

National Aeronautics and Space Administration
Washington, DC

NASA ADVISORY COUNCIL

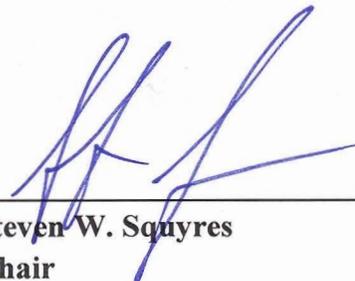
April 24-25, 2013

NASA Headquarters
Washington, DC

MEETING MINUTES



P. Diane Rausch
Executive Director



Steven W. Squyres
Chair

Table of Contents:

Call to Order, Announcements	3
Opening Remarks by Council Chair	3
Remarks by NASA Administrator	3
Aeronautics Committee Report	7
Information Technology Infrastructure Committee Report	9
NASA FY 2014 Budget Request	10
NASA Plans for Future Human Spaceflight	12
Human Exploration and Operations Committee Report	14
Science Committee Report	16
Technology and Innovation Committee Report	20
Commercial Space Committee Report	23
Audit, Finance, and Analysis Committee Report	25
Education and Public Outreach Committee Report	26
Curiosity’s Exploration of the Habitability of Ancient Mars: Overview of Early Mission and SAM Discoveries in Gale Crater	29
Council Discussion	31
Public Comments	33
Appendix A: Meeting Agenda	34
Appendix B: NASA Advisory Council Membership	36
Appendix C: NASA Advisory Council Meeting Attendees	37
Appendix D: Materials Presented	39

*Meeting Report prepared by
Mark Bernstein, Zantech IT*

NASA ADVISORY COUNCIL MEETING**NASA HEADQUARTERS
Washington D.C.****PUBLIC MEETING****April 24-25, 2013****Wednesday, April 24, 2013**Call to Order; Announcements

Ms. Diane Rausch, Director, NASA Advisory Committee Management Division, Headquarters (HQ), and Executive Director, NASA Advisory Council (NAC or Council) called the meeting to order and welcomed all members. She noted that the NAC was established under the Federal Advisory Committee Act of 1972 (FACA). As such, the meeting was open to the public but members of the public were asked not to interrupt the speakers. She noted that all comments made were on the record and that formal minutes were being kept. She reported that all NAC members had been appointed by Mr. Charles Bolden, NASA Administrator, due to their standing as individual subject matter experts. NAC members, she added, had status as Special Government Employees (SGEs). As such, they were to recuse themselves from any matter in which they might have a potential conflict of interest. Should any uncertainties arise, she said, NASA attorneys were available for consultation. She introduced the NAC Chair, Dr. Steven W. Squyres, who presided over the meeting.

Opening Remarks from Council Chair

Dr. Squyres noted this had been a difficult meeting to schedule. The NAC generally met three times annually, with the first meeting falling in February to correspond with the Federal budget process. This year, due to continuing budget uncertainties, the meeting had been postponed. He expressed gratitude to Council members for their patience. He noted that Gen. Lester Lyles, recovering from knee surgery, was unable to attend.

The present meeting, Dr. Squyres said, would focus on the coming year's budget and discuss new directions and initiatives for the Agency. He noted that while recommendations forthcoming from the group came from individual committees, where major new budget initiatives and funding matters were concerned, recommendations should come forward from the entire NAC.

Remarks by NASA Administrator

Dr. Squyres then introduced NASA Administrator, Charles F. Bolden, who said he always found it a pleasure to meet with the NAC. He thanked Diane Rausch for her work in bringing the NAC together again and for her continuing service as NAC Executive Director. He noted that the NAC usually has its first meeting of the year in February, coinciding with the release of the President's proposed budget, but this year, the President's budget was not released until April 10, 2013, so the NAC meeting had to be delayed in order to give the most current update of the President's FY 2014 budget request for NASA. He thanked the Council members for their dedicated service. In 2012, the Council had been very productive and had forwarded 22 formal recommendations and 16 findings to him. He observed that each of the 22 recommendations had in turn received a formal response from NASA, though not necessarily the response that was hoped for. Sometimes, resources did not exist. He opined that the coming year would be equally productive and conveyed best wishes for fruitful Council deliberations over the coming two days.

Mr. Bolden noted that NASA's Chief Financial Officer (CFO), Dr. Beth Robinson, and other members of NASA's senior leadership would present a detailed look at the proposed NASA budget FY 2014 later that day. He stated he would set the stage and provided a broad overview. The President's NASA budget request for FY 2014 was \$17.7 billion. That figure would allow NASA to maintain world leadership in space exploration and scientific discovery for years to come, while making critical advances in aerospace and aeronautics to benefit the American people. He

stated the proposed budget reflected today's fiscal realities and aligned NASA's full spectrum of activities to meet the President's challenge to send humans to an asteroid in 2025 and Mars in the 2030's. It also supported the Administration's commitment to NASA leading in innovation through cost-effective solutions that inspire the world. The President's budget advances a strategic plan for the future that builds on U.S. preeminence in science and technology, improves life on Earth, and protects our home planet, while creating high-paying jobs and strengthening the American economy.

Mr. Bolden stated that due to excellent management by Center Directors, the sequestration had had no impact on programs. NASA's leadership team had early on opted to spend at a level below that of other agencies. In consequence, most Centers were already meeting the mandated five percent across the board reduction. Mr. Bolden noted that some NASA contractors had laid off employees, though not as many had it not been for reduced spending on the International Space Station [ISS]. He noted that some NASA prime contractors reported being healthier in the post-Shuttle period than before. Mr. Bolden expressed the view that the President's FY 2014 budget advanced a strategic plan that will strengthen the nation and increase jobs in the United States.

Mr. Bolden stated that NASA is using game-changing technologies advanced by the Administration, and is developing a first-ever mission to identify, capture and relocate an asteroid. The mission was an unprecedented technological challenge, raising the bar for human exploration and discovery, while helping to protect our home planet. NASA's asteroid strategy brings together a synergy of everything NASA did best in science, technology, and human activities. It will achieve the President's goals faster and at lower cost to taxpayers than continuing with business as usual. Mr. Bolden noted that NASA's American industry partners are developing new ways to reach space, creating jobs and enabling NASA to focus on new technologies that benefit all of its missions.

Mr. Bolden noted that a little more than one year after the end of the Space Shuttle Program, one industry partner, SpaceX, began resupplying the ISS with cargo launched from the U.S. The recent successful test launch by Orbital Sciences inaugurated NASA Wallops Flight Facility on Virginia's eastern shore as the newest U.S. spaceport, and opened up additional opportunities for commercial and government users. It was another significant milestone in NASA's plan to rely on American companies to launch supplies and astronauts to the ISS, bringing this important work back to the United States where it belongs. He noted that the cargo resupply program was being funded to keep the operations on track.

Mr. Bolden stated that the Administration is committed to launching American astronauts from U.S. soil within the next four years, and the proposed FY 2014 budget provided the necessary resources to achieve this goal. He further stated that any reduction to the proposed level of funding for the Commercial Crew program would result in a delay in bringing these launches back to America and force NASA to continue paying the Russians millions of dollars to carry our astronauts into space.

Mr. Bolden stressed that the ISS remains the springboard to the next great leap in exploration; it is a convergence of science, technology, and human innovation that is helping us to learn what it means to be a spacefaring people by demonstrating new technologies and making research breakthroughs not possible on Earth. The proposed NASA FY 2014 budget continues investments that are developing the rocket and crew vehicle that will take astronauts to deep space, and is driving development of space technologies such as solar electric propulsion that will power tomorrow's missions and help improve life on Earth. Our technology investments not only increase the capabilities of NASA, but other government agencies and industry as well.

Mr. Bolden also noted that the proposed budget also continues to build on our nation's record of breathtaking scientific discoveries and achievements in space, with science missions that will reach farther into our solar system, reveal unknown aspects of our universe, and provide critical knowledge about our home planet. He stated that on the heels of Mars Curiosity, the most daring mission to Mars in history, the FY 2014 proposed budget includes funding for another mission to the Red Planet, continues operations of NASA rovers and orbiters already there, and makes possible the MAVEN [Mars Atmosphere and Volatile Evolution] launch in November 2013 to study the Martian upper atmosphere, plus the InSight mission to launch in 2016. The budget will also sustain NASA's vital role in helping us understand Earth's systems and climate, and the dynamics between our planet and the sun. These efforts will provide critical knowledge about our home planet and potential threats, he said. In addition, NASA will continue its steady progress toward the next Great Observatory as it develops and conducts critical tests on JWST (James Webb Space Telescope). Mr. Bolden stated the planned 2018 launch in 2018 of JWST would again revolutionize our understanding of the universe.

Mr. Bolden stated that NASA is creating new jobs on Earth as it reaches for new heights in space, especially for the next generation of American scientists and engineers, by supporting cutting edge aeronautics and space technology innovations and research, and development that will help fuel the nation's economy for years to come. The FY 2014 budget also supports the Administration's plan to consolidate and improve the many science, technology, engineering and mathematics (STEM) education programs across the Federal government, maintaining NASA's unique ability to inspire the next generation of scientists, technologists, engineers and astronauts. He noted that NASA has had to make tough choices with the FY 2014 budget, but is using its resources strategically for a unified, cohesive exploration program that raises the bar of what humans can achieve.

Before taking questions, Mr. Bolden said he wanted to take the opportunity to recognize one distinguished Council member who will be stepping down from his position at the end of April 2013, Dr. Wesley T. Huntress, Jr. Mr. Bolden recalled appointing Dr. Huntress to the Council in October 2009, and since then, he had served with distinction and shared his unique insights. He noted that Dr. Huntress had served as Chair of the NAC Science Committee and had led a very broad portfolio with his Committee and five Subcommittees in Astrophysics, Earth Science, Heliophysics, Planetary Protection, and Planetary Science. Mr. Bolden noted that Dr. Huntress had tremendous scientific expertise and leadership experience, and that had made him incredibly valuable as a member of the NAC. In addition to his outstanding long career as a planetary scientist at the Jet Propulsion Laboratory, he had served as the NASA Associate Administrator for Space Science for five years, and retired as Director Emeritus of the Carnegie Institution's Geophysical Laboratory. Mr. Bolden then presented Dr. Huntress with the NASA Exceptional Public Service Medal and an accompanying plaque which stated: *"For exemplary leadership, dedication and commitment to NASA as a member of the NASA Advisory Council. Your contributions will benefit the Nation for generations to come."* Mr. Bolden congratulated Dr. Huntress on the very high honor, thanked him again for his service, and extended best wishes to Dr. Huntress in his future endeavors. Responding, Dr. Huntress said it had "truly been an honor and a privilege to participate." He added that now he would get to be a spectator of NASA's continuing achievements.

Mr. Bolden concluded his remarks by again thanking the Council members for their time and willingness to serve on the NASA Advisory Council. He noted that the counsel, advice and constructive criticism that the Council provided to him and the entire NASA leadership team is a big part of why NASA remains the world's preeminent space agency and the best place in the U.S. Government to work. He said he appreciated everything the Council does to help support and guide NASA and the U.S. civil space program. He then opened the floor for questions.

Dr. Charles Holmes, commenting on the sequester, noted that as certain high profile programs were not touched, others were cut by more than the five percent across the board figure. Mr. Bolden said there was no instruction not to cut. The Agency had made the decision to protect agreed upon priorities, e.g., JWST and ISS. The Agency had the prerogative to shift funds between programs. Dr. Holmes asked if other areas received more than a five percent cut. Mr. Bolden said specifics would come later in the meeting; some matters were still to be resolved.

Mr. Lars Perkins asked how NASA's role in STEM may change. Mr. Bolden said that policy changes in travel and outreach had had an unintended consequence. Weeks had been spent determining travel and conference attendance issues; education had been dealt with in a single day. People were directed to attempt to secure waivers on anything "on the plate." Several events defaulted; default was in the direction of turning everything off rather than of keeping everything moving. He noted that appearances by astronauts were an exception because these were reimbursable events. Mr. Perkins said NASA's proposed FY 2014 education budget was hit very hard. He believed NASA's philosophy on its own stake in STEM was going to have to change. Mr. Bolden said no other agency could match NASA's resources: the new approach gives other agencies access to NASA content and gives NASA access to two agencies very skilled at education-related metrics – the Department of Education and the National Science Foundation. As an example, at one point in the past, he had been told, that NASA reaches one million young people a year. When he asked, "How do we impact them? What are the measurable outcomes?" he was told the same thing: NASA reaches one million young people a year. He noted that programs for underrepresented groups – e.g. minorities, women, tribal schools – would be unaffected because the entities providing these services had remained intact.

Ms. Marion C. Blakey noted that the Aerospace industry spent \$150 million annually on STEM, but little effort was made to follow up with these young people. She noted that the Chairman of Northrop Grumman headed this effort, working closely with the President's Council. When these organizations are brought together, it was clear that problems with metrics exist. Mr. Bolden reported that all the executive educators from STEM have been working

for two years on how the STEM effort can be consolidated. This effort will not be wasted. He reported on the efforts of CO-STEM, an interagency group, which was now taking the NASA "Summer of Innovation," as a program to extend across the country. NASA had not intended this as an Agency program, but had taken it on for three years when no partner was available.

Ms. Blakey said it would be difficult to explain to outsiders how hurtful sequestration would be without a clearer idea of what it would entail. Mr. Bolden said if Congress and the White House could not solve the sequestration issue, then NASA was a \$16.8 billion agency; he thought the Agency could live with that. The Centers had managed programs exceedingly well financially. But their futures remained uncertain. He cited commercial crew as a good example. NASA had promised that by 2017 it would be able to put astronauts aboard U.S. vehicles. Sequestration will prevent this. Additionally, the planned 2018 JWST launch date will be in question. Continued sequester would reduce NASA to a \$16 billion budget; the [Congressman] Ryan budget would reduce the Agency to \$15 billion. Ten years of sequester, he said, would "end NASA as we know it." Serious problems set in when the budget drops below \$16.2 billion. He noted the Agency had yet to furlough any employees. Dr. Huntress said that the Agency will survive with the funds available for FY 2013 but if such levels continue in FY 2020 and beyond there will be a major content loss. Dr. Matt Mountain said even a two or three percent cut could have impact.

Dr. Squyres said the NAC would hear from Mr. Bill Gerstenmaier, NASA AA for HEOMD, about capturing an asteroid and placing it in orbit around the Moon. How did the Administrator believe this effort fit with the Agency's longer-range goals for journeys into deep space? Were they a step toward these longer goals or as a substitute for them? Mr. Bolden said the new Asteroid Initiative was a step toward the ultimate destination of Mars. It involved incurring more risks earlier than some other projects. The Mars mission was not dependent on the success of the Asteroid mission; however, the asteroid mission will increase the capability of Orion and the subsequent Mars surface module. He noted work in progress on long-term propulsion systems that would reach Mars. Mars was the goal; the asteroid mission was a contribution. The development of a propulsion system that can reach an asteroid will demonstrate important capabilities. He noted that robotic technology might be developed for satellite repair. There were many approaches to capturing an Asteroid of 10 meter diameter; these would require considerable study. Risk, he stressed, is something the Agency will have to learn to accept.

