, NASA Headquarters

Michael Gazarik, NASA Headquarters

Harold Gerrish, NASA MSFC

Mike Green, NASA Headquarters

Billy McMillan, NASA KSC

Susan Motil, NASA GRC

Bryan Smith, NASA GRC

Karen Thompson, NASA KSC

Appendix C

Martin Waszak, NASA LaRC

Other Attendees:

David Frankel, PB Frankel, LLC

Bergit Uhran, PB Frankel, LLC

Appendix D

NAC Technology and Innovation Committee

NASA Kennedy Space Center

Cape Canaveral, Fl

December 10, 2013

Presentation Materials

1) Welcome to Kennedy Space Center [Cabana]
2) Chief Technologist Update and update on Roadmapping [Peck]
3) Space Technology Mission Directorate [Gazarik]
4) Update on Solar Electric Propulsion (SEP) [Taylor]
5) Update on Cryogenic Propellant Storage and Transfer [Motil]
6) Barriers to Innovation and Innovation Enablers [Thompson]