National Aeronautics and Space Administration

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

Hybrid Meeting
November 30, 2023

Meeting Minutes

G. Michael Green, Executive Secretary

Michael Johns, Chair

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Meeting Report prepared by
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NASA Advisory Council Technology, Innovation, and Engineering Committee

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Overview of Agenda

Mr. G. Michael Green, Executive Secretary of the NASA Advisory Council (NAC) Technology, Innovation, and Engineering (TI&E) Committee, welcomed the meeting participants. On the previous day, Committee members had an outstanding tour of NASA's Langley Research Center, with five stops. Mr. Green thanked Mr. Clayton Turner, Langley Director. He then explained that the full NAC has not met since TI&E's last meeting in May, so the recommendations and findings from that meeting have not been presented. Mr. Green also noted the recent passing of Mr. Steve Jurczyk. Among other roles at NASA, Mr. Jurczyk had been Associate Administrator (AA) of the Space Technology Mission Directorate (STMD).

Opening Remarks

Mr. Michael Johns, TI&E Chair, welcomed the Committee members and thanked Mr. Turner. NASA Langley was doing some good work with early career (EC) engineers and scientists.

Welcome to NASA's Langley Research Center

Mr. Turner welcomed the Committee members. The workers at Langley are passionate about their activities because of the impact they have, doing exciting things and making history. The Center is constantly recruiting while also keeping retention in mind. At the same time, external collaboration is part of the culture. Mr. Turner gave the example of a toothbrush company with which Langley discovered synergy. This example shows that it is important to expand the idea of who NASA works with and what they do, while communicating the impact of the Agency's efforts.

Of the approximately 3,500 individuals centered at Langley, about half are civil servants and the rest are on contract. Some activities are still being done on a hybrid basis, which is a work in progress, as it is important to interact. Seeing colleagues in person helps with that and yet there is a need to be flexible. Former Langley Director Lesa Roe had the foresight to make investments in center facilities and infrastructure, currently worth about $5 billion. Mr. Turner listed the center missions, noting that an iconic flying national lab is being assembled in an Langley hangar. It is important to inspire everyone, including small children.

There are six core competencies at Langley. In addressing the entry, descent, and landing (EDL) area, Mr. Turner noted that a photo of an EDL device looks as if it is a "before" picture, but it was actually taken after the mission occurred. Industry is ready to take it on and now NASA can move onto next thing. Systems Analysis and Concepts (SA&C) takes a long-term view of engineering. Another core competency is atmospheric characterization. In the area of intelligent flight systems (IFS), the entire center is a city simulator where vehicles become "aware" of their own safety. The aerosciences area is very specific to vehicles that do not go as fast. Langley has some old buildings and needs craftsmen and others in order to maintain them. These facilities include labs, wind tunnels, simulators, and flight facilities. The flying national lab, to replace a DC-8, will allow investigators to be anywhere in the world. It will be loaded with instruments and still have room for as many as 100 people on board. Capable of going for 18 hours, it will allow work in shifts and is expected to be operational in 2025. Mr. Turner then presented a chart on the major capabilities within aeroscience, broken out by speed regimes. Among other things, Langley handles hypersonics, which is an area of interest to industry.

In showing the Langley organizational chart, Mr. Turner observed that all the individuals depicted are necessary to make the center work. He has moved people around to have cross-pollination. He also collaborates with the other NASA centers. The goal is to solve problems on Earth so we can move on to other planets. NASA is critical to the nation and the world.

Mr. Johns asked where the hypersonics effort is headed. Mr. Turner replied that Langley has significant expertise on the research side, and works with other government agencies and limited private industry sources. Most of this is not yet open for discussion, however. Dr. Michael Gazarik asked about off-site partnering. Mr. Turner said that this is more necessary than it was in the past. His teams are working to make it more efficient and ease budget pressure by pulling in external partners, and his leadership team was recently condensed to enable him to do more of this work. Mr. Walter Engelund of STMD observed that a lot of people support both sides. Dr. Heshmat Aglan asked about outreach. Mr. Turner said that NASA as a whole does a lot of that, but at Langley specifically, there were 40,000 visitors to an outreach event. Langley personnel visit schools and volunteer in Boys & Girls Clubs, finding that long-term commitments bring results.

Space Technology Mission Directorate (STMD) Update

Dr. Prasun Desai, Acting AA for STMD, provided an update. A lot has happened over the last year. Technology drives exploration, and this is measured by the technology readiness levels (TRLs). The STMD portfolio and budget are structured to reflect this, with programs in each area. Early Stage Innovation and Partnerships (ESIP) encompasses the lower TRLs. Within this area, engagement with academia has been strengthened, and there are many different avenues for engaging EC engineers and scientists. Ideas can come from anywhere and are not constrained by geography, institution, or other factors. STMD is trying to bring in people who are not already part of the NASA ecosystem and has given awards to individuals working in informal settings. NASA Innovation Advanced Concepts (NIAC) looks 40 years out to see what is on the edge for the future. This is how CubeSats entered the space environment, the initial ones coming from a NIAC proposal some years ago. There are now CubeSats in deep space serving as part of the communications relay system. In addition, the helicopter that recently flew on Mars originated in NIAC. This program is open to anyone for any idea and is typically academia, industry, and government in equal shares. Technology Transfer (TT) transitions NASA work to the greater economy, an example being the cameras on cellphones. The Agency is now being deliberate in these transitions. Once these ideas have some plausibility, NASA takes them to higher TRLs.