Dr. Squyres said many believed the goal of the asteroid mission was to send a human crew into deep space. Mr. Bolden commented that President Obama's speech on April 15, 2010, made no mention of Orion. The President's proposal, rejected by Congress, was that NASA focus on developing propulsion techniques, that is, NASA should get out of the rocket business and focus on the technology business. Ares, he said, was a very different and potentially very good rocket, but it was not within budget guidelines. Mr. Bolden said he had made three promises regarding a human mission: that it be realistic, affordable, and sustainable. Two years ago, the consensus was that commercial cargo was affordable, but not realistic or sustainable. Now, it is. Mr. Bolden said that if the \$822 million in the President's budget was passed, NASA would have the money to get an American crew to the ISS. Whether a redundant carrier will be built is uncertain. The President has twice asked for one billion dollars; Congress twice rejected that figure. Mr. Bolden noted that the Augustine Committee had emphasized the need to be aware of flexible paths, and the asteroid mission offered a flexible path to Mars. Dr. Charles F. Kennel urged articulating the connection between the asteroid mission and the ultimate goal of sending humans to Mars. If, he noted, NASA decided to head directly for Mars, there would be nothing for the public to see for 15 years. Beyond saying how the asteroid mission ties to Mars, one has to show that the asteroid mission has value in and of itself.

Dr. Squyres said this NAC meeting could go beyond making recommendations and give the Agency advice on how to articulate the importance of the asteroid program. Mr. Bolden said he would be meeting with NASA internal "murder boards" in preparation for upcoming Congressional testimony. These preparatory sessions, he said, were very useful in raising topics otherwise overlooked. He added that the Congressional committees had pummeled NASA on planetary defense and its programs; this, he noted, was an entirely new mission for NASA with new questions to address. He noted that going to Capitol Hill provided a rare opportunity to engage in the public forum about what NASA does. He noted that after appearing at a hearing, he received more comments from members of his own church who had seen CSPAN. He noted that his job was not just to follow instructions; his job was to be the President's principal advisor on exploration in space. He noted that President Obama had talked to third graders at the recent White House science fair; the President had wanted these children to receive the same level of recognition as the University of Alabama football team.

Mr. Michael Montelongo asked why it would not be possible for Mr. Bolden to appear on shows like “Oprah.” In addition to technical responsibility, he said Mr. Bolden had a personal narrative that can inspire young people. He believed someone like Oprah Winfrey would find him personally appealing and he could use that as a platform to bring in information about NASA. Mr. Bolden said this was not out of the realm of possibility. The difficulty was that one has to be welcomed by the organization with which one might wish to work. He noted the influence Canadian astronaut Chris Hadfield had on Canadian television with his ISS demonstrations such as how to wring out a washcloth in space and his many other activities to engage the public and especially young people.

Aeronautics Committee Report

Dr. Squyres introduced Ms. Marion C. Blakey, Chair of the Aeronautics Committee, who presented its report.

Ms. Blakey identified the Committee membership and noted it contained “a wonderful mix of people and backgrounds.” She presented the CY 2012 work plan, noting that it included a review of the revised Aeronautics Research Mission Directorate (ARMD) rotorcraft portfolio, including its relevance to industry; review of the activities of the Unmanned Aircraft Systems (UAS) Subcommittee and other activities. She reported that topics explored at the group’s February 28-March 1, 2013, session included budget; ARMD strategic planning; the future direction of the Integrated Research Systems Program (ISRP); NRC autonomy study planning and Unmanned Aircraft Systems Subcommittee briefing. She noted that ARMD had “received justifiable kudos.”

Ms. Blakey then presented the Committee’s strategic trend analysis. She noted that both China and India were expanding their Gross National Product (GNP) at rates double or triple that of the U.S. and Japan. In consequence, the Asia-Pacific region will in time have the numerically largest middle class, the most common aviation users. The Committee expected the number of air travelers would increase by 360 million by 2030. As a comparison, Ms. Blakey said, this was equivalent to adding “seven Chicago’s” to the world’s traveling population every year. She noted the accelerated pace for adoption of new technologies: for example, while it took 46 years [1873-1919] for twenty-five percent of the U.S. population to become users of electricity, only seven years [1984-1991] passed between the creation of the World Wide Web and a similar adoption rate.

Ms. Blakey then reported on the mega-drivers affecting the industry; these included growth and climate change. She noted that the Agency had aggressively addressed its carbon impact, but must continue to do so. This was both a climate and cost issue, she observed, as fuel costs have tripled since 1975. The final mega-driver she cited was the continuing revolution in automation and communications technology that may enable safety-critical autonomous systems. Ms. Blakey then discussed the ARMD Strategic Implementation Plan. This, she said, was distributed among four programs and eleven research projects. The plan lays out in considerable detail how things are progressing. She described it as a “dynamic document” – during first quarter 2014 it will be dovetailed with what emerges then. Ms. Blakey identified six strategic research & technology thrusts; these being safe, efficient growth in global operations; innovation in commercial supersonic aircraft; ultra-efficient commercial transports; transition to low-carbon propulsion; real-time system-wide safety assurance, and assured autonomy for aviation transformation. One practical question, she said, was how low did sonic boom volume have to be before it could be judged as without imposition? Ms. Blakey then presented the following Aeronautics Committee Finding:

The Committee endorses the approach that NASA ARMD is taking to establish a strategic direction to inform future research portfolio decisions. The Committee feels that the underlying process of utilizing strategic trends analysis, systems and portfolio analysis, and community/stakeholder engagement will enable ARMD to respond more effectively to new needs and new approaches to plan future research. The Committee notes that ARMD has made significant progress in an area which the Committee had commented on in a previous observation (regarding the use of systems analyses and trade studies to inform prioritization and advocacy of ARMD research – August 2011). The Committee looks forward to engaging with ARMD as their efforts mature and helping to inform the plan.

Dr. Squyres said he regarded this finding as a well-earned pat on the back. Dr. Squyres asked how ARMD strategic plans dovetailed with SARB (Surface and Atmospheric Radiation Budget). Ms. Blakey said there was strong interface between the plans; a roundtable existed that involved both groups and joint taskings were made. Dr. Mountain commented on how difficult it was to get traction with Congress. Was there an aspect of this work that communicated with a broader constituency? Blakey noted that she was not part of the presentations. She thought the submissions and oral testimonies made were well organized to show a strong technological undergirding existed.

She believed that ARMD had been quite successful in suggesting to the Office of Management and Budget [OMB] that it should be funded to act in additional areas.

Dr. Squyres asked if any Council member had issues with the Finding. Dr. Kennel said the wording could be made somewhat stronger. Ms. Blakey said she would undertake to do so following the meeting. Dr. Squyres noted there was no substantial objection to the Finding.

Ms. Blakey then presented slides on the ISRP goal. She noted, relative to autonomy research, that a workshop had been held in February to conduct a gap analysis; to determine the direction in which research should be directed and to identify what was not being addressed. The April meeting had addressed the question of when cockpit autonomy had reached the point where two pilots were no longer required.

Ms. Blakey then presented the roadmap for UAS, identifying six meetings, with those in May and July 2013 making further recommendations prior to the ending of the group's charter. Work will segue into the unmanned work NASA is doing. She noted that the UAS Subcommittee members constituted a good cross-section. She noted that the group's most recent meeting, in February 2013, had focused on the relationship between NASA Project and FAA UAS aviation rulemaking; on the role of systems engineering in designing and informing Project Task Elements; and on UAS Systems Analysis Work.

Ms. Blakey then presented the Recommendation of the Aeronautics Committee (final version):

The NASA UAS in the NAS Project plans as part of their Phase II a variety of flight tests to validate concepts developed as part of their research. The Committee recommends that in addition to these flight tests, one or more "capstone" demonstrations be incorporated into the program plan. These "graduation exercises" should serve to pull together and focus multiple research threads, and provide a compelling test or demonstration that the program's various stakeholders will find compelling and convincing. The Committee encourages NASA to continue working with the UAS Subcommittee in the development of such a capstone demonstration.

Ms. Blakey commented that she believed the "capstone" demonstrations would find their way onto the master schedule. The Committee had not discussed the budget limits. Dr. Squyres invited questions from the Council. Ms. Smith asked whether the already planned flights #1 and #2 could be turned into capstone efforts. Ms. Blakey said this may be possible. If the Council thought this desirable, the matter could be returned to the subcommittee for further review.

Dr. Squyres noted that NAC Recommendations needed to be actionable. Would the wording here be clear to the intended audience? Ms. Blakey said she believed so; the Aeronautics Committee included many engineers. Dr. Squyres said he would like to see a more detailed definition of what is to be achieved. Ms. Blakey said additional language could be created. Dr. Kennel suggested sending the recommendation back down to the subcommittee for further elaboration of what the capstone might be. Ms. Blakely said that if the Council agreed the outcome was desirable, then new wording could be completed.

Ms. Blakey then described the approach used to create three UAS "flight data sets." It depended, she said, on how one counts aircraft. Clearly, there would be a very substantial increase in UAS use, with law enforcement surveillance thus far the biggest source of demand. She noted that during FY 2012, the Joint Planning and Development Office (JPDO) UAS Coordination Team had completed four specific business case scenarios, which should be regarded as preliminary until vetted by the larger community. She noted that much of public debate on UAS looked to privacy issues because so much use was going to be law enforcement. She noted there would be tremendous growth in this area, in part because UASs would substitute for other aircraft.

Ms. Blakey presented the Aeronautics Committee's next Finding (final version):

The Committee would like to commend the UAS Systems Analysis work that NASA is supporting through the Joint Program and Development Office (JPDO). The business analysis and future flight data modeling is highly necessary work and of great benefit to the community. While the analysis is preliminary, it is a good starting point and clearly illustrates UAS will have a significant impact on the national airspace system as indicated by the graph below. The Committee strongly encourages NASA and the UAS Project to continue supporting and expanding this

important effort throughout the next Phase which starts in October 2013. This work should also be fed back directly into project planning efforts, to focus and enlighten the planning of the next phase research elements.

Dr. Squyres invited comments. He characterized the Finding as “another pat on the back.” Dr. Mountain noted that the Finding contained many acronyms; were definitions needed? Dr. Squyres said that as the Finding was directed toward the Agency, he saw no problem with the wording. Dr. Kennel observed the estimates for potential markets were largely assembled by engineers for particular users. How might economists become involved? He believed the business case should be reviewed by a broader group, as there were many more applications. Ms. Blakey said it was somewhat like cell phone “apps.” No one dreamed four or five years ago of what would be possible today. Dr. Squyres said it was hard to predict future uses; he knew people at Cornell University who used UASs to do unobtrusive observation of elephants. Ms. Smith asked if Phase II should be defined. Ms. Blakey said she did not as yet know. Reference could be to “the next phase” rather than to the more specific-sound “Phase II.”

Information Technology Infrastructure Committee Report

Dr. Steven Squyres, Chair, introduced Dr. Charles P. Holmes, Vice Chair of the NAC Information Technology Infrastructure Committee, to report on that Committee’s activities in the absence of committee chair, Dr. Larry Smarr.

Dr. Holmes noted that the Committee’s March 2013 meeting had been cancelled. Its membership consisted of ex-government officials and university-based individuals, with deep expertise in supercomputers and the bandwidth capabilities required. He noted that the group had discussed continuing projects, visiting the Goddard Space Flight Center (GSFC) and the Marshall Space Flight Center (MSFC). As a common thread, more could be accomplished through better connectivity. This, he said, had led to group’s recommendation #2 of March 2012:

NASA should formally review the existing national data cyberinfrastructure supporting access to data repositories for NASA SMD missions. A comparison with best-of-breed practices within NASA and at other Federal agencies should be made.

We request a briefing on this review to a joint meeting of the NAC IT Infrastructure, Science, and Education Committees within one year of this recommendation. The briefing should contain recommendations for a NASA data-intensive cyberinfrastructure to support science discovery by both mission teams, remote researchers, and for education and public outreach appropriate to the growth driven by current and future Science Mission Directorate [SMD] missions.

Dr. Holmes said this recommendation had prompted an urging to talk with the various Science Subcommittees. Dr. Smarr believed an opportunity existed to improve the existing infrastructure. Dr. Holmes noted that SMD data resided in highly distributed servers; partnering opportunities with the Department of Energy (DOE) were important. Dr. Holmes noted NASA’S increased use of supercomputers. He presented, first, a map of the National-Scale 100Gbps Network Backbone and, second, a chart showing SMD’s rapid growth as a High Performance Computing (HPC) user. Dr. Holmes added that the Science Subcommittees (Heliophysics; Astrophysics; Planetary Science and Earth Science) had been briefed on this material; the information had been well received and feedback obtained. Dr. Holmes felt the next step was to schedule meetings between the SMD Associate Administrator and the heads of the ITIC Committee, the Science Committee and the Education and Public Outreach Committee. He hoped these could occur prior to the scheduled July 2013 session of the NAC.

Dr. Squyres said this topic had been under discussion for some while. He believed the Committee had done its requested “homework.” He requested Ms. Rausch, NAC Executive Secretary, to determine the time and place of the recommended meetings. Ms. Marion Blakey asked what outcome was hoped for. Dr. Holmes said he thought it was far easier to protect existing infrastructure than to gain approval and funding for additional infrastructure. He believed the group would firmly recommend expanded infrastructure.

Dr. Huntress reported he had detailed responses in hand from three of the five Science Subcommittees. The subcommittees were happy with the systems that they have; their urging was that recommendations made not disrupt continuing operations. Dr. Kennel said that the steps in discussion would, when finished, be of great value to NASA science activities; perhaps the NAC could be briefed later in the year. He noted the data was not solely of interest to NASA. For example, NASA work in Earth Science required a mechanism for connecting to other data sources. The

same was true of Astrophysics, through increasing input from on-ground sites. He urged the Committee to think broadly in terms of what data NASA required to do its work.

Dr. Squyres then adjourned the session for lunch.

NASA FY 2014 Budget Request

After lunch, the session reconvened. Dr. Squyres introduced Dr. Elizabeth Robinson, NASA Chief Financial Officer (CFO), who presented the Agency Budget Request for FY 2014. Dr. Robinson said she preferred speaking first of benefits: NASA, she said, was advancing U.S. space leadership; was improving life on earth as well as planetary protection; and was helping to strengthen the U.S. economy through investments in science and technology. She then presented a series of highlights.

The proposed budget ensured the U.S. would remain the world leader in space exploration and scientific discovery; it invested in American ingenuity and innovation and supported development of the Space Launch System (SLS) and the Orion crew vehicle for deep space exploration. Dr. Robinson noted that NASA would undertake 400 experiments in the coming year. She noted investments in crucial and cutting edge technologies, which provided spinoffs to American industry. She noted partnership efforts with the Federal Aviation Administration (FAA) and others to improve aeronautics operation, efficiency and safety.

Dr. Robinson noted NASA funding of crucial Earth Science work. She cited three new things: the takeover of funding for several National Oceanographic and Atmospheric Administration (NOAA) instruments; work with NOAA on the joint polar satellite system; and takeover of JPSS funding. Dr. Robinson reported that with the Department of the Interior (DOI) NASA had flown the continuity mission that will become Landsat 8. Landsat 9 will be part of NASA's budget; the next year will be spent working with DOI, which owns the Landsat requirements. Dr. Robinson noted in 2014 many construction aspects of JWST would come together. MAVEN was scheduled to launch at the end of 2014; work continued on the 2020 Mars Rover.

Dr. Robinson cited "two biggest changes." The first was the Asteroid Initiative, for which \$105 million was available. Of this, \$27 million was for examining ways of mitigating hazards and \$78 million for the mission itself. She viewed the Asteroid Initiative as a very exciting response to the challenge issued by President Obama in April 2010. The second "big change" was that President's proposal to streamline and consolidate the 13 agencies that participate in Science, Technology, Engineering and Mathematics (STEM). Funding would be consolidated into three main areas with three different lead agencies: K - 12 education (Department of Education); college to post-doctoral level (NSF); informal education (Smithsonian). She estimated that \$50 million would be transferred from NASA to these agencies.

Dr. Robinson then presented the NASA FY 2014 Budget Request. She said the budget was built to the pre-sequester levels. If Congress puts the Agency into a Continuing Resolution (CR) and sequestration was enacted in October 2013, the Agency FY 2014 budget would drop to \$16.1 billion, compared to its current \$16.9 billion. That would constitute, she said, a "quantum jump." The numbers she was presenting had been formulated without these steps occurring.

Dr. Robinson noted the current campaign to promote efficient and effective spending. Several years ago, NASA had been challenged to achieve non-mission operating efficiencies of \$100 million annually. This had been achieved in FY 2012. Those savings had been raised to \$200 million for the current year, and each year thereafter. She noted that personnel were being shifted to achieve economies and rehiring reduced. Dr. Robinson said budget comparisons with FY 2013 were difficult because the Agency had closed its database prior to the impact of sequester. Final numbers would not be available until late May 2013.

Dr. Robinson then presented specifics of the NASA FY 2014 Budget Request. She noted that the year 2013 had been an anomaly, with very few launches. In 2014, many launches were scheduled. Earth Science would launch the Orbiting Carbon Observatory (OCO)-2; the Global Precipitation Mission (GPM); and the Stratospheric Aerosol and Gas Experiment III (SAGE III). Planetary Science had been operating an asteroid-mapping program for five years; its budget would be increased to \$40 million, partly to look for small asteroid targets. She noted that data previously analyzed for larger asteroids could always be reviewed for smaller ones. Additionally, the Earth Science budget funds the 2014 launch of MAVEN, the 2020 launch of the robotic Mars science rover, and funds a partnership with

DOE to produce Plutonium-238 (Pu238) as an energy source for longer missions. She noted that the Pu238 in the world was being consumed; more would be needed for missions in a decade. The Administration's position was that the Pu238 should be paid for by its users; at present, NASA was the only such user, which meant a cost to the Agency of \$50 million annually.

In Astrophysics, Dr. Robinson reported that all operating missions were supported, including Explorer missions, demonstration of Stratospheric Observatory for Infrared Astronomy (SOFIA) capabilities, and confirmation of Kepler exoplanet candidates, and balloon flights. In Heliophysics, work continued toward a June 2013 launch of the Interface Region Imaging Spectrograph (IRIS) and toward a 2015 launch of the Magnetospheric Multi-Scale (MMS) mission.

Dr. Robinson then summarized joint agency satellite programs, where SMD managed satellite development for other U.S. Government agencies on a fully reimbursable basis. Continuing developments for FY2014 included the Joint Polar Satellite System (JPSS), the Geostationary Operation Environmental Satellite-R (GOES-R series), Jason-3, and the Deep Space Climate Observatory (DSCOVR). For the Aeronautics Research Mission Directorate, Dr. Robinson said the budget allowed stable fundamental research that has been funded for some while, along with work on NextGen. Additionally, an effort will be made to speed development of composite materials.

On Space Technology, Dr. Robinson called attention to Asteroid Initiative. The goal of the initiative, she said, was simple: find the target, get the target, put astronauts on it. She noted that the human rendezvous with the asteroid was targeted for 2025. She noted that Exploration Research and Development in HEOMD had begun planning and early development for the asteroid capture mission. She also noted considerable work was being done at Kennedy Space Center (KSC) to ready Launch Complex 39 for the planned 2017 launching of astronauts in U.S. vehicles.

Dr. Robinson noted that commercial crew was a project that had a project profile reaching its peak requirements of the \$821 million budgeted for FY 2014. She noted that the program would reduce NASA's dependence on the Russians for astronaut transportation to and from the ISS. Mr. Kohrs asked if the commercial cargo program was completed. Dr. Robinson said it was; all money was now for commercial crew. Dr. Robinson reported that Exploration Research and Development would increase investment in asteroid capture and redirection activities and would direct activities to ways astronauts could remain in space for a year or more.

Regarding ISS, Dr. Robinson noted that the \$3 billion budget divided about equally between operations and maintenance, and crew and cargo. The intention was to maintain a continuous international crew of six aboard ISS. On Space and Flight Support, Dr. Robinson called attention to the continued modernization efforts for the 21st Century Space Launch Complex.

Dr. Holmes commented that, generally, NASA was asking people to do more with the same amount of money. Dr. Robinson said this was "more or less" the case, though there were some incidental budget increases. Mr. Kohrs asked if the Plum Brook Station at the Glenn Research Center in Ohio was still viable. Dr. Robinson said it was overall, but was unevenly used. She noted that European Space Agency (ESA) would be using one Plum Brook facility for several years, on a reimbursable basis.

Mr. Perkins said the Education budget reduction sent a very serious message to how NASA would educate the next generation. He understood the desire to coordinate STEM activities around the Agency; however, NASA did many center-based activities. The initiative represented a 90-degree turn. Money spent at the NASA center level would drop by two-thirds, unless the center-based programs competed successfully for other funds. Further, what would happen to NASA's Education staff? Dr. Robinson responded that these transition plans were still being made, e.g. NASA has a number of curriculum writers; the Department of Education needs more curriculum writers. Mr. Perkins asked, "Will they just hire those people let go from NASA?" Dr. Robinson responded "no". Mr. Perkins asked "Will some NASA people successfully compete for positions?" Dr. Robinson responded, "Probably, but not all."

Dr. Kennel noted that Earth Science received \$2 billion from National Oceanic and Atmospheric Administration (NOAA) and National Geodetic Survey (NGS). What impact might sequester have on these figures? Dr. Robinson said funding was "pretty concrete"; these were long-term programs and had reached maximum funding levels. The same was true of the JASON mission. Matters were less certain with DOD programs. These operated separately from 25 to 30 different locations and it was not yet known what each would do.

Mr. Perkins asked about the apparent 50 percent increase in Education in Space Technology. Dr. Robinson responded that these were for fellows who came to NASA to work on NASA projects; it was considered staffing rather than an educational program and currently involved 80 individuals.

Ms. Blakey asked, relative to JPSS, who ended up with the funding. Ms. Robinson said many proposals about shifting funds existed. The entire JPSS budget was about \$1 billion. Between \$600 million and \$800 million comes to NASA to build the actual instruments and satellites. She noted that the governance structure of JASON and other undertakings varied; she would emphasize the need to simplify the collaboration. Bigger issues existed, including transferring the entire program to NASA. The Administration did not currently support this. Ms. Blakey asked if JPSS was being "held harmless?" Dr. Robinson said that, in effect, it was.

Dr. Mountain asked if the EPO cuts would eliminate the programs that sent down pictures from the Hubble Space Telescope (HST). Dr. Robinson said that it would, unless the Hubble program successfully competed for funds. Ms. Blakey asked to what degree the emphasis was on saving money and to what degree on streamlining and efficiency. Ms. Robinson said there was no difference between the two.

Dr. Squyres noted that in regards to Pu-238, NASA was picking up "the full tab" as sole customer. Was NASA going to take any role in managing production? If so, what? If not, how could NASA be assured of receiving what it needed? Dr. Robinson said various discussions were taking place with DOE; OMB in particular had promised to convene sessions with DOE. She noted that OMB was concerned with the overall direction of the Pu-238 program; it did not believe former users are "gone for good." This led to a question: should the Pu-238 program be organized so as to maintain capabilities that would be needed in the event other users resurfaced? Dr. Squyres asked if NASA would have a management role. Dr. Robinson said NASA will have approval of the planning and investments; DOE would execute the contracts. This is because DOE has the appropriate authorization where nuclear material is concerned.

NASA Plans for Future Human Spaceflight

Dr. Squyres, Chair, said the Council had for some time believed NASA needed a target, a destination. The Asteroid Initiative might fulfill this need. Dr. Squyres then introduced Mr. Bill Gerstenmaier, Associate Administrator for NASA's Human Exploration and Operations Missions Directorate (HEOMD).

Mr. Gerstenmaier began by highlighting the Orion accomplishments; showing photos of the completed heat shield; the inert abort motor; the launch abort system panel; the backshell panel drilling; the service module assembly and the Super Guppy that carried the Orion heat shield to Boston's Hanscom Air Force Base. He said it was well worth a trip to Kennedy Space Center to see the progress. Dr. Squyres said the NAC's December 2013 meeting would likely be held at that site.

Mr. Gerstenmaier summarized the Space Launch System [SLS] accomplishments. Equipment was being assembled to manufacture the core pieces. This task will likely be completed by the end of 2013; actual equipment production will begin in 2014. NASA's Stennis Space Center (SSC) would begin testing in December 2016, when the four Shuttle engines would be combined to ensure they worked correctly. Mr. Gerstenmaier reported that Ground Systems Development Organization (GSDO) was undertaking considerable work at the Launch Pad 39. While this "was not glorious work, it was work that needs to be done."

Mr. Gerstenmaier showed footage of the Antares A-1 Launch, held Sunday, April 21, 2013. The Cygnus preparation for fuel will be ready to be mated to the Antares system in several weeks. He noted that considerable time had passed between the test and SpaceX, which therefore would have more hardware ready to fly. The demonstration flight was set for July 2013. He presented a chart of the Commercial Crew Program (CCP), noting it was in the certification requirements phase. This included sharing specifications with private contractors and responding to any concerns they may have. He believed the central requirement of a good program was to have well designed specifications.

Regarding the ISS, Mr. Gerstenmaier expressed pleasure at the substantial increase in the utilization rates; the highest number of research hours ever was being achieved. Expansion from two to four ground links was permitting dual operations. He said 140 separate areas of investigation were in progress; 82 were NASA activities; 58 were from other nations. He noted that the first results were being obtained from the Alpha Magnetic Spectrometer

(AMS). The data – which involved 11 billion separate data points – may provide the first detection of dark matter. Further reports were expected this summer.

Mr. Gerstenmaier introduced the Asteroid Strategy with humorous film clip from the “Colbert Report,” in which Stephen Colbert reported that NASA would be “lassoing” an asteroid as, due to budget cuts, rope was the most expensive thing it could still afford. More seriously, Mr. Gerstenmaier stressed that the Asteroid Strategy aligned important aspects of NASA science, space technology, human exploration capabilities, advanced technology development, planetary protection and industrial capability and partnerships. He identified four key leverages with existing NASA efforts: asteroid identification and characterization efforts for target selection; solar electric propulsion for transport to and return of the target asteroid; robotic servicing techniques for capture; SLS and MPCV missions for asteroid rendezvous.

Mr. Gerstenmaier identified three benefits the Asteroid Strategy offered to future deep space endeavors: deep space navigation and rendezvous enabling crewed operations; high power solar electric propulsion that will enable efficient transportation; in-space robotics for capture/control of uncooperative objects

Mr. Gerstenmaier said NASA would not “drag back” an asteroid; instead, it would move the asteroid so that Earth and lunar gravity drew it into permanent lunar orbit. Dr. Squyres asked if Orion had EVA capability for support as needed. Mr. Gerstenmaier said it did. Mr. Gerstenmaier said no single target had yet been identified, though many were potentially available. What was required was an asteroid with the low spin rate and low mass that would come naturally close to the required orbit. The plan, he added, was to build the spacecraft without knowing the target, but knowing the type of target that was being sought. Mr. Gerstenmaier said the general concept was to capture and redirect a near-Earth asteroid that was seven to ten meters in diameter [about 500 tons] and bring it to a stable orbit. Astronaut missions could begin by 2021. He presented a slide showing the trajectory of the asteroid and of its retrieval. He noted remaining questions, including: how tightly does the spacecraft have to tie to the asteroid? What is the highest spin rate that can be accommodated? He said a whole series of bonding criteria were being considered.

Mr. Gerstenmaier presented a graphic of the Earth-Moon system trajectory. He noted that 12 metric tons of xenon would be needed; acquisition needed to start soon to acquire a sufficient quantity. He reported that the exact thruster design had not been chosen. The technology involved required an effort the Agency would need to undertake sooner or later. The asteroid’s closest approach to the Moon would be 9,300 kilometers, with the object remaining in stable spiral orbit for perhaps 100 years, thus allowing repeated visits. He said asteroid “capture” would take 257 days; delivery to stable orbit would take 251 days.

Mr. Gerstenmaier then presented a chart of the 22-day nominal asteroid retrieval mission. It would be an Orion-based undertaking with perhaps five days of proximity at the object. The natural abort cycle had to be determined. The whole project meant “good learning” for the Agency and would develop techniques of used in the future. Mr. Gerstenmaier then presented a chart on asteroid mission capabilities that would support long-term Mars strategy. These, he noted, included a variety of deep space mission core competencies and would demonstrate the ability to work and interact with a small planetary body. The asteroid mission did not preclude an additional lunar mission, but would move NASA lunar activity outside its existing range.

Mr. Gerstenmaier identified six key principles for building capabilities incrementally: execute with current budget with modest increases; apply high Technology Readiness Level (TRL) technologies for near term, while focusing on technologies to address challenges of future missions; near-term mission opportunities with a defined cadence of compelling missions providing for an incremental buildup of capabilities for more complex missions over time; opportunities for U.S. commercial business to further enhance the experience of the business base; multi-use space infrastructure; and significant international participation

Summarizing, Mr. Gerstenmaier said the Agency needed a sustainable program that moved NASA forward, builds its capabilities, and builds its science base. His final comment was that he thought this was a good project; the short-term budget was tight but workable, and the effort will take the Agency a long way toward its goal of a manned mission to Mars. Mr. Kohrs asked the identity of the next milestone. Mr. Gerstenmaier said the next step was a more refined plan to be completed this summer. This would entail making decision on electric propulsion, identifying international involvement and other steps. Mr. Kohrs asked if “the troops” were excited. Mr.

Gerstenmaier said they were. He noted that new things have the capability of bringing the agency together. The sharing between centers had been excellent.

Mr. Montelongo asked how the program stood on Capitol Hill. Mr. Gerstenmaier said two Appropriations and two Authorization Committees had been addressed. Initially, there had been some skepticism. This skepticism largely passed as many saw the asteroid mission as a way of reducing the risk for other things.

Dr. Kennel noted that one reason for the “uptick” in ISS utilization was the decision to prolong ISS life. Had this been discussed with international partners? Mr. Gerstenmaier said conversations with international partners needed to begin this summer. With the research horizon extended beyond 2020, the commercial market for crew and supplies would also benefit. He noted that some international interest already existed, particularly among the Canadians and the Japanese. At present, he said, the Russians are more lunar focused robotically. They do see this capability to learn to operate in deep space as a critical learning.