STMD leads the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs for all of NASA. These programs make hundreds of awards annually. STMD is now working to extend some of the awards past Phase 2 to better enable commercialization. Ideas with traction go into Technology Maturation, and more promising technologies are migrated to Technology Demonstration to determine how they function in the relevant environment. The breadth and strength of the program comes from all of these different avenues to get innovation across the "valley of death" into reality. A graphic illustrated the TRL bands for each program. STMD generally does not mature technologies beyond TRL 7, after which they are more appropriate for implementation in a mission at TRL 8 or 9. Not everything has to grow through STMD from the beginning. Ideas and technologies can enter and exit at various stages. STMD strives to be flexible.

First among the technology highlights was the Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) heat shield, led by Langley. Having had a successful test, it offers a plausible approach to landing heavy payloads on another planet. The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (CAPSTONE) is a CubeSat doing early risk reduction on the Moon. The TeraByte InfraRed Delivery (TBIRD) system is another CubeSat, in this case demonstrating optical communications. It has been very successful. Solar Electric Propulsion (SEP) will power the lunar Gateway. Roll-Out Solar Arrays (ROSA) have been infused onto the International Space Station (ISS). The Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) technology demonstration on Mars Perseverance tested the extraction of carbon dioxide from the Martian atmosphere into oxygen to meet our needs. This technology could now be applied to address issues on the lunar surface. The Thruster for the Advancement of Low-temperature Operation in Space (TALOS) is a new thruster about to launch on a Commercial Lunar Payload Services (CLPS) lander. It is a low-temperature thruster that will not require heaters, while needing less energy and being smaller. The Demonstration Rocket for Agile Cislunar Operations (DRACO) agreement with the Defense Advanced Research Projects Agency (DARPA) will demonstrate nuclear thermal propulsion (NTP). The Deep Space Optical Comm (DSOC) device launched on the Psyche mission recently. The Starling Swarm is a set of four SmallSats and CubeSats doing autonomous positioning and navigation. This effort will be followed by a hazard avoidance capability test to address the space clutter issue. The In-space Servicing, Assembly, and Manufacturing (ISAM) Consortium just kicked off, with huge interest.

Dr. Desai described how STMD investments align with Agency goals, from the Strategic Plan to the Moon to Mars (M2M) Blueprint. The Directorate takes input from several sources, both internal and external. STMD is the lead on M2M infrastructure and has identified technology gaps to help direct priorities and programs. Of the nine M2M infrastructure objectives, the first three address basic things like utilities. Numbers 4 through 6 address the longer-term state, mobility, surface operations, and building on the lunar surface. The last three are industrial-scale capabilities. Part of the process involves the 2023 Architecture Concept Review, done in November at Kennedy Space Center (KSC). This review is done annually, and this year the focus was on M2M exploration plans. The Architecture Definition Document (ADD) will discuss functions needed and the use cases. This will come out in January, with annual updates. It is a distinctive document that will define current architectures to share with all partners. Mr. Engelund said that the mission directorates are all working closely together on M2M, and STMD's role is critical, as it provides input on what to invest in for early stages across the board.

Dr. Desai noted new partnerships to work with industry using the Announcement of Collaborative Opportunity (ACO). Sixteen projects from 12 companies have been selected. The ACO involves no exchange of funds but rather calls for investments from both parties. The Tipping Point program funding mechanism has changed. Industry now provides an average of 40 percent of the support, going as high as 90 percent. In the area of technology demonstrations, DSOC tries to move the communications bottleneck further down the line, with the goal of someday eliminating it. The Flight Opportunities program did 31 tests via 20 commercial suborbital flights in Fiscal Year 2023 (FY23). This allows PIs to recover their technologies and tweak them to iterate the design. A solicitation is out now. Dr. Desai noted the additive manufacturing testing done under Technology Maturation, where there has been substantial investment. In the area of autonomous capabilities, the Cooperative Autonomous Distributed Robotic Exploration (CADRE) will launch on an early CLPS mission.

The Lunar Infrastructure Foundational Technology-1 (LIFT-1) demonstration has issued a Request for Information (RFI) to obtain feedback and gauge industry interest in doing an in-situ resource utilization (ISRU) demonstration on the Moon. There are five areas that feed into ISRU. The goal is to demonstrate different types of technologies, some at the subsystem level and some integrated. Mr. Engelund added that NASA has been investing with industry and academia all along, and now wants more from them in terms of ideas and capabilities to determine what is and is not ready.