Ms. Blakey asked where industry entered the picture when resource-bearing asteroids became involved. Mr. Gerstenmaier said that discussion still needed to happen; the mission at hand would not be targeting an asteroid from a resource perspective. Dr. Charles F. Kennel asked: who will own the asteroid? Mr. Gerstenmaier said he was repositioning the asteroid, not taking ownership of it. Dr. Mountain asked if a mapping existed that showed how the technology needed for the asteroid mission related to going to Mars. Mr. Gerstenmaier said work on that was beginning.

Dr. Squyres noted that Mr. Gerstenmaier had said the NAC could aid the mission by being its advocate. He had been impressed by some things Mr. Gerstenmaier had not said, e.g. that this was a better way to explore asteroids or to provide planetary defense. Instead, the mission had been presented on its individual parts, including the search for near-earth objects and learning how to work with humans in space. He thought the presentation was a model. Even though Mr. Gerstenmaier had not come in “selling mode,” he had sold the undertaking. Dr. Huntress said he wholeheartedly agreed. He suggested using as the first sentence: “Here is our next step on the way to Mars.”

Human Exploration and Operations Committee Report

Dr. Steven Squyres, Chair, introduced Mr. Richard Kohrs, who as chair of the NAC Human Exploration and Operations Committee presented on its recent activities. Mr. Kohrs noted that two non-FACA meetings had been held; the session with Mr. Bill Gerstenmaier was similar to his presentation to the NAC.

Mr. Kohrs presented the ESD summary schedule: major items were the SLS, Orion and the ground systems development. He noted that a major milestone was the Exploration Flight Test (EFT)-1, which uses a Delta IV heavy launch and Delta IV upper stage, to be launched in late 2014. Mr. Kohrs then discussed the ESD organization, calling attention to Cross-Program System Integration (CSI). The organization had been built out of civil servants at KSC; MSFC, and JSC, working collaboratively through monthly teleconferences. Of the CSI, he said, Systems Engineering, headed by Paul McConnaughey, was “the meat.” He said the group had spent three hours looking at schedule and products; persons initially critical came out of the session fairly positive.

Next, Mr. Kohrs presented a graphic of the Exploration Systems Development, beginning with the September 2014 Test Article, Orion MPCV commercial launch vehicle and continuing through the August 2023 Crewed Orion MPCV SLS, with competed boosters. Mr. Kohrs then addressed the Orion Service Model/ESA Partnership. Until now, he said, the Service Model (SM) was built by Lockheed and managed for JSC by Glenn Research Center. He reported through the intercession of Mr. Bill Gerstenmaier, they would build the SM rather than the HTV-5. Dr. Squyres asked if the SM carried its own avionics. Mr. Kohrs responded it would not.

Mr. Kohrs reported that the Crew Module (CM) and the SM would interface via a ring called the Crew Module Adapter (CMA). NASA would supply the CM; CMA; spacecraft adapter; separation mechanism (SM); jettisonable fairings, and the Launch Abort System. ESA would be responsible for the SM, consisting of the load bearing primary structure; gas and water consumable storage tanks; two coolant loop 24 m² radiators; four solar arrays and the propulsion system.

Mr. Kohrs then talked about the Center for the Advancement of Science in Space (CASIS) and the National Space Biomedical Research Institute (NSBRI). Mr. Kohrs then presented information on NASA’s Space Life and

Physical Science Research and Application Division (SLPS), which was undertaking high quality research in space biology, physical sciences and human research. He reported that CASIS had been selected to manage the ISS National Laboratory, with the tasks of identifying unique ISS capabilities, prioritizing the most promising research and increasing the utilization of ISS.

Mr. Kohrs then presented a “very dense” chart showing events on ISS. Currently, six crew members were on board; that number would be maintained for a long period. He noted the chart’s upper line that described the resupply schedule – including the previous Sunday’s Orbital launch – and the lower line showing crew participation. He reported the Russians were undertaking a series of EVAs to prepare their modules to accept docking from other modules. Mr. Kohrs then presented a chart showing ISS Utilization during Increment 35-36; the total USOS average was 40.71 work hours per week. Mr. Kohrs then addressed the total ISS consumables status: while food was scheduled to run out on September 28, 2013, resupply would be launched on April 26, 2013. Dr. Mountain said the supply issue underscored why getting to Mars would be very difficult. Mr. Kohrs said it demonstrated the importance of water reclamation.

Mr. Kohrs then identified the major USUS system enhancements. These included the ELC wireless system to provide a Commercial off the Shelf (COTS) solution for external high data rate. Among other things, this would allow converting the DC power generated by the ISS solar panels into AC power, which would simplify and reduce the schedule and cost of hardware used on ISS, thereby providing researchers with important added flexibility.

Mr. Kohrs reported that the SpaceX-2 mission (launched March 1, 2013; reaching ISS March 3, 2013) had been completely successful. The mission had delivered 577 kg of pressurized launch cargo; 221 kg of unpressurized external cargo; and had returned 1235 kg of pressurized cargo. Mr. Kohrs noted that the 7K Hot Fire Test had been successfully completed on February 22. He gave a status report on the ATV-4 launch to the ISS, noting that various small difficulties had delayed the launch date until June 2013. He presented the cargo manifest for the ATV-4 launch scheduled to take place at Japan’s Tanegashima Space Center.

Mr. Kohrs then presented the ISS Program Focus. This included such tactical aspects as maintaining and increasing crew time and resources for utilization. Strategic aspects included maximizing utilization of ISS as a National Laboratory, proceeding on the crew transportation plan, and undertaking the needed technical analysis and planning to extend ISS life extension to 2028.

Mr. Kohrs then presented the first of two recommendations from his committee:

The Committee recommends that NASA elevate priority of the Commercial Crew development and vigorously protect its funding, and reduce the number of funded providers. These NASA actions are needed to avoid undesired growth in Commercial Crew development time and risky increased reliance on a single provider, Soyuz.

Dr. Steven Squyres sought the opinion of Ms. Patti Grace Smith, Chair, Commercial Space Committee. Ms. Smith noted that she had received the recommendation only two days previously; she had sought a quick turnaround from her committee. The committee did not favor the recommendation. The argument against the recommendation, she said, was based in part on the ELV experience and the nation’s need to have two launchers. The committee did not think this was feasible. Further, she said, NASA “went around and around” as to how to approach this matter. Her committee thought the Agency could decide whether to allocate the money and make one of the three current contenders the front runner. Mr. Kohrs said he did not disagree. He doubted the FY2014 budget as presented to the NAC would happen. This effort’s funding had been reduced almost 50 percent over last three years. He thought this would happen again. If, he added, NASA wanted U.S. crew transportation it would have to allocate the money. Dr. Squyres asked if the views of the two committees could be reconciled. Ms. Smith, he said, had presented a strong desire that funding for three contractors continue. Mr. Kohrs said the program was going to be cut and that reducing to two contractors was “a flat-out necessity.” Was it possible to say: NASA vigorously protects its funding; if for whatever reason it fails in that effort, it may be necessary for the Agency to reduce the number of funding contractors? Ms. Smith said that, as phrased, the statement assumed a budget cut, which was not a given. Dr. Squyres noted that many budget decisions would be made before the NAC next met. Dr. Mountain observed that if the sequester was not resolved, shortage of funds was a given. Dr. Squyres said that “reading between the lines,” there appeared to be a high chance that the \$821 million in President’s budget would prove infeasible. Dr. Huntress suggested waiting until July 2013 to see how the budget prospect resolved itself.

Ms. Blakey asked how much money was at issue here, compared to the charges from the Russians. Dr. Kennel said NASA was purchasing three "seats" a year at about \$60 million each. Personally, he urged tabling the recommendation to see what transpired on the budget. Mr. Michael Montelongo said the President's Budget, as submitted, included funds for three contractors. So long as that budget stood, the Agency should not assume a downselect. Should Congress make a different decision, an adjustment could be made then. Dr. Squyres said the recommendation was based on a "pessimistic but plausible" reading of the tea leaves. Once, he added, matters were better understood, it may be in the Agency's interest to downselect sooner rather than later. He believed it best to table the recommendation until the July 2013 NAC meeting.

Mr. Kohrs then presented his committee's second recommendation:

NASA should expand and actively advocate the strategy for NASA's asteroid mission to highlight multiple benefits to be gained. NASA should herald mission spin-offs that benefit humankind as well as achieve NASA goals, while furthering science and technology:

- *Benefits U.S. advanced science and technology by developing operations capabilities like propulsion, life sciences, human performance.*
- *Benefits NASA as a stepping stone to NASA's ultimate goal of a manned mission to Mars. Involves operations that apply to future missions, including ground and space operations, on-orbit rendezvous and capture, asteroid sampling, storage and analysis, and advanced propulsion.*
- *Benefits the United States by forging new industrial capabilities and partnership.*
- *Benefits humankind by advancing a defense strategy for Earth-bound asteroids.*

Dr. Wesley Huntress said this recommendation had the strong support of the Science Committee. He believed, however, that the final-named benefit was overstated. Mr. Kohrs recommended dropping the final benefit statement. Dr. Squyres noted that the NAC would be hearing from Dr. Huntress' committee. Considerable time was available in the following day's session for discussion. His personal wish was to craft this into the centerpiece recommendation from this body for this meeting. Mr. Lars Perkins commented that the Stephen Colbert segment had been humorous, but that was how the mission was being framed in the public eye.

It was suggested that this recommendation be re-worked by Dr. Squyres, Mr. Kohrs and Dr. Huntress and be re-presented to the Council. The final text of the recommendation approved by the Council is provided below.

NASA should clearly demonstrate and articulate a strategy for the agency's new asteroid initiative that highlights the benefits that will be gained, making progress toward NASA goals while furthering science and technology and benefiting mankind. The agency should clearly demonstrate how the initiative will serve as a stepping stone to NASA's ultimate goal of human mission to Mars. Potential benefits include involving operations that could apply to future missions, including life support and deep space habitability, advanced propulsion, complex ground and space operations, rendezvous in new gravitational environments, and sampling of small objects.

The agency should also demonstrate and articulate other potential benefits:

- *Benefit the United States by forging new industrial capabilities and international partnerships.*
- *Benefit humankind by advancing technologies and operations that might someday assist in the development of a defense strategy by Earth-bound asteroids.*

Science Committee Report

Dr. Steven Squyres, Chair, introduced Dr. Wesley Huntress, who as chair of the NAC Science Committee presented that body's report. He provided a list of the committee membership. Dr. Huntress then presented a Finding:

The agency's Asteroid Initiative is an innovative approach to a human spaceflight mission to an asteroid. It would develop capabilities required for human exploration to the Moon and beyond.

SMD can support this human spaceflight mission in several ways. First, by finding and characterizing asteroids in the size, mass, rotation rate, orbital characteristics and velocity range required for transfer to lunar orbit. This effort should search all space as well as near-Earth space to increase the rate of discovery of smaller asteroids.

Second, by providing expertise and advice on the space weather environment that astronauts may encounter beyond low Earth orbit. While not a science-driven mission, there may be an opportunity for doing some science.

There are some challenging technical requirements as well as schedule and cost issues that require further investigation. SMD should provide support to HEOMD and STMD in the 2013 summer feasibility study.

Dr. Huntress commented that he saw the proposal as a bold and risky mission; just the thing this Agency (NASA) should do. Dr. Squyres thought the middle of second paragraph (“This effort should...”) was burying an important point. He believed this was central to the effort. Ms. Smith noted that for 2013 the budget for asteroid-finding had been doubled; she urged the search be broadened. Dr. Squyres suggested that perhaps an enlarged asteroid-finding effort should be made as a separate recommendation. Dr. Kennel expressed agreement. One had to locate the mission asteroid before defining broader achievements. Dr. Squyres recalled the view of the Human Exploration and Operations Committee to sell the Asteroid Initiative on its constituent parts; he believed this finding strengthened the case. Dr. Mountain said one did not want to encourage creation of a stand-alone mission. Dr. Squyres asked if Dr. Huntress could create wording to avoid that. Dr. Huntress summarized recent science results.

First, both temperature and vegetation cover were experiencing decreased seasonal variation in the high northern latitude. Interestingly, winters were becoming warmer faster than summers. One could argue about causation, he said, but global weather change was clearly occurring.

Second, The NASA Van Allen probes mission had identified what proved to be a short-lived third radiation belt. The identification came soon after the August 30, 2012 launch; the radiation belt was present for about four weeks.

Third, Dr. Huntress said a comet might well impact Mars in October 2014; this was fortuitous as NASA would have in place the right instruments to measure its nature. He also noted the February 15 meteorite explosion in Chelyabinsk, Russia. That same day – though to considerably less public attention – an asteroid flew within the earth’s geosynchronous ring.

Fourth, Dr. Huntress characterized one of the most exciting discoveries in many years: namely, that at least one explored region of Mars had been habitable. Evidence was clear that below its immediate surface, Mars was gray rather than red. Once the oxidized surface was penetrated, clay was clearly present. Clays, he noted, are formed in neutral pH waters. Additional proof existed that energy had been available to create life. The Gale Crater was at one time habitable.

Fifth, Dr. Huntress discussed Mt. Sharp, a geographic target of the Curiosity mission. The mountain was “a layer cake” of deposits, with large clay concentration at its base. Prospects of what might be found were highly exciting. Mt. Sharp was approximately 5 km (17,000 feet) high.

Sixth, Dr. Huntress reported that Kepler had identified an increase in “planet candidates.” A significant number were “earth size and near earth size.” He noted that all observations were of planets that made a transit across the star in question. He called attention to Kepler-62, which had two planets in the habitable zone approximately the size of earth. He noted that the “sharpness” of a planet’s edge suggested the presence or absence of an atmosphere.

Dr. Huntress turned next to programmatic status. He described the Transiting Exoplanet Survey Satellite (TESS), which will undertake an all-sky survey, unlike Kepler, which looks in the same direction. Because the stars it views will be much closer than those recorded by Kepler, spectral information from the planets will be recorded. In response to a question, Dr. Huntress said launch date was 2017. Dr. Squyres asked if the focus would be on nearby stars. Dr. Mountain said nearly every red star would be recorded.

Dr. Huntress said JWST was doing very well. All mirrors and sunshade templates were built. Problems had occurred with wrinkling in the sunshade material, but these had been solved. Work on the focal plane problem was ahead of schedule. Matters were on track for the spacecraft Critical Design Review (CDR) later this year.

Dr. Huntress noted that the LANDSAT Data Continuity Mission (LDCM) Observatory had been successfully placed in orbit on February 11, 2013. Landsat 7 Underflight Validation had occurred at Sioux Falls on March 30, 2013. He noted that LDCM would on occasion underfly Landsat 7 to gather calibration data. He noted the August 2013 Lunar Atmosphere and Dust Environment Explorer (LADEE) launch would be Wallops first deep space launch.

Dr. Huntress then discussed the science budget request. Science accounts were flat, with one major exception. Planetary Science had received a \$300 million cut in the President's FY 2013 Budget Request; JWST and Earth Science were the beneficiaries. The sacrifice Planetary Science was making was not being returned in the 2016-2018 period, the time when the 2020 Mars Rover project was to be in development. Planetary Science was forced to take funds from its Medium and Discovery lines; Dr. Huntress viewed this as wrong. Dr. Huntress said his committee's recommendation in this area was the same as last year, except for the change in year:

The Council recommends that NASA seek restoration of funds in its FY15 budget proposal to recoup the damage to the Nation's robotic planetary exploration program in the FY14 budget proposal and to meet Congressional guidance in the FY13 passed budget.

Dr. Huntress said it was probable that only launches to Mars would be made in the future; the outer planets program would end. This, he said, was the largest budget cut he had seen in his 45 years in this field. As a "personal editorial," he said, he did not understand why Planetary Science was at the bottom of the barrel. The Mars program has probably the most scientifically fruitful and publicly supported thing the Agency is doing. Expertise will be lost; data flows will cease. Losses will not be limited to planetary activities.

Dr. Squyres invited comments. Dr. Kennel asked if NASA leadership was really at hazard. Dr. Huntress replied that NASA would surrender its monopoly on outer planet missions. In astrophysics, it would be unable to start its next mission, while the Europeans were already addressing dark energy. Dr. Kennel urged that the areas in which leadership would be lost should be identified. Dr. Holmes urged adding the National Academy priorities to the list. Mr. Kohrs noted that both the House and Senate had appropriated more money, but had been overruled. Dr. Kennel said he had emphasized to Congress that these cuts were so large they could not be recovered from. Dr. Mountain asked if the question of "why planetary science was being picked on" had been raised. Dr. Huntress said while one could pose the question, one could not get an answer. Dr. Kennel said none of the answers received were persuasive.

Dr. Squyres gave Dr. Huntress the "homework assignment" to add "meat" to the recommendation, specifically, what was being lost and what could be gained. He noted that matters were in the exact same situation as a year ago; the NAC needed to be more forthright. Dr. Mountain asked if NASA Administrator Bolden might feel he was being "end run." Dr. Squyres said that while tough times meant pain, in this instance the pain was disproportionately inflicted on one part of the Agency. Mr. Perkins suggested the NAC either say the \$223 million was required or that it did not believe science should bear the cost. Dr. Kennel said the "bottom line" was that a de facto policy had been made without serious consultation about the science consequences of the decision. Maintaining commitment to Planetary Science was essential.

Dr. Huntress presented his committee's Finding:

The NASA SMD Education and Public Outreach (EPO) Program has arguably caused the most inspirational and successful infusion of science into the public consciousness, from content from K-12 curriculum to public awareness of the Sun, Earth, solar system, and universe. Images from NASA's great observatories and results from other science missions appear in every current science textbook. Moreover, effective engagement of the scientific community has brought many Earth and space scientists directly into public outreach, and has sharpened the accuracy and quality of materials seen by the public.

The Science Committee therefore finds it shocking that this incredibly successful and low-cost EPO enterprise (1% of science mission budgets) will now be managed centrally by other entities, largely outside NASA. The Nation risks losing a critical tool for inspiring the future STEM workforce, as well as the extraordinary expertise NASA scientists bring to public education, and for informed public assessment of the NASA enterprise.

Mr. Perkins said he agreed with everything stated and had written an identical recommendation. In brief, he "wanted his \$100 million back in the NASA EPO program." The action being taken was an absolute decimation of the knowledge and skills that have been built up over decades. The program was wildly successful; to assume NASA would receive equal exposure from the Smithsonian was unrealistic. Dr. Squyres said he thought the EPO Finding should come from the full NAC. Dr. Huntress said he would undertake the appropriate wording. Ms. Blakey said the consolidation of the STEM programs seemed to be a fait accompli. Ms. Smith noted that, formally, the NAC advised the NASA Administrator. Was it appropriate to share the Council's thinking with Congressional committees? Dr. Squyres noted that while the NAC's charge was to advise NASA Administrator, all its actions

were public. To the extent that members had views, he could see no objection to them expressing those views. Dr. Kennel said the NAC's job was to advise NASA Administrator Bolden; and Mr. Bolden's job as to carry out the Administration's program. That was not to say that NAC members should refrain from expressing their views. He thought, however, that testifying as members of the Council was not appropriate. Ms. Smith said she thought Administrator Bolden would agree with the position advocated; however, as policy it may be above his rank. Ms. Blakey noted that the proposed actions put the NAC in opposition to the Administration's policy. Dr. Squyres commented that this would not be the first time such a thing had happened. The decision was to table Dr. Huntress' Recommendation until the Recommendation from Mr. Perkins had been heard.

Dr. Huntress presented the next Science Committee Finding:

The proposal selection rate for high quality proposals has fallen to levels sufficiently low to cause an unstable feedback loop where the Earth and space science community write much larger number of proposals, resulting in a significant non-productive burden on the community and NASA staff.

Dr. Huntress stated the level of grant support has been constant for years, losing buying power to inflation for over a decade. Funding levels were sufficiently low that the success rate is going down; in consequence, people write more proposals, which are a significant waste of time, including the time demands on reviewers. Dr. Kennel asked if a "critical phase" was being reached. Dr. Huntress said success rate had fallen below 20 percent; response time had lengthened, and a third response had been created: "You were selectable but we haven't got the money." He said he saw nothing that could be done except to be aware of the circumstance. Dr. Mountain said the success rate of applications at the National Science Foundation is now at a 10-12 percent rate.

Dr. Huntress presented the Science Committee's Finding #3:

Pu238 is vital to the future of NASA's planetary science program. There is a long, complex history of negotiations concerning its production. Rather than simply purchasing Pu238, the NASA Planetary Science Division has now been tasked with managing and funding DOE facilities involved in the production of this material. NASA is a customer for Pu238, however, it has no expertise in the management or engineering of its production. The Science Committee finds this an inappropriate, ineffective and highly risky method for inter-governmental mutual support.

Dr. Holmes noted that NASA was being asked to maintain a capability that was a national rather than NASA requirement. Mr. Perkins said he thought the Finding was "a recommendation in sheep's clothing." Dr. Squyres said the final sentence might be replaced with something that called attention to the potential pitfalls of this approach. Dr. Kennel said it was an issue of governance – put the program in the charge of the people who actually wanted it. That point, he said, was separate from the management of the project.

Dr. Steven Squyres, NAC Chair, adjourned the session of Wednesday, April 24, 2013 at 5:02 p.m.

Session of Thursday, April 25, 2013

The session of Thursday, April 25, 2013, was called to order at 9:00 a.m. by Ms. Diane Rausch, Executive Director, NASA Advisory Council. She welcomed all to the second day; reminding everyone that this was a FACA public meeting and that all comments will be on the record. Dr. Squyres, NAC Chair, said the morning session would focus on Committee reports. The afternoon would include an additional Committee report and then a report from Dr. Paul Mahaffy, Principal Investigator of the SAM instrument on the Curiosity mission to Mars. The day would conclude with Council discussion.

Dr. Squyres then introduced Dr. Huntress, who had revised several of his committee recommendations from the previous day upon request of the Council ("homework assignment"), and reintroduced them for final approval by the Council. The first was a Recommendation:

The augmented ground-based search for a small asteroid meeting the requirements for NASA's Asteroid Initiative should be formulated to broadly increase the rate of discovery of small asteroids that could threaten Earth.

This Recommendation was approved by the Council.

The second was a Finding:

The proposal selection rate for high quality proposals has fallen to levels sufficiently low to cause an unstable feedback loop where the Earth and space science community writes a much larger number of proposal, resulting in a significant non-productive burden on the community and NASA staff.

This Finding was approved by the Council.

The third was a Finding:

Pu238 is vital to the future of NASA's planetary science program. There is a long, complex history of negotiations concerning its production. Rather than simply purchasing Pu238, the NASA Planetary Science Division has now been tasked with managing and funding DOE facilities involved in the production of this material. NASA is a customer for Pu238, however, it has no expertise in the management or engineering of its production. The Agency will need to apply their best efforts to get up on the learning curve and apply its management expertise to insuring the most effective and efficient production of Pu238 at DOE.

This Finding was approved by the Council.

The fourth was a Finding:

The agency's Asteroid Initiative is an innovative approach to a human spaceflight mission to an asteroid. It would develop capabilities required for human exploration to the Moon and beyond.

SMD can support this human spaceflight mission in several ways. First, by finding and characterizing asteroids in the size, mass, rotation rate, orbital characteristics and velocity range required for transfer to lunar orbit. Second, by providing expertise and advice on the space weather environment that astronauts may encounter beyond low-Earth orbit. While not a science-driven mission, there may be an opportunity for doing some science.

There are challenging technical requirements as well as schedule and cost issues that require further investigation. SMD should provide support to HEOMD and STMD in the 2013 summer feasibility study.

This Finding was approved by the Council.

Dr. Squyres then introduced Dr. William Ballhaus, Chair, Technology and Innovation Committee, who was reporting by speakerphone from California and presenting his report via WebEx.

Technology and Innovation Committee Report

Dr. Ballhaus stressed that NASA's investment in Space Technology provided transformative capabilities to enable new missions, stimulate the economy; contribute to the nation's global competitiveness, and inspire the nation's next generation of scientists, engineers and explorers. He reported that Space Technology is delivering on its promises – including FY 2014 demonstrations for Small Spacecraft; Green Propellant; Composite Cryotank and Low Density Supersonic Decelerator (LSDS). He noted that the President's FY 2014 Budget Request supported accelerated development of a Solar Electric Propulsion (SEP) demonstration effort.

Dr. Ballhaus reviewed the Space Technology Program, which, he said, created innovation-based commercial markets; pioneered an innovative community and provided transformative and crosscutting technology breakthroughs. He then outlined Space Technology's FY 2014 strategy:

- Align the Space Technology Program with the Administration's research and development priorities
- Align and support proposed Asteroid retrieval and redirect mission
- Ensure progress on transformative and cross-cutting technology projects
- Maintain a sustainable pipeline of revolutionary concepts and develop the workforce for the future U.S. aerospace enterprise

- Create new space markets and explore alternate technology approaches
- Enhance technology transfer and commercial partnership opportunities

Dr. Ballhaus reported that the establishment of the Science Technology Mission Directorate (STMD) had been done “very intelligently.” The division is now split between the STMD and the Office of Chief Technologist, the latter who looks across the entire agency and has a seat at the Administrator’s table. Dr. Ballhaus presented an update from Dr. Mason Peck, Chief Technologist, who defined technology as: “A solution that arises from applying the disciplines of engineering science to synthesize a device, process or subsystem to enable a specific capability.”

Dr. Ballhaus offered a “nutshell” description of NASA’s basic research in engineering: NASA performs and sponsors research in engineering science; NASA’s investments in engineering research were once the basis of a successful national research enterprise in aerospace engineering sciences, both at NASA Centers and in academia; Now, Office of Chief Scientist (OCS), Office of Chief Technologist (OCT), and Office of Chief Engineer (OCE) are working to bring together and prioritize engineering-science research, including internally directed and externally sponsored pre-Technology Readiness Levels (TRL) work.

Dr. Ballhaus then described the basics of foundation engineering science – basic research in engineering science and research in engineering methods. He noted that NASA’s financial commitment had eroded over recent decades, and continued to do so. The Office of Science, Technology and Policy (OSTP), Office of Management Budget (OMB) and various independent advisory groups had highlighted the issue. He quoted the 2010 National Research Council (NRC) assessment: “The fundamental research community had been severely impacted by these budget reductions and the ability to achieve future NASA goals is in serious jeopardy.”

Dr. Ballhaus then presented the Recommendation of the Technology and Innovation Committee:

The Council recommends that NASA establish a basic research (engineering science) program relevant to its long-term needs and goals. The Council suggests that the Chief Technologist collaborate with the Chief Scientist and the Chief Engineer to establish formal guidance and seek funding for basic research in engineering science. The Council further suggests that NASA begin by managing the Agency’s basic research portfolio as a pilot activity that is funded separately from the Space Technology Program, similar to how OCT coordinates the Agency’s technology portfolio.

Dr. Ballhaus then defined a solar sail, which was propelled by the pressure of sunlight striking the surface. On earth, solar pressure was very weak – perhaps one-millionth of the pressure of a gentle breeze. The solar sail mission would include deploying the sail by segment; demonstrating attitude control; executing a navigation sequence with mission-capable accuracy, and flying to (and possibly maintaining) position at a sub-L1 and/or pole sitter position. The sails are 1200 square meters and made of five-micron thick film.

Dr. Ballhaus then turned to robotics. Robots would be precursors, assistants, and caretakers, allowing humans to undertake higher-level capabilities. Robots would prove useful in extreme terrain, operating autonomously. The development of robots faced a variety of challenges, including time delay operations, dexterity and higher levels of system automation. Dr. Ballhaus described the “pipeline” approach of the National Robotics Initiative, a partnership of agencies and companies that foresee capability of interest to NASA. Mr. Kohrs noted the popularity of high school robotics teams. Dr. Ballhaus said that 14 percent of MIT freshmen had been involved in robotics in high school.

Mr. Mike Green (in audience; Director of Communications, NASA Office of Chief Technologist; and Executive Secretary of NAC T&I Committee) noted that a robot was undertaking experimental tasks on ISS measuring airflow; holding sensors; etc. In September 2013, the ISS Robonaut’s “legs” will be sent up, enabling it to work outside the ISS. Dr. Ballhaus called attention to the X1 exoskeleton, which would augment humans’ ability to carrying weighty packs. As a further advantage, this would allow ISS crewmen to maintain their muscle and bone strength.

Dr. Ballhaus noted several Findings, which were combined by the Council into one Finding:

There is a significant lag time between deciding to support a technology and flying it on a mission. Hence, the missions we're flying today have been enabled by technology investments made years ago. The NASA technology shelf has been depleted over the last decade due to lack of investment. NASA has begun to correct this over the last three years with the formation of OCT and the STMD. This has been supported by senior government decision-makers in the Agency and within the Administration. The Committee commends Dr. Gazarik, Dr. Peck and their teams for rebuilding a program that effectively fosters technology development and innovation, especially in a challenging budget environment. We need to sustain and grow STMP's technology program [in accordance with the Strategic Space Technology Investment Plan (SSTIP)] to continue to enable future NASA missions.

Dr. Mountain expressed concern about playing "catch-up". Normally, he said, "we set up an analysis group at the same time." On the James Webb Space Telescope (JWST), analysis was brought in later. It was not an integrated end-to-end model; in part because the contractor base was way behind the curve. The Agency itself was doing catch up on the thermal modeling. The reality is that one can no longer test everything; some things are never assembled until brought together in space. It is complicated and expensive." He noted developing the Space Shuttle involved 50,000 hours of wind tunnel time. The contractor base no longer had the resources to do modeling.

Dr. Ballhaus said that during the 1990s the U.S. Government was more ready to support a private company's internal R&D. When Government interest declined, 57 companies consolidated. They listed all the individual laboratory facilities; if no operating division was prepared to take over management of a given facility, it was shut down. The mindset became "lowest credible cost wins." If the Government will not pay R&D associated overhead, a company will maintain it only if it leads to other business or improves margins on existing business. The T&I Committee commended Dr. Gazarik, Dr. Peck and their teams for rebuilding a program that fosters technology development and innovation. Dr. Ballhaus reported that budget cuts in technology had ranged to eight to nine percent, higher than the five percent average.

Dr. Squyres invited comments: the Findings appeared to be a "pat on the back" for the Agency, correcting a problem that has existed for some time. Mr. Kohrs asked if a contractor had been designated for solar electric propulsion. Dr. Ballhaus said he did not currently know, but believed it would be presented at the next NAC meeting. Mr. Green (in audience) said work had begun last year. It was determined that the solar arrays needed to provide more power; this would require them to be larger. No prime contractor had yet been chosen. Dr. Mountain asked how technology for the Asteroid mission mapped against that needed to get to Mars. This subject will be addressed at the next NAC meeting.

Dr. Squyres said that looking at the new STMD organization, much of the technology being developed was cross cutting; other was not. What was Dr. Ballhaus' view on how the portfolio should be spread within the agency? Should programs with specific needs have specific technology programs to meet them. Dr. Ballhaus said the Chief Technologist should pay attention and maintain neutrality. His personal view was that if something was mission specific, it should remain in the Mission Directorate. If there are multiple mission pulls, then technology should be centralized with high "bandwidth" joining participants.

Dr. Squyres said some of Dr. Ballhaus' earlier charts emphasized autonomy research and the growing role NASA may play in autonomy. He asked Ms. Blakey if she saw opportunity for synergies between the new organizations. Ms. Blakey said she thought there should be. She regretted that Dr. Kennel was not present to comment. Her NAC Aeronautics Committee had been asked to take a sweeping analysis of gaps in autonomy and priorities for tackling them. SMTD should definitely be consulted early. Dr. Squyres said it appeared "the right people were talking to each other." He believed the NASA Chief Technologist should pay attention.

Dr. Squyres then raised a different point: reviewing NASA's development of new technologies, was the failure rate high enough? Dr. Ballhaus noted that he had given a presentation on this topic at MSFC NAC meeting. His point, he said, was that if you meet all your objectives all of the time, perhaps you are not taking big enough steps in an R&D environment. Mr. Green (in audience) announced that several setbacks had indeed occurred this week: one involved fuel cells that did not produce the expected results; the second was with 2.4 liter composite tanks experiencing pressure failure at a joint. Dr. Holmes said failure level was strongly associated with TRL levels; one expected a higher failure rate among less developed technology.

Commercial Space Committee Report

Dr. Steven Squyres, NAC Chair, introduced Ms. Patti Grace Smith, Chair of the Commercial Space Committee, who presented its report to the NAC. Ms. Smith identified recent highlights of NASA's Commercial Space programs:

- The March 2013 completion of SpaceX's second commercial cargo resupply mission to the ISS.
- The Sunday, April 21, 2013 launch of the Antares rocket, which inaugurated activity at the new Mid-Atlantic Regional Spaceport at NASA's Wallops Flight Facility in Virginia.
- The Sierra Nevada Corporation had completed flight readiness review of the Dream Chaser Engineering Test Article flight termination system.
- SpaceX's Merlin 1D engine had achieved flight qualification, accumulating test time equal to 10 full mission durations, in support of upcoming free flight drop tests. Dr. Steven Squyres asked what was different about the Merlin 1D engine. Ms. Patti Grace Smith said she would report back.
- At Boeing, the structure that will join the CST-100 spacecraft to an Atlas V rocket completed preliminary design review, April 5, 2013.

Ms. Smith reported on recent Committee meetings with the Sierra Nevada Corporation (SNC) in Louisville, Colorado, and with United Launch Alliance in Denver, Colorado, for briefing and discussion of sub-orbital utilization activities. She noted that sequestration was in the middle of the discussion, which focused on how cost reductions had been achieved through consolidation and how further reductions were expected. Ms. Smith identified key takeaways from recent activities:

- First, the Sierra Nevada Corporation (SNC) was highly motivated and making excellent technical progress on Dream Chaser.
- Second, NASA could benefit from sub-orbital space tourism and, further, from participating in the sub-orbital commercial market.
- Third, utilization of ISS would be improved by reducing the time to place research onboard ISS from three-years to nine - months.
- Fourth, a Commercialization Study will be undertaken to document better ways of enabling space partnerships.
- Fifth, the Committee viewed the United Launch Alliance as a good partnership with Space Launch System and the first MPCV/Orion test flight by 2014.

Dr. Squyres directed comments at the lag time in getting research started on ISS. Anecdotally, he said it was widely believed that many barriers existed to getting one's hardware onto ISS. This inhibited some people from trying. If a shorter timeline was achieved, it should be made widely known. Ms. Blakey asked what barriers existed. Dr. Holmes said barriers included safety requirements and hosting requirements. Mr. Kohrs said the biggest present reason for delay was crew safety. Earlier, he added, the biggest issue had been payload viability. Many people came in from labs with things that would not pass any safety test. He believed that as ISS emphasis moved to the implementation side, delays would decrease. Dr. Mountain said the perception still needed addressing. Mr. Kohrs said he hoped by the next NAC meeting to have time-to-fly data on what projects were currently in progress. Dr. Squyres said that nine-month period was important, as it allowed a graduate student to be with a project from start to finish.

Ms. Smith presented the first Recommendation of the Commercial Space Committee:

The Committee recommends that NASA create a formal transparent process for Space Act Agreements that present novel issues and require coordination between headquarters and a center, including: (1) designating a person responsible at headquarters and the center for resolving the issues, (2) establishing a timeline for a headquarters decision, and (3) identifying to the potential commercial partner a person with sufficient authority to move the process toward resolution.

Mr. Kohrs asked why the Center Director could not make the decision. Ms. Smith said her Committee was informed that there were reasons why the decision could not be made at that level. Dr. Squyres asked if the Committee had considered making a formal Recommendation to allow Center Directors to do this. Ms. Smith said no. Mr. Montelongo asked if there was a policy currently in place. Ms. Smith said matters were “catch as catch can.” There was, she said, a process for handling Space Act Agreements; however, when participation was required from multiple layers within Headquarters, no defined way to proceed existed. Mr. Montelongo said it was not so much a matter of starting a new process as of updating the existing one to incorporate this type of situation. Ms. Smith said that, for example, the NASA Ames Research Center might enter into an agreement that had to go to Headquarters, where it churns and churns for months with the company waiting for an answer. What we want to do is to identify a specific person and time line.

Dr. Squyres asked if it was possible to establish a single point of contact at Headquarters for all Space Act Agreements. Mr. Kohrs asked if this would extend to both reimbursable and non-reimbursable. Ms. Smith said it would be limited to non-reimbursable. Dr. Squyres said that made sense to him; at present, the best interests of neither NASA nor commercial corporations were being served. Mr. Montelongo said he had worked in organizations, including DOD, where it was typically easier to modify something already in place than to try to start from the very beginning. Ms. Smith said she found it encouraging that this wording was supported by the Council; it would help get things done. She noted that she could cite a DOD matter that went in circles for a year because it lacked a specific owner. Dr. Squyres suggested that limited rewording of the Recommendation would help clarify the issue. The reworded Recommendation was presented as follows:

The Committee recommends that NASA update its Space Act Agreement process to be more transparent and efficient for those SAAs involving new policy issues between NASA and commercial partners which require broader coordination between headquarters and a center. The Committee recommends including: (1) designating a person responsible at headquarters and the center for resolving the issues, (2) establishing a timeline for a headquarters decision, and (3) identifying to the potential commercial partner a person with sufficient authority to move the process toward resolution.

The Council approved this Recommendation.

Ms. Smith presented a proposed Finding of the Commercial Space Committee:

The Council recommends that NASA explore use of Cooperative Research and Development Agreements (CRADAs) with its commercial partners. Initially, NASA should identify an office (or a person) at headquarters that would (1) identify the current number of active CRADAs between (a) a party and headquarters and (b) a party and each of the centers; (2) assess the success of each of these CRADAs; and (3) evaluate the benefits of promoting use of CRADAs.

Ms. Smith said the advantage of this was that it allowed a company to hold its intellectual property; NASA was helped because NASA needs were advanced. Dr. Squyres said commercial entities may not enter into agreements unless they can protect their intellectual property. Mr. Kohrs noted that provision for intellectual property rights could be included in the Space Act Agreement itself. Ms. Blakey asked if CRADAs entailed any disadvantages; were they obscure or cumbersome. Ms. Smith said that the agreements required review time, but were no more cumbersome than any other method. Dr. Squyres said NASA should make the mechanism more widely known. Ms. Smith noted that the recommendation allowed NASA to assess the relative success of CRARAs. Dr. Squyres suggested substituting the phrase “expanded use of CRADAs” for the phrase “explore use of CRADAs.” The Council asked that this Finding be reformulated as a Recommendation

Ms. Smith then presented a proposed Recommendation of the Commercial Space Committee:

The Committee recommends that the Center for the Advancement of Science in Space (CASIS) develop a Memorandum of Understanding for collaboration with the National Space Biomedical Research Institute (NSBRI). The results from NSBRI’s support of human research which address future exploration risks could be assessed by CASIS for their potential to expand non-NASA-sponsored utilization of the ISS.

Ms. Smith characterized this as “a vanilla recommendation.” The Committee had determined that no MOU currently existed. This would be an area of considerable activity and these two bodies needed to be talking. Dr. Squyres said that as a Council the NAC had a limited number of “silver bullets” and a limited number of issues it

could influence. If two organizations were interested in coordinating, they did not need a NAC recommendation to do so. Could this statement be reformulated as a Finding? He wanted every Recommendation to rise to a certain level of significance. Ms. Smith said she agreed. The Council asked that additional explanation be provided in the revised Finding. The final proposed Finding in this regard was presented as follows:

The Committee finds that the Center for the Advancement of Science in Space (CASIS) does not currently have a Memorandum of Understanding (MOU) for collaboration with the National Space Biomedical Research Institute (NSBRI). The results from NSBRI's support of human research which addresses future exploration risks could be assessed by CASIS for their potential to expand non-NASA-sponsored utilization of the ISS

There is synergy between the missions of CASIS and NSBRI whose responsibilities are to enhance the non-exploration related research uses of the ISS and lead a national effort to conduct the integrated, critical path, biomedical research necessary to support long-term human presence, development and exploration of space and enhance life on Earth by applying the resulting advances in human knowledge and technology respectively. They should be aware of each other's programs and work together to ensure the successful, sustainable, scientific research and technical output of the ISS. There is potential for these two organizations to miss opportunities to collaborate in areas of common interest without an MOU.

The Council approved this Finding.

Ms. Smith then outlined her Committee's plans for 2013:

- What should commercial space be in 20-30 years?
- Success and failure modes for commercial space
- Structure and expertise of NASA to facilitate commercial partnerships
- Utilization of prizes
- Commercialization lessons from Aeronautics
- How can NASA gain support for commercial space enterprises?
- Non-traditional commercial space ventures, e.g. weather satellites

Ms. Smith commented that her Committee would be prepared to address the down-select issue discussed earlier during the HEO Committee Report at the July 2013 NAC meeting.

Audit, Finance, and Analysis Committee Report

Dr. Squyres introduced Mr. Michael Montelongo, who in the absence of Robert Hanisee, Chair of the Audit, Finance, and Analysis Committee, would report for that body. Mr. Montelongo reminded the NAC that the clean audit the Agency had received for 2012 was a great achievement. Issues, however, remained; forward progress was being made on them in 2013. Mr. Montelongo cited asbestos as one area that likely comprised a significant share of the Agency's unfunded liability estimate. Asbestos, he added, was coming to the fore. All NASA Centers contain asbestos; the information for each varied widely. Marshall Space Flight Center has developed an estimate; Kennedy Space Center and Glenn Research Center had undertaken some tracking. He noted that information available from MSFC, KSC, and GRC was that 99.5 percent of asbestos present was in buildings constructed prior to 1981. Only MSFC had a solid estimate for cleanup costs.

Mr. Montelongo then addressed the budget cycles, presenting a chart showing where budget aspects now sat on a timeline. He called attention to the President Obama's March 26, 2013, signing of the FY 2013 Full Year Continuing Resolutions Act. Mr. Montelongo then addressed NASA funding. On March 1, 2013, \$893 million was cut from the Agency's \$18.7 billion FY12 budget. While the amount requested for FY13 – \$17.7 billion – almost equaled the post-2012 cut, only \$16.87 billion had been enacted. Commenting on the \$893 million sequester cut, Mr. Montelongo said one additional cut would cut into program content. Mr. Montelongo noted that OMB was seeking reductions in the level of conference spending and attendance; both OMB and Congressional committees were seeking formal reports. Ms. Smith noted that waivers were available for events regarded as mission critical: was there any real definition of this? Mr. Montelongo said he did not know. He did not regard the request as unreasonable, but it did strike him as micro-management.

Mr. Montelongo then discussed Conference Reporting Requirements. These included:

- NASA Office of Inspector General (OIG) sessions to be held quarterly
- External reporting requirements from Office of Management and Budget (OMB) to be posted annually on the NASA public website
- Congressional inquiries from various sources, including Senator Thomas Coburn (R-Oklahoma) and Congressman Darrell Issa [R-California]. Mr. Montelongo noted that the number of Congressional inquiries had increased under sequestration; each took time to answer.

He then identified three emerging initiatives:

- Hurricane Sandy Disaster Relief Funds Internal Control Plan and Assurance: Congress has directed funds be used as intended. NASA received \$14.25 million for sand and restoration projects at Kennedy Space Center.
- USAspending.gov – Establishing an Integrated Quality Assurance Framework: This will require more public information on Federal contracts and grants.
- Improper Payments Elimination and Recovery Improvement Act: Beginning September 30, 2013, all Agency heads must certify in writing that appropriate controls are in place and functioning; by 2014, all agencies must implement the framework that validates the data accuracy. Mr. Montelongo then explained the Improper Payments Elimination and Recovery Improvement Act, intended to ensure appropriate internal controls over improper payments. The good news, he said, was that in the past six years 99.9995 percent of NASA funds had been expended properly.

His central conclusion, he said, was that “the financial community was well positioned to continue to meet expected expanding internal control requirements.” Mr. Montelongo then addressed the results of the FY 2012 audit. He noted that many sessions had been held with PwC (the former Price Waterhouse Coopers). The good news was that NASA had received an unqualified opinion. However, a significant deficiency existed related to environmental liabilities. PwC, he said, had issued a management letter of findings of lesser consequence, mostly intended to bring matters to the Agency’s awareness. He forewarned the Council of four areas that would receive attention in the FY 2013 audit: government owned/contractor held property; environmental liabilities; financial reporting; and expenses, including grants. Mr. Montelongo noted that there was now an oversight body that “audits the auditors.” Lately, he said, the “volume” on this activity has been turned up. This, he said, led to second-order consequences. If auditors were placed under increased pressure, they will “turn the volume up on us” and expect “every I dotted and every T crossed.”

Mr. Montelongo returned to the topic of environmental deficiencies, as discussed in the FY 2012 audit. He noted that all Federal agencies, not just NASA, had received a reprieve until 2013. In the past, he said, NASA had used the Initiating, Diagnosing, Establishing, Acting and Learning (IDEAL) model to determine costs; in truth, the auditors have not been quite comfortable with this. He believed that use of Statements of Federal Financial Accounting Standards (SFFAS #6) “will pass muster.” Mr. Montelongo said NASA’s Office of the Chief Financial Officer (OCFO) had a good handle in addressing those issues cited in 2012; further, they were well on their way to undertaking the 2013 audit. In terms of budget, he said, “it is what it is” – he believed the agency could manage with the funds available at present. He noted that more was likely to be forthcoming on the asbestos issue. Mr. Kohrs asked how, in terms of asbestos, the various NASA Centers were discriminated. Was the per square foot figure established for MSFC “ratcheted up” for other operations? The agency had been informed that Marshall could not serve as the sole source because it did not take into account one-off and unique items.

Education and Public Outreach Committee Report

Dr. Squyres introduced Mr. Lars Perkins, Chair, Education and Public Outreach (EPO) Committee, to report on his Committee’s activities.

Mr. Perkins began by noting that Bill Nye ‘The Science Guy’ would be joining the EPO Committee – he had just been appointed by NASA Administrator Bolden. Mr. Perkins said EPO was a fast moving issue under the FY 2014

budget, with considerable uncertainty regarding transitions. Centrally, EPO's discretionary budget would drop from \$64 million to \$20 million from 2012 to 2014. Mr. Perkins called attention to "the taxi driver problem." If one asked a taxi driver about what NASA did, one typically gets the response: "NASA? I thought they were out of business." That taxi driver was NASA's customer.

Mr. Perkins summarized the EPO Committee's March 4, 2013 meeting. He gave the NASA Education Vision Statement: "To advance high quality Science, Technology, Engineering, and Mathematics education, using NASA's unique capabilities." Mr. Perkins noted that NASA's STEM expenditure of \$117 million was only about four percent of the total \$2.951 billion national expenditure. He presented the STEM education framework, which progressively seeks to Inspire, Engage, Educate and Employ. Mr. Perkins reported a performer making "on his own dime" a "reach for the stars" video that brought tears to the eyes at JPL. Mr. Perkins explained efforts at leveraging: working with 10 teachers was better than working with 10 students; 10 schools better than 10 teachers.

Mr. Perkins explained the NASA leadership had briefed the EPO Committee on NASA's four-year strategic planning process, which sought input from all stakeholders. NASA's current vision statement was: "*To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind.*" This, he noted, was not specifically a NASA vision statement; it read rather more like a mission statement. He noted Google's mission statement as an example: "We organize and make universally accessible the world's information." He believed it very important to have both an external and an internal message.

Mr. Perkins offered examples of vision statements:

- 'Dare Mighty Things'
- 'Inventing the Future'
- 'We Reach Farther'
- 'Invent. Discover. Explore'
- 'We Explore the Universe. So Can You'

Mr. Perkins presented his Committee's first Recommendation:

NASA should, as part of its strategic planning process, create a short inspirational "vision statement" that embodies NASA's aspirational goals. In addition, NASA should rewrite the current vision statement to be clear, more focused, and reposition it as the "mission statement."

Mr. Montelongo expressed agreement. Development of the vision statement should engage the public, rather than NASA "looking at its own feet." Dr. Huntress expressed strong approval. Dr. Squyres requested some minor editing. The final text of this Recommendation was approved as follows:

NASA should, as part of its strategic planning process, create a short, inspirational "vision statement" that embodies NASA's aspirational goals. In addition, NASA should rewrite the current vision statement to be clearer, more focused, more NASA-specific, and reposition it as the "mission statement."

Then, Mr. Perkins presented a chart with a cartoon in which one person asks, "Would you please elaborate on 'then something bad happened'?" That "something bad," he said, was a NASA memo dated March 22, 2013, reading in part: "Effective immediately, all EPO activities should be suspended, pending further review. In terms of scope, this includes all public engagement and outreach events, programs and activities, and products developed and implemented by Headquarters, Mission Directorates, and Centers across the Agency, including all education and public outreach efforts conducted by programs and projects." Mr. Perkins characterized it as "an axe that came down on a Friday afternoon." Mr. Perkins then presented the effects on NASA STEM education inventory funding for the FY 2014 budget. The \$15.2 million remaining in the Space Technology budget was for a fellowship program; the actual discretionary budget was being reduced from \$74 million to \$19 million.

Mr. Perkins stressed the importance of using actual NASA scientists and technologists in designing curricula. He noted that under pending U.S. Government-wide consolidation, K-12 activities would be coordinated by the Department of Education; all undergraduate and post-graduate activities by the National Science Foundation; and all "informal education" by the Smithsonian Institution. Mr. Perkins noted a second problem: even if a NASA Mission Director found program funds, they would not be allowed to expend them on EPO, e.g. the Agency would be

precluded from establishing a website for EPO to post JWST images. The one percent of mission program budgets directed to EPO would be eliminated.

Mr. Perkins then explained how EPO activities would proceed under sequestration. As of March 22, 2013, all activities were suspended with a waiver process established for activities initiated prior to May 1, 2013. To date, 153 waivers had been sought; 118 approved; 21 conditionally approved, and 14 denied or declared out of scope. The circumstance, he said, involved not only a staggering budget cut. The total NASA Education budget was being reduced from \$203 million in 2012 to \$109 million in 2014; the non-directed budget by \$64 million to \$20 million in the same period. Additionally, use of mission program funds was being refused.

Mr. Perkins noted that, for 2013 Mr. Leland Melvin, NASA Associate Administrator for Education, would have oversight on all activities; this would improve consistency in materials. NASA's 1600 websites currently lacked such consistency; they should have similar look and branding. He noted that no site existed that gave a full list of educational NASA "apps." Because a video might be available from half a dozen sources, one could not say which video NASA had produced was the most popular. Mr. Perkins said his belief was that expertise in Education should develop organically from the individual centers who did each programmatic aspect best. The EPO Committee committee had recommended that "one message" be pursued; NASA had concurred. The text of this prior NAC recommendation was as follows:

NASA should develop one overarching message under which all NASA activities and programs [e.g. Aeronautics] can be integrated and presented to the public. All NASA websites, videos, apps and social media should be consolidated and be organized thematically under this message view WWW.NASA.GOV.

Mr. Perkins presented his second EPO Committee's Recommendation, which was accepted by the Council:

Rather than halting most EPO programs immediately, fund and recast FY 2014 as a transitional year, where existing programs can be evaluated and slated for shutdown, transfer to other agencies, or continuance in an orderly fashion.

Dr. Squyres invited comments. Dr. Huntress said he liked the statement, particularly Mr. Perkins' identifying FY 2014 as a transition year. As many content providers as possible should be kept engaged. Mr. Kohrs asked about funding requirements. Mr. Perkins said the entire NASA Education program budget was the equivalent of NASA purchasing one seat on a Russian spacecraft for astronaut transportation to/from the ISS. Ms. Smith suggested using the first sentence under "reason" as the first sentence under "recommendation." Dr. Huntress asked whether "significantly degrade" should be altered to "abrupt." Dr. Squyres asked whether it was generally accepted that NASA's popularity was at a decade high. Mr. Perkins said "arguably" could be added. Dr. Mountain said hard data existed, including the number of people in contact with astronauts and participating with Hubble. Mr. Perkins said he had never seen a response equivalent to that for the Mars Rover Curiosity. Dr. Squyres asked if the Council should give NASA guidance on implementing this recommendation; it was particularly important to prioritize those areas where NASA's STEM contribution was unique. Mr. Perkins said he would be happy to work with Leland Melvin on such activities as Hubble, Curiosity, etc. Mr. Holmes asked if "continuation in an orderly fashion" was equivalent to seeking a waiver. Mr. Perkins noted EPO would still have \$20 million, so a few things would be supported. He had been told that 59 staff positions would be covered, so no one would be "RIFed" (Reduction-in-Force).

Ms. Smith asked Mr. Perkins what response he wanted from the NAC. Mr. Perkins said he sought the sense of the group. Dr. Squyres termed the March 23 memo "like a guillotine coming down." Ms. Smith noted that if the transition decisions were made by the Federal government, they might be different than Mr. Perkins might want. Mr. Holmes said he was appalled by this FY 2014 budget action; his entire experience with NASA told him it was wrong. Dr. Squyres said suggested adding a sentence along the lines of: "Let us fight to retain those truly unique things the Agency does." Mr. Perkins agreed. The final approved wording of this Recommendation is as follows:

Rather than halting most EPO programs immediately, fund and recast FY 2014 as a transitional year, where existing programs can be evaluated and slated for shutdown, transfer to other agencies, or continuance in an orderly fashion. In particular, the Agency should fight for continuance of EPO activities that are enabled by capabilities that are uniquely NASA's.

Mr. Perkins then presented the Education Committee's fourth Recommendation, which was accepted by the Council:

If a mission team, along with the Office of Education, determine that an educational initiative is in the best interests of the mission and can identify funding from non-educational budget funds, they should have the authority to spend these funds for that purpose.

Mr. Perkins then stated that since this Council meeting may be his last due to his pending reappointment for another two-year term. He had a "final" statement he wished to read:

"We are part of a culture of explorers who can touch a little bit of immortality by leaving to our children, and their children's children, the very important legacy of our discoveries. Why do this? We are human. We are curious. Curiosity – named by a Chinese American girl, built by the finest engineering organization on the planet in concert with our international partners, commanded by a team including an Iranian-American with a Mohawk – a true American melting pot We came together for an event we could all celebrate. Not divided by city, sports team, or political affiliation. Not drawn together by shared tragedy but by shared success. Who else can do that? No one asks these questions better than NASA. No one answers them better. No other arm of government has been more passionately connected to the American people and to the American spirit. Could we do better? Of course. And we are on the way. To interrupt our progress at this point is, in my opinion, a mistake that could be very difficult from which to recover."

Several NAC members expressed praise for Mr. Perkins' statement.

Curiosity's Exploration of the Habitability of Ancient Mars: Overview of Early Mission and SAM Discoveries in Gale Crater

Dr. Steven Squyres introduced Dr. Paul Mahaffy, of NASA's Goddard Space Flight Center, Principal Investigator for Sample Analysis at Mars (SAM) instrument on the Mars Curiosity mission, who reported on Curiosity mission and preliminary science results. Dr. Mahaffy said the primary scientific goal is to explore and quantitatively assess a local region of Mars' surface as a potential habitat for life, past or present. The investigation included such factors as biological potential, geology and geochemistry, the role of water and surface radiation. The consensus was that it would be most fruitful to look into the Martian past. The search, he said, was for settings with suitable chemistry, radiation and water. He noted that "microbial life, not cows" was what was envisioned.

Dr. Mahaffy presented a slide of the Mars landing site selection, the Gale Crater and Mount Sharp, and presented a brief history of the Mars landing site selection process within the Curiosity mission. The first site selection workshop was held in 2006; about 60 original potential sites were reduced to four. Many scientifically interesting sites were removed because of safety factors, such as rocks. When the engineers were presented with the "short list," they responded that the decision should be based on the science. The four candidate sites was Eberswalde Crater, which included a clay-bearing delta likely formed by an ancient river; Holden Crater, which offered alluvial fans, flood deposits and clay-bearing sediment; Mawrth Vallis, where differing mineralogy was exposed; and Gale Crater, which offered a range from clays to sulfates.

Dr. Mahaffy introduced Curiosity's science payload of 10 selected scientific instruments. Work on these began in 2004. New components included a mass spectrometer, a "two-eyed" camera with differing focal lengths; a laser that will "interrogate a rock for a few nanoseconds." Assessment of the radiation emitted by that rock would allow a quick decision if further investigation was warranted. The Curiosity rover had the ability to scoop and drill attached to an arm; a Russian instrument that could seek below-surface hydrated minerals; and a weather station. He termed it "a really capable payload."

Dr. Mahaffy showed a photo of the November 26, 2011 Curiosity mission launch. He showed a slide of Martian dust being kicked up at landing and slides of the SAM team celebrating touchdown. He said that once the lander was on the surface and the camera began presenting images, "everyone breathed a sigh of relief." Dr. Mahaffy presented a mosaic shot of Mt. Sharp; an image of Mt. Sharp's layers, canyons and buttes, and a "self-portrait" of the arm-mounted Mars Hand-Lens Imager. He noted that everything of consequence had survived the landing in good shape; the exception was that one of three wind sensors was knocked out of line by a pebble.

Dr. Mahaffy showed before and after shots of ChemCam's laser creating five small holes in a rock. One test rock proved to be similar to alkaline basalts on earth produced by partial melting of the mantle. Dr. Mahaffy then shared with the NAC a number of science findings, including: day to night temperature swings are tremendous; temperatures reached -70 degrees C. overnight; pressure varies by 10 percent a day, similar to the change in pressure between Los Angeles and Denver.

Dr. Mahaffy reported that Curiosity had reached the Glenelg location. Because this spot had three distinct terrains (hummocky, cratered, and fractured units) a 'side trip' to it was deemed worthwhile. As an added attraction, the flow of an alluvial fan headed in this direction. Many of the pebbles were as smooth as those generally found in a streambed. He described the efforts to rid Curiosity of any terrestrial organics that "might have come along for the ride." He showed a slide of a scoop of Mars sand, commenting that since the dust blows about a great deal, a sample is probably close to the "average" dust on the planet. As measured, the dust's elemental composition proved quite similar to that measured by the earlier Mars Rovers Spirit and Opportunity. He reported that the first XRD experiments from the Rocknest showed weathered basalt (pyroxene olivine, such as found in Earth's mantle and plagioclase feldspar also found in the Earth's crust.)

Dr. Mahaffy then introduced the Sample Analysis at Mars (SAM) suite of instruments, which included a quadruple mass spectrometer; a 60-column gas chromatograph; two-channel tunable laser spectrometer; a gas processing system; and a sample manipulation system. SAM was in a clean room becoming integrated for a year; the challenge was getting all components into something "the size of a microwave oven" and weighing about 40 kg. The prime experiment, he added, was to take a small sample skin; heat it up, and see what comes off. Dr. Squyres noted that Mr. Mahaffy was "too modest" to say that SAM was the most sophisticated science instrument ever put into space on a planetary spacecraft. Dr. Mahaffy listed various experiments to be attempted with both rock and air samples. He showed slides of the SAM unit and its gas flow diagram. Mr. Mahaffy noted that the script and software was being changed every time something new was done on Mars; the intention, he said, was to make the best use of the instrument by developing new scripts. To facilitate this, a test bed was maintained on Earth just like that on Mars.

Dr. Mahaffy noted several major findings. Argon and nitrogen were present in almost identical quantities. One important question was: how much Martian atmosphere was lost 3 to 3.5 billion years ago; previous to that, did liquid water persist on the surface? He noted efforts to discover methane – methane could be an important sign of microbial life. It was produced by microbes; further, methane can be produced below ground level and then diffused out. He noted that the comet expected to hit Mars in November 2013 might show that space had been a source for methane. To date, he said, no methane had been found.

Dr. Mahaffy explained the process whereby SAM analyzed atmospheric gas; he noted that the Martian atmosphere was rich in heavy carbon and heavy oxygen – similarly with deuterium. Heavy oxygen was present at a degree five to seven times as great as that in terrestrial oceans. Dr. Mahaffy reported on the first detection of a deuterium to hydrogen ratio (D/H) on the Martian surface. This was important because D/H was one of several isotopic ratios that tracked the extent of atmospheric escape and the change from early environments. He also reported on carbon dioxide levels, and oxygen and sulfur compounds, released from Rocknest samples. These efforts were tied to determining how different Mars past climate had been. SAM results show that the Rocknest sand drift does not contain abundant organics. Organics could, he said, have reached Mars from space as micrometeorites or been transformed in cosmic reactions; by ultraviolet radiation; by hydrogen peroxide; by dust induced electrical discharges and/or by other oxidants in soil and dust. Mr. Mahaffy noted that samples were not "swimming in organics." One needed to remember that cosmic radiation over hundreds and millions of years can tear compounds apart. As another finding, Dr. Mahaffy noted that as daily temperature rises the radiation level declines. He showed additional slides relating to the first drilled holes on Mars, February 6, 2013. A rotary percussive drill was used; powders with grain sizes as small as 150 microns were capable of being studied.

Dr. Mahaffy closed with the statement from Clara Ma, the student winner of the NASA/JPL "Name the Rover" contest: *"Curiosity is the passion that drives up through our everyday lives. We have become explorers and scientists with our need to ask questions and to wonder."*

Dr. Huntress asked if a method existed for enhancing the methane concentration. Dr. Mahaffy said there was. He noted that the scientific pace depended in part on getting the "very complex" Curiosity rover operating. That is, certain tests needed to be vetted on Mars. He believed the travel to Mr. Sharp will be a good time to do this.

Dr. Squyres asked about “consumables” on SAM. Mr. Mahaffy noted that consumables were, very straightforwardly, the number of cups available for taking samples. One of the two helium tanks were down 20 percent; that meant years of supply remained. He said the largest consumable was the electromechanical system. The turbo molecular pumps were remarkable devices: they had been created for double the mission life; at present, a lifetime of three to four years could be assumed. Dr. Squyres noted an inherent tradeoff between undertaking the science that is right in front of you and the science you may run across.

Dr. Mountain asked if one was going to undertake sample return, what samples you would wish to have returned. Dr. Mahaffy said he would be better able to answer that at the end of the mission. Would it be possible, he was asked, to find organics showing evidence of early microbial activity? He said, “The jury is still out.” Dr. Huntress said a lot of hard work was involved.

Council Discussion

Dr. Squyres suggested the group “circle back” to how to articulate the virtues of the proposed Asteroid Initiative. He noted one stepping stone technology was life support in deep space habitability; one benefit was the possibility of forging new international partnerships. Dr. Huntress and Mr. Holmes both said they liked this point. Ms. Smith commented, “It is in NASA’s best interests to clearly articulate the benefits of the Asteroid Initiative to the public and Congress in a way that accurately represents its merits... but doesn’t oversell.”

Dr. Squyres noted two things. First, at 4:00 pm, the Council would take input from the public. Second, he thought it particularly important that nothing “fell between the cracks” at this session. Did any NAC member have anything to suggest? Mr. Kohrs said he hoped the next budget cycle would be completed when NAC met next in July 2013; as a minimum, he added, he hoped for a budgetary update. Dr. Mountain said he would welcome a clearer mapping of how the Asteroid Initiative’s technology developments tied to those required to get to Mars; otherwise, some might view the asteroid mission as a distraction. Dr. Squyres said that what Dr. Mountain and Dr. Ballhaus were saying was that the Agency should actually convince itself that this was true. Dr. Huntress termed this “an excellent point.” There should be specificity on how each asteroid mission component benefits the goal of reaching Mars. Dr. Squyres noted that the asteroid mission involved operations that could apply to future missions, including life support and deep space habitability, advanced propulsion, complex ground and space operations, rendezvous in new gravitational environments, and sampling of small objects. Further, it benefited the United States by forging additional industrial capacity and building international partnerships. Further, the mission could advance technologies and operations that might defend against Earth-bound asteroids. Mr. Kohrs said that when people say they can do that, they have to make clear how they can do it. Additional time needs to be devoted to this question. Dr. Steven Squyres asked if any other topics needed to be discussed. None were raised.

At this point, Dr. Squyres suggested they go around the table to see if anyone had any comments they had not had the opportunity to make.

Mr. Lars Perkins said he had nothing to add. Dr. Squyres said Mr. Perkins’ final statement at the end of his EPO Committee report had been eloquent; Dr. Squyres reiterated his belief that it deserved a much broader audience.

Ms. Patti Grace Smith posed a question: “How can we best help the NASA Administrator?” She remembered three years ago the NASA Administrator had said that by telling the story, the real story, on Capitol Hill to those who had not heard it or do not understand, one was performing a valuable service. One did not frequently get to talk to Congress. Ms. Smith said she had worked in the Federal government and had learned that if one failed to make a pro-active showing with Congress then things were left to chance, a very risky situation. She asked if members of the NAC could speak to appropriate committee members if they did so as interested individuals. Mr. Richard Kohrs asked if the legal status as a Special Government Employee (SGE) established a restriction. Ms. Diane Rausch, NAC Executive Secretary, said the NASA Advisory Council was an Executive Branch advisory committee that reported to the Executive Branch. Dr. Squyres asked whether SGE status prohibited people as individuals from meeting with their respective Member of Congress. Ms. Rausch said she would consult the NASA’s attorneys for legal guidance on this matter. Dr. Huntress said he found it hard to believe that one could be prohibited from going to one’s own Member of Congress as a private citizen. That was different than going as a member of a FACA committee. Dr. Squyres asked Ms. Diane Rausch to look into the matter with the NASA attorneys and provide guidance to the Council, to which she agreed.

Mr. Richard Kohrs made reference to the next NAC meeting in July 2013. He doubted Congress would make much headway on the budget by then. At that meeting, he said, Council members would like to hear from Mr. Bill Gerstenmaier on the latest status of the Asteroid Initiative, and perhaps in a joint session of the Human Exploration and Operations (HEO) Committee and Science Committee. He noted that a HEO Committee joint session with the Technology and Innovation Committee on systems engineering and integration might occur as a fact-finding discussion prior to the next NAC meeting. He believed that the current NAC meeting had been a very productive meeting.

Dr. Matt Mountain thanked the NAC for extending him the opportunity to participate. It seemed to him incredible not only what NASA was doing but that it was doing it on a declining budget. He closed by noting that a friend of his had once said that the Department of Defense existed to defend the country, NIH existed to keep the country healthy, the Department of Education existed to educate the country, and NASA existed to inspire the country.

Mr. Michael Montelongo thanked Dr. Squyres and NASA for permitting him to participate in the NAC meeting, representing the Chair of the Audit, Finance and Analysis Committee, Mr. Robert Hanisee.

Dr. Charles Holmes stated that he appreciated being able to attend the NAC meeting, representing the Chair of the IT Infrastructure Committee, Dr. Larry Smarr, and he thought Dr. Smarr would be pleased with the results of this meeting. The next meeting of the IT Infrastructure Committee would take place in July, and would discuss laser communications, systems engineering in the SLS and Orion programs and cybersecurity. He expressed the personal view that the proposed elimination of the "1% for EPO" funding in NASA's Science Mission Directorate was very shortsighted, and he was very unhappy that this outstanding program of education and public outreach started by Dr. Ed Weiler (former SMD Associate Administrator) was being "thrown away."

Dr. Charles Kennel said he had made various contacts and was pleased to report that meeting would go forward with science and education to start improving interconnectivity. He hoped to address common initiatives in human interactions and other areas. Dr. Kennel then said he wished to mount his soapbox: he concurred with Dr. Holmes that the proposed removal of the "1% for EPO" in SMD mission budgets was extremely shortsighted. He remembered from his years working at NASA Headquarters that when he would testify on the Hill, he would be congratulated on the fine job NASA was doing on education. Members of Congress would say: 'If there's anything I like about NASA, it the way they do mission education and public outreach.' We're throwing that away. He commented on the sequester. Overall, the reduction was to be five percent. Certain protected programs had not received cuts; instead, additional funds had been taken from the grants programs. This, he said, was a continuing story that had yet to come to solution. The grants, he said, represented the Agency's investment in the future, and they are being strangled.

Dr. Wesley Huntress noted that he had presented his main concerns the previous day. He closed by stating, "I love this Agency. I love what it does and I think a lot of people here are passionate about what we do." He said he believed NASA was under severe stress. He believed the NAC could be of considerable assistance to NASA Administrator Bolden. While he was personally departing from the NAC and this was his last meeting, he intended to help from the outside to relieve some of the distress. He said it had been "a delight to work in this fine fellowship."

Dr. Squyres noted two points. First, he wanted to express sincere thanks to Dr. Huntress, "who had served both the Agency and this Council extraordinarily well." He noted that Dr. Huntress' Science Committee reports were always fabulous, and his report at this meeting had highlighted a number of missions whose development traced back to Dr. Huntress' watch as NASA Associate Administrator for Space Science, e.g. Kepler, the Discovery Program, the Mars Exploration Rovers, and others. Dr. Squyres thanked Dr. Huntress on behalf of the NASA Advisory Council and the nation. Second, he noted that twice in recent weeks he had been called upon to speak before panels convened by the National Academy of Sciences and the National Research Council about the future of NASA. He had represented the views of those in this room as well as possible; his central view has been that there is an "elephant in the room" and that is that NASA needs a clear and compelling goal for future space flight that is consistent with its budget. He was very encouraged that for the first time since he had been associated with the Agency NASA had articulated a goal consistent with its budget, and that it took place at this meeting.

Public Comments

Ms. Kim Terrill (audience member) noted a recent report about NASA and small business and the Agency's performance related to its small business goals and agenda. She asked if the NAC at this meeting had addressed concerns related to this subject. She was aware, she said, of the stresses caused by sequestration. Dr. Squyres said the Council had not done so, but he thanked Ms. Terrill for calling it to the group's attention. He expected the matter to be addressed by one of the Council Committees in the future.

Question by unnamed speaker (speakerphone): To what extent has there been a strategy about combining commercial crew in the second round of Commercial Resupply Services? Since by 2016 it was likely NASA would have a new cargo contract; it might be a good idea to provide further incentive to the commercial crew. Combining it with the cargo crew might provide a multiplier effect. Dr. Squyres responded that this had not been discussed as yet, but would fall in the province of the Commercial Space Committee headed by Ms. Patti Grace Smith.

Mr. Alan Angleman (speakerphone) introduced himself as the study director of the new NASA autonomy study. He noted that his group would be reaching out beyond the Aeronautics Research Mission Directorate for research related to aeronautics. He expressed a concern about commercial crew. At present, he said, there were three companies involved. He wondered if there was a way to extending engagement, on an unfunded basis, to other companies that might be involved perhaps not in the next few years but eventually.

Ms. Kim Terrill (audience member) said she understood the changes in STEM; still, she thought it important to point out that people like her had been inspired and put through school by NASA's STEM activities. She noted that she had a seven-year old niece participating in a NASA program, "which delights me no end." Dr. Squyres said he thought Ms. Terrill's remarks resonated around this table. He noted that the Council was making a recommendation to stress the importance role the Agency played in inspiring people through those things NASA does best. Ms. Terrill thanked NASA for funding her Bachelor's and Master's degrees.

Dr. Steve Squyres adjourned the meeting the NASA Advisory Committee at 4:10 pm.



NASA ADVISORY COUNCIL

NASA Headquarters
Washington, DC 20546

PUBLIC MEETING
April 24-25, 2013

AGENDA

Wednesday, April 24

Council Public Meeting

NASA HQ, Program Review Center, Room 9H40

9:00 – 9:03 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council
9:03 – 9:10 am	Opening Remarks by Council Chair	Dr. Steven W. Squyres Chair, NASA Advisory Council
9:10 – 10:00 am	Remarks by NASA Administrator	Mr. Charles F. Bolden, Jr. NASA Administrator
10:00 – 11:00 am	Aeronautics Committee Report	Ms. Marion Blakey, Chair
11:15 – 11:30 am	IT Infrastructure Committee Report	Dr. Charles Holmes Vice Chair <i>(for Dr. Larry Smarr, Chair)</i>
11:30 – Noon	Council Discussion	
12:00 1:00 pm	Lunch	
1:00 – 2:00 pm	NASA FY 2014 Budget Request	Ms. Elizabeth Robinson Chief Financial Officer NASA HQ
2:00 – 3:00 pm	NASA Plans for Future Human Spaceflight	Mr. Bill Gerstenmaier Associate Administrator for Human Exploration and Operations Mission Directorate, NASA HQ
3:00 – 4:00 pm	Human Exploration and Operations Committee Report	Mr. Richard Kohrs, Chair
4:00 – 5:00 pm	Science Committee Report	Dr. Wesley Huntress, Chair

5:00 pm

Adjourn

Thursday, April 25**Council Public Meeting**

NASA HQ, Program Review Center, Room 9H40

9:00 – 9:01 am

Call to Order, Announcements

Ms. Diane Rausch
Executive Director
NASA Advisory Council

9:01 – 9:03 am

Remarks by Council Chair

Dr. Steven W. Squyres
Chair, NASA Advisory
Council

9:03 – 10:00 am

Technology and Innovation Committee Report

Dr. William Ballhaus
Chair

10:00 – 11:00 am

Commercial Space Committee Report

Ms. Patti Grace Smith
Chair

11:15 – Noon

Audit, Finance and Analysis Committee Report

Mr. Michael Montelongo
Vice Chair
(*Mr. Robert Hanisee, Chair*)

12:00 1:00 pm

Lunch

1:00 – 2:00 pm

Education and Public Outreach Committee Report

Mr. Lars Perkins, Chair

2:00 – 3:00 pm

Curiosity's Exploration of the Habitability
of Ancient Mars: Overview of Early Mission
Discoveries in Gale Crater
Sample Analysis at Mars (SAM)Dr. Paul Mahaffy
Principal Investigator
SAM
NASA Goddard
Space Flight Center

3:00 – 4:00 pm

Council Discussion

4:00 – 4:15 pm

Public Input

4:15 – 5:00 pm

Council Wrap-up; Final Acknowledgments

5:00 pm

Adjourn

Dial-In (audio): You must use a touch-tone phone to participate in this meeting. To join via Dial-In, dial the toll-free access number 866-753-1451 or toll access number 1-203-875-1553, and then the numeric participant pass code: 6957984 followed by the # sign.

WebEx (view presentations online): To join via WebEx, the link is <https://nasa.webex.com/>, meeting number 999 465 732, and password: AprilNAC@2013

Appendix B: NASA Advisory Council Membership

Chair - NASA Advisory Council	Dr. Steven W. Squyres, Ph.D. , <i>Goldwin Smith Professor of Astronomy, Cornell University</i>
Chair - Aeronautics Committee	Ms. Marion C Blakey , <i>Chief Executive Officer, Aerospace Industries Association</i>
Chair - Audit, Finance, and Analysis Committee	Mr. Robert M. Hanisee, CFA , <i>Managing Director, Trust Company of the West</i>
Chair - Commercial Space Committee	Ms. Patti Grace Smith , <i>Patti Grace Smith Consulting, LLC</i>
Chair - Education and Public Outreach Committee	Mr. Lars Perkins , <i>Entrepreneur</i>
Chair - Human Exploration and Operations Committee	Mr. Richard Kohrs , <i>NASA (Ret.)</i>
Chair - Information