Dr. Desai said that ESIP is trying to bring in innovation from nontraditional players through a challenge mechanism called the Space Tech Catalyst Prize. The Center Innovation Fund (CIF) invests in development of transformative technologies at the NASA centers. STMD supports two consortia. In FY23, the Lunar Surface Innovation Consortium (LSIC) had more than 3,000 participants from across the United States and worldwide. The Consortium for Space Mobility and ISAM Capabilities (COSMIC) just had its kick-off meeting. The area of Science, Technology, Engineering, and Math (STEM) engagement has been active, with the TechRise student challenge, which tested student payloads on suborbital vehicles. The Minority University Research and Education Project (MUREP) Space Technology Artemis Research (M-STAR) program awards grants to minority-serving institutions and historically Black colleges and universities. The second issue of the "First Woman" graphic novel just came out in October. There will be a number of technologies on the December CLPS launch. Some of the work for these and upcoming CLPS payloads occurred at Langley. DSOC is en route to the Psyche asteroid. A graphic illustrated where DSOC will do communications, going well past Mars.

The FY24 budget is still pending but is likely to have reductions from FY23. Program flexibility is an issue due to mandates and requirements. The Senate markup is particularly problematic, so STMD is being conservative in the event of the worst-case scenario.

Ms. Lisa Callahan asked if there are metrics to get a sense of STMD impact, especially regarding M2M. Dr. Desai explained that the emphasis is on advancement, not incremental improvements, so metrics are specific to each area. Mr. Engelund added that STMD is mapping to M2M objectives, which serve as metrics. Ms. Callahan observed that technology development is tough to gauge, and the mapping sounds helpful. Dr. Desai explained that STMD constantly assesses the performance parameters and whether to continue. Mr. Engelund added that transitions are included in that. Ms. Callahan asked if, in the consortia, industry is really sharing or being guarded. Dr. Desai said that it is a bit of both, especially in open forums. Mr. Engelund said that LSIC is further along, and newer companies are more open about sharing.

Low Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) Results Discussion and Follow-on Research

Mr. Joe del Corso, LOFTID Project Manager, noted that Mr. John DiNonno was the LOFTID Chief Engineer. LOFTID was a Hypersonic Inflatable Aerodynamic Decelerator (HIAD) technology demonstration. The device is a soft-goods aeroshell that can be deployed to decelerate payloads. The test was a rideshare with the launch of Joint Polar Satellite System 2 (JPSS-2) mission and was the largest blunt-body aeroshell ever to have entered the atmosphere. Mr. Del Corso showed the architecture and photos of the encapsulation and explained the re-entry. It weighed about 1100 kg.

LOFTID used lessons learned from the Inflatable Re-entry Vehicle Experiment-3 (IRVE-3), a suborbital mission flown in 2012 that was a small-scale proof of concept. Mr. del Corso explained the mechanics of LOFTID. Some data signals were supposed to arrive during re-entry, but the satellites were not aligned for that to succeed. However, the device worked. LOFTID did not get hot at all. Infrared cameras on the device show blue-purple streaks that are plasma flow.

LOFTID developed analytical tools for future capabilities even beyond HIAD. The team did a physics-based model and ran Monte Carlo analyses for thermal assessments. The flight demonstration data suite included nose and aeroshell instrumentation, video/imaging, and data recovery. The internal instrumentation failed to record data, however. The Fiber Optic Sensing System (FOSS) was a ride-along on this ride-along; it measured temperature distribution. Mr. del Corso showed images of the re-entry pulse and the distribution of constituent elements on entry. Recovery of the re-entry vehicle was optional. LOFTID demonstrated aerodynamic stability at the 6-meter scale and had dynamic stability throughout. Mr. del Corso showed the predicted versus measured pressure pulse and the predicted versus measured temperatures. In both cases, the predictions were close to the actual data.

Having demonstrated HIAD technology at the 3- and 6-meter scales, NASA believes it should be applicable to 12 meters, which ULA will be building. It is a huge jump but the company is paying for it. Of the six areas identified for the future of HIAD technology development, industry will have to make most of the investments. NASA is working with the commercial sector on several of the applications. ULA is the principal industry partner, but other entities are also involved. Ultimately, HIAD will enable larger, bolder space missions. Mr. Englelund added that this is a great example of long-term STMD investment resulting in a demonstration that industry is now transitioning to a commercial capability, and Mr. del Corso described some of the work that began in this area and went by the wayside. ULA came to NASA in 2018, which led to LOFTID.

Space Technology Research Institute Update: Advanced Computational Center for Entry System Simulation (ACCESS)

Dr. Matthew Deans, Program Executive for Space Technology Research Grants (STRG), gave an overview of the program. STRG engages academia through five programs with a range of awards. New recipients are coming in at all times. The overarching goal of the Space Technology Research Institutes (STRIs) is to strengthen NASA ties to the academic community through long-term, sustained investment in the research and technology development critical to NASA's future. The institutes invest in large, multidisciplinary, university-led research efforts enabling coordination of experts from a wide range of fields and organizations. These are 5-year awards, one of which is ACCESS.

Dr. Michael J. Wright, at the NASA Ames Research Center (ARC), listed the key needs for entry-system reliability. The intent was to develop new simulation capabilities allowing meaningful trades and assessments. He summarized the required elements. Regarding a question about hypersonics, Dr. Wright explained that EDL and hypersonics have a lot of overlap, creating a need to identify the gaps. Modeling and simulation might be where the STRI can help.

Dr. Iain Boyd, of the University of Colorado, described ACCESS. Many of the participants also work with the Department of Defense (DOD), so there is a lot of cross-leveraging. This is both good and bad, but some thinking applies to both areas. ACCESS pulls in six U.S. universities, all of which are state schools. There are unfunded international observers as well. He described the vision and four primary research objectives. The intent is to move away from validation toward uncertainty quantification. Each calculation involved is expensive, so an aspect of the research is determining how to maximize the throughput of the simulations. The second of the four main tasks, for the integrated simulation framework, pulls everything together.

Two upcoming missions will help focus the thinking. One is the Dragonfly mission, which will deliver a rotorcraft to the Titan surface. There is little to no oxygen available, and radiation is a factor. The Dragonfly Entry Aerosciences Measurements (DrEAM) instrumentation will take measurements from the heat shield during entry. Dr. Boyd described the instruments and noted the desire to back out the level of methane in the atmosphere. All of the focus areas for this project require continuous progress in Task 2. Another exemplar project is the Mars Sample Return (MSR) Earth entry system. The goal is to be running simulations to understand the reliability of the system.

Dr. Boyd noted the Task 2 subtask of coupling approaches, which involves a tightly coupled multidisciplinary analysis capability in an Integrated Simulation Framework (ISF). This encompasses innovative approaches that are high risk/high reward. He also presented a roadmap for the ISF development and planning processes. Seven demonstrations have been identified thus far, three of which have been completed for Dragonfly; a fourth is scheduled for 2024. The three for the MSR Earth entry system are planned for 2024 through 2026. This is how the project is gauging progress. A graphic illustrated the coupled flow and radiation for the Dragonfly back shell. Task 4 is uncertainty quantification and reliability. The need is to develop methods that allow maximum information from a small number of runs. The team wants a workflow to estimate heat shield reliability. In describing sensitivity analysis, Dr. Boyd noted the Bayesian calibration. He also described the Kinetic Rate and Physical Process Modeling task, and the Gas Phase Chemistry and Radiation task. The final area of task 3 is High Fidelity Modeling of TPS Features, Damage, and Failure.

ACCESS educational activities involve 37 graduate students and research staff, and graduate hypersonics certificates at two universities. There has been strong attendance at the seminar series. Dr. Deans said that STRI awards can tap into a wide expertise. Dr. Aglan asked about the graduate certificates. Dr. Boyd explained that at the University of Colorado, it is a subset of a masters degree, with 4 courses selected from a slate of 12. The classes are done online. Mr. Engelund said that he liked that this is tied to real NASA missions, as it engages students and academia with the Agency. Dr. Gazarik asked if the program is looking back at the Mars Science Laboratory Entry, Descent, and Landing Instrument (MEDLI) efforts. Dr. Boyd said that they are using all the data they can find, including from these past efforts. Dr. Desai pointed out that the STRIs attack hard problems, and prediction in this area has been difficult.

Mr. Johns asked about STRI management. Dr. Boyd agreed that it is an unusual size for a university. He knows a lot of the people involved, so he can be straightforward with them. A leadership council and task leads move things forward. ACCESS is doing well for being so large, though they cannot always go as quickly as they want. It is helpful for the grad students to see this. Student involvement has exceeded expectations. Dr. Rebecca Kramer Bottiglio asked if there is funding for administrative support. Dr. Boyd said that there is, and Dr. Deans explained that the program tries to anticipate the coordination needed. Each STRI takes a different approach, and there has been some ad hoc student coordination.

Office of the Chief Engineer Update

Ms. Katherine Van Hooser, Deputy Director of the Office of the Chief Engineer (OCE), explained that she is the Chief Engineer at Marshall Space Flight Center (MSFC) and also a recent detailee to OCE. The Office includes the NASA Engineering and Safety Center (NESC), which helps identify and mitigate risks across the entire NASA portfolio. OCE does technology reviews and uses other means to help achieve mission success within budget constraints and other requirements. OCE also seeks and considers diverse and dissenting opinions. Over two-thirds of the OCE FY23 budget was directed toward reducing risks or addressing a range of cross-cutting challenges. Ms. Van Hooser presented the key OCE achievements for FY23 by mission directorate, giving examples such as commercial crew and the Artemis-1 launch.

Ms. Van Hooser listed the NESC assessments requested in FY23 and broke them out by organization. Over half of the FY23 NESC active work portfolio was related to human spaceflight. She also listed the major studies completed in FY23; such studies can lead to improved practices or guidelines. NESC major knowledge products for FY23 included 22 engineering reports, 7 technical bulletins, 95 citations in journal articles and conference papers, and 3 innovative techniques. Plans for FY24 were broken out by mission directorate and include a number of first flights or continuations of flight programs.

Mr. Johns asked if there were plans to interact with space nuclear propulsion (SNP). A representative from MSFC said that he was heavily involved in this, overseeing the technology activities. Ms. Van Hooser explained that MSFC develops the requirements and does documentation. Dr. Desai added that DRACO is somewhat different from typical NASA development because the contract is held by DARPA. The chief engineers will be involved, however. Ms. Van Hooser compared it to contracts where NASA gives external providers more control early on while maintaining safety and other standards.

She concluded by stating that OCE focuses on the technical and programmatic readiness of the Agency's programs and projects. This includes advising NASA officials on technical readiness, overseeing and ensuring continuity in Agency engineering, and assessing mission development and operations for sound engineering.

NASA Nuclear Propulsion Update

Dr. Anthony Calomino, STMD's Space Nuclear Technologies Lead, provided an update. SNP is reliable, powerful, and extremely energy-dense, making it the next generation of deep space propulsion and transportation. NASA is looking at how to use some commercial grade enrichment levels, primarily High-Assay Low-Enriched Uranium (HALEU), which presents reduced security concerns while also providing the desired power. It also allows NASA the opportunity to work more broadly with both U.S. and international organizations. The Agency is working with a good number of organizations, starting with the Department of Defense (DOD) to advance space fuels. NASA is also working with the Department of Energy (DOE) on the power and propulsion side. In addition, NASA has the DRACO partnership with DARPA. The Air Force Research Lab (AFRL) has let out contracts for space power capabilities and NASA is collaborating with the U.S. Space Force (USSF) on those efforts. Dr. Calomino gave examples of the many industry engagements.

NASA is interested in both nuclear electric propulsion (NEP) and nuclear thermal propulsion (NTP). Both are possible for high-mass delivery of payloads to Mars. However, they are very different from each other, with NTP being more of a flow-through. They both have benefits, and both present investment challenges. The National Academies of Sciences, Engineering, and Medicine (NASEM) did a study in 2021 that identified their pros and cons. Both systems require investment in order to mature further, and NASA has sought design concepts from industry in order to learn how the commercial sector might handle a megawatt reactor for NEP. There were a lot of surprising and promising results. The Agency would like to grow both NEP and NTP in order to have the option of which to choose. The obvious risk with NTP is the reactor operating temperature, while the NEP system itself is more complex, with subsystems that still require development.

Dr. Gazarik asked about AFRL investments. Dr. Calomino replied that AFRL has invested $60-70 million, split between a Westinghouse concept that is similar to the company's work for NASA, and another concept similar to what NASA did under the Kilowatt Reactor Using Stirling TechnologY (KRUSTY) project from 2018. Both concepts are 20 kW and pick up where NASA left off. The Agency is looking at how it might leverage this.

There is now some Congressional support, currently in the direction of favoring an NTP program, as illustrated on the SNP roadmap. There is also more evidence of support from the White House and the Office of Management and Budget (OMB). NASA did a subscale NTP system test that allowed the Agency to work with DARPA. There is talk of a system being ready for launch in early 2027, which is aggressive. NEP received a bit of funding in FY23 and there is some indication that this will grow in FY24. NASA is changing the focus to a subscale system, which is a more efficient, cost-effective approach. The goal is to have two capabilities for a Mars mission, allowing NASA a choice.

Dr. Calomino then gave the status of current NTP activities. A 900-sec Isp engine is now feasible. The program is looking at some carbide fuels developed in the 1960s. Other options could be applicable to fission surface power (FSP). The program closed out some design concepts over a year ago but is continuing with those industry engagements via extensions. One of the goals is risk reduction. DRACO will be a prototype, not an operational system. It will provide the information needed to build other projects when the budget allows. Industry is demonstrating more interest in cislunar transportation infrastructure, and Dr. Calomino listed the external partners. The FY24 deliverables include the DRACO preliminary design review (PDR) and the nuclear thermal rocket engine (NTRE) critical design review (CDR).

Mr. Johns observed that the Committee had previously discussed fuel and architecture as being risks. Dr. Calomino explained that the team has settled on a design they believe could succeed in a demonstration. The fuel form was proven robust in testing. All solutions have tradeoffs. For NEP, there was some FY23 funding and there will be some development work in FY24. The focus is now on a subscale effort and the team plans to talk to science investigators about their missions over the longer term.

NASA came in after Phase 1 of DRACO in order to partner with DARPA on Phase 2. The Agency is interested in the NTRE. The plan is to launch with USSF on a Vulcan/Centaur in spring of 2027. DARPA does own and control the project, and DARPA prioritizes schedule, cost, and flexibility over risk aversion, which is different from NASA, and which has made it necessary for the Agency to adapt. Dr. Calomino described the governance process, which is very new for NASA.

The DRACO vehicle system includes three primary modules. In discussing the architecture, Dr. Calomino said that it will run at 2000 km. DARPA is managing launch safety but NASA is involved. The mission objective is to collect data on novel HALEU NTR behavior. The team is moving forward after closing comments on environmental protection; no substantive comments were received. Many government organizations are interested in how this is done. The DRACO engine has a much lower thrust than what would be used for Mars. However, it is a moderator block design with evenly spaced fuel rods and it is modular, which lends itself to extensibility, accounting for NASA's interest. Thus the challenges are for engineering and are not R&D challenges. The team is working closely with Lockheed and is embedded with some of its teams. There is an independent review board (IRB) of experts from diverse disciplines, providing their feedback and perspective on major design reviews. DRACO completed the PDR for the reactor in November.

NASA benefits from the partnership with DARPA in many ways. The result will be an engine that is relevant to Mars exploration, and the nation will have the capacity for a safe launch of a fission system for first time since the 1960s. A lot has changed over the decades, and NASA is reviewing the documentation from the earlier efforts. The team is learning about what worked while also identifying gaps. Overall, it will bolster the use case. The team will work through a lot of questions and is identifying regulatory issues and challenges while setting up a way to address them. The cost-sharing is also quite helpful. The next milestone is the PDR for the NTRE in 2024. Dr. Mitchell Walker asked about power management and distribution. Dr. Calomino said that this is not on the agenda for NTP, but the team wants to use high voltage systems for NEP.

Early Career Initiative (ECI) presentation on Aerocapture System as an Enabling Technology for Ice Giant Missions

Dr. Soumyo Dutta explained that he has been at Langley for 10 years. The Aerocapture system, an ECI project, can take orbiters to ice giants. He showed a video that was part of his proposal. The goal of Aerocapture is to save transit time for long missions through a maneuver to insert a mission into an orbit that will result in a desired exit orbit. It involves a single pass, unlike captured orbit systems. There are many good reasons to visit the ice giants, Uranus and Neptune, and the Planetary Science Division (PSD) Decadal Survey (DS) stated that visiting Uranus should be the Division's highest priority.

Aerocapture is a 2-year project. The key technological areas include a thermal protection system (TPS); guidance, navigation, and control (GNC); packaging of the instrumentation; and optical navigation (OpNAV). The Aerocapture concept has been suggested many times as the orbital insertion method for missions that were canceled for completely unrelated reasons. However, due to a perception of risk, there have been no missions using Aerocapture as a baseline. On the other hand, air braking in a captured orbit can be time consuming and use a lot of fuel, and Aerocapture presents an alternative. Dr. Dutta described the properties of the large ice giants that make travel to them so complex. For example, the launch mass for such missions is largely fuel. In addition, it takes 13 to 17 years to reach these planets. Given the time needed to design, develop, and build a mission, the timeline to simply reach the destination can exceed 30 years. Aerocapture reduces that time, saves mass, and even allows the use of a smaller launch vehicle. It does call for a new kind of EDL. Dr. Dutta reviewed the goals and referred to a white paper that made it into the DS.

As the PI for Aerocapture, Dr. Dutta wanted the team to be multi-center and multi-disciplinary, as illustrated by the organizational chart. All of the NASA team members are EC and the Draper team is mostly EC, but the other partners include more experienced participants. He learned from others what to do and what not do. For external partners, he had to go through the procurement process, where they are scored. He knew the internal members from the other centers. Some team members moved, which sent him to branch heads; they were receptive despite some concern that they might not be. He wanted to make sure that the project helped develop the workforce throughout NASA.

He also recruited mentors, some of whom had to be paid for their time. They were helpful during the project and served as the review committee. For project management, the team used the "scrumban" approach, combining scrums and Kanban visualization. The scrum approach starts with a quick daily update, but for a team this large needing to get to work, he incorporated a "team of teams" approach. Booz Allen coaches and follows the teams, which cannot all operate the same way.

Dr. Dutta listed the key milestones. The baseline technologies grew from the 2021 Uranus Orbiter and Probe (UOP) mission concept study. The PSD DS assumes a launch date in the early 2030s with another 13 years of transit. He believes it is optimistic, but there are key windows that add urgency to a launch by 2033, and scientists want to observe the Uranus spring, which will occur in 2049. That makes Aerocapture more compelling, as it expands the transit choices, including whether to go with a lower-cost launch vehicle or a large one that is faster. The team wanted to avoid reinventing the wheel, however, and is using some tested technologies, as well as using standard EDL analysis and modeling. There is little data about the pressure on Uranus, leading to concern that the orbiter might burn up in the atmosphere, but it appears that Mars EDL is harder. Radiant heating is small, only 5 percent. Regarding navigation, Uranus is a challenging OpNAV target, but there is a plan to use Uranus satellites as beacons to indirectly observe correlated to the planet's position. The team has determined that it is possible to have the desired entry accuracy.

Dr. Dutta described plans for the second year and listed publications. There is a transition plan for after ECI.

Mr. Engelund said that there have been multiple Aerocapture studies over the years. PSD looked at it in relation to Uranus. Mr. Johns asked Dr. Dutta how prepared he was to run this. Dr. Dutta replied that he had good help but someone he wanted as a project manager left NASA. He was able to add partners via tasks for which they already had funding. Dr. Julia Cline, another ECI at Langley, advised him to not get hung up with procurement. He received training upon selection. Mr. Turner said that there may be modules that can be made available as training to become a PI. He liked Dr. Dutta's creativity in looking for an alternative to procurement. Training provides guard rails. Dr. Dutta noted that he is learning what he does and does not want to do.

Early Career Initiative presentation on Lightweight Surface Manipulation System AutoNomy Capabilities Development for Surface Operations and Construction (LANDO)

Dr. Walter Waltz, Deputy Lead for LANDO, was presenting on behalf of Dr. Cline. LANDO grew out of the Artemis and M2M programs, where a gap in payload offloading was identified. The team saw that the architectures for addressing the gap would apply elsewhere and decided to examine what an autonomous system might look like. The lightweight surface manipulation system (LSMS) already existed; it is very large and industry is familiar with it. LANDO was to be a smaller version, though both are scalable. Mechanically and functionally, they are the same, but demonstrating the smaller system provides flexibility.

The first goal with LANDO was to generate a lightweight package, then do a demonstration using a mix of both structured and unstructured payloads. The latter have to do with scenarios such as landing on a slope or finding a big rock, etc. Another consideration is whether to move regolith. The software will be modular to enable use across different types and sizes of missions. The hope is that LANDO architecture will be useful for other projects and platforms. It can develop in parallel or with additional pieces or updates, so that there will be a library of modules to extend systems.

Graphics depicted the project elements and the work breakdown structure, which involves hardware and software. The team was able to test the modularity in preparing for the TI&E tour on the previous day. Next steps involve integrating perception and intelligent capabilities. Perception will allow detection and following of the payloads. The intelligent capabilities will enable autonomous decisions. This is essentially a behavior tree. The team will determine how and when to pull in humans for decision-making and information updates. Humans will do verification and set some thresholds. A video showed LANDO moving boxes around. The results of experiments with payloads compared desired and actual angles. The team noticed a tracking error induced by a sensor that created friction and is trying to address that.

The project is in its third year thanks to an extension and has 8 months left. The pattern has been to work in 3- to 5-week sprints, while also having weekly meetings. Typically, a sprint begins with a planning segment that breaks down the work to determine how much time is necessary. User stories are documented and provide flexibility. Sprints conclude with another meeting. To encourage candor, participants can give feedback anonymously.

LANDO started at the same time that the coronavirus spread began, which complicated things. A lot of the new hires were unfamiliar with how the government worked, which pointed to a need for review and orientation. Procurement and the supply chain were chaotic and the team had to learn contracting and reporting processes. Previous ECIs were helpful, and all predicted that the contracting would be an issue. LANDO also had six interns who came in through different means. Two are undergrads and four are getting their masters degrees. One intern was paid by the Pathways program, while the others were paid through LANDO. The Pathways timelines differ from those of the project as well. The team tried to match up the interns with their interests, and remains in contact with all of them.

Dr. Waltz had done project management in the past and was able to bring that experience forward. No project can follow these systems completely. R&D requires flexibility, so the stories of how work was done were very helpful. He sought a lot of information via reports on the sprints. Dr. Cline is the project lead. LANDO had an open house for the public and gained lots of media attention. There was significant commercial interest as well, including from Blue Origin and Astrobotic. The latter has been the partner with which the team has done the most work.

The goal for the next steps is to reach TRL 5 or 6, preferably 6. The team is seeking other proposal development options within STMD. Some papers are in the works, though nothing has been published yet. The effort in obtaining the 1-year extension caused a delay. Dr. Kramer Bottiglio asked if there is any differentiation within NASA on the types of publications. The videos would be helpful in disseminating information, for example. Dr. Waltz said they are looking at the various options.

Discussion, Findings, and Recommendations

Mr. Johns said that TI&E could take summary information from the presentations to the NAC. He asked the members for their additional comments. Dr. Walker said that he wanted to hear more about the SLS and the workforce, specifically how many people left after SLS was developed. Dr. Gazarik thought the flight demonstrations were terrific, one good story after another. He would like an update on the status of DSOC. He was also interested in learning more specifics about the impact of the various programs on building talent. Mr. Engelund said that it could be interesting but it would be hard to put together. Mr. Green added that the current level of tracking is not sufficient for that kind of information. A study to go back and find people and see where they are might be worth it, however.

Dr. Aglan thought that LANDO was impressive and robust, and seemed to be a mature technology, more so than Aerocapture. It could help NASA with recruitment. Dr. Kramer Bottiglio liked that LOFTID evolved over the course of 20 years, and a chart showing how that occurred would be impactful. It was great to see the EC programs and training. They continue to struggle with opportunities for where to go next, however, and there are parallel academic programs. This might be something to think about. She asked if there is an ECI program review. Mr. Engelund replied that there is an annual presentation, but alums have not participated. Dr. Kramer Bottiglio said that it might be helpful to bring in current and past participants in order to make connections and create more partnerships.

Dr. Gazarik said that it is important to recognize that NASA has nudged EDL capabilities continually since 2010. He would like to note the investments, technology transitions, and hypersonics. Mr. Johns said that there could be a finding of a vote of confidence and continuation of expanded support. Regarding Dr. Walker's suggestion that the next meeting discuss the retirements following SLS, Mr. Johns added that there is the related issue of industry paying more and offering good projects. He thought the radiofrequency mass gauge would be a good technology transition story. Regarding nuclear propulsion, settling on the fuel choice for DRACO is a major milestone. He wanted to note that the ECI training modules have been helpful.

Dr. Desai thanked the Committee for its input. He added that NASA Administrator Bill Nelson said that when Congress established STMD, they were not quite sure what they wanted, but what they have now is what they wanted. All the successes show that. The mission directorate will face budget headwinds, but everyone's efforts are commendable.

Mr. Green said that for the next NAC presentation, TI&E will have these findings plus those from May. He thanked everyone and said that the next meeting will be in March or April.

Adjournment

The meeting adjourned at 4:40 p.m.

Appendix A

Agenda

November 30 – FACA Public Meeting, Hybrid

8:30 a.m. EST	Overview of Agenda Mike Green, Executive Secretary
8:35 a.m.	Opening Remarks Michael Johns, Chair
8:40 a.m.	Welcome to NASA's Langley Research Center Clayton Turner, Director, NASA Langley
9:10 a.m.	Space Technology Mission Directorate (STMD) Update Prasun Desai, Associate Administrator (Acting), STMD
10:10 a.m.	Low Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) Results Discussion and Follow-on Research Joe del Corso, Project Manager, LOFTID
11:10 a.m.	Break
11:25 a.m.	Space Technology Research Institute Update: Advanced Computational Center for Entry System Simulation (ACCESS) Matt Deans, Program Executive for Space Technology Research Grants, STMD Iain Boyd, Principal Investigator, University of Colorado
12:10 p.m.	Lunch Break
1:10 p.m.	Office of the Chief Engineer Update Katherine Van Hooser, Deputy Director, Office of the Chief Engineer
1:45 p.m.	NASA Nuclear Propulsion Update Anthony Calomino, Space Nuclear Technologies Lead, STMD
2:30 p.m.	Break
2:45 p.m.	Early Career Initiative presentation on Aerocapture System as an Enabling Technology for Ice Giant Missions Soumyo Dutta, NASA Langley
3:30 p.m.	Early Career Initiative presentation on Lightweight Surface Manipulation System AutoNomy Capabilities Development for Surface Operations and Construction (LANDO) Walter Waltz, Deputy Lead, LANDO, NASA Langley

4:15 p.m.	Discussion, Findings, and Recommendations
5:00 p.m.	Adjournment

APPENDIX B

Committee Membership

Mr. Michael Johns, Kratos SRE, *Chair*
Mr. G. Michael Green, *Executive Secretary*
Dr. Heshmat Aglan, Tuskegee University
Ms. Lisa Callahan
Dr. Michael Gazarik, Ball Aerospace
Dr. Rebecca Kramer Bottiglio, Yale University
Mr. Andrew Rush, Copernicus Space Corporation
Dr. Bradford Tousley
Dr. Mitchell Walker, Georgia Institute of Technology

APPENDIX C

Presentations

1) Welcome to NASA's Langley Research Center [Turner]
2) Space Technology Mission Directorate (STMD) Update [Desai]
3) Low Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) Results Discussion and Follow-on Research [del Corso]
4) Space Technology Research Institute Update: Advanced Computational Center for Entry System Simulation (ACCESS) [Deans, Wright, Boyd]
5) Office of the Chief Engineer Update [Van Hooser]
6) NASA Nuclear Propulsion Update [Calomino]
7) Early Career Initiative presentation on Aerocapture System as an Enabling Technology for Ice Giant Missions [Dutta]
8) Early Career Initiative presentation on Lightweight Surface Manipulation System AutoNomy Capabilities Development for Surface Operations and Construction (LANDO) [Waltz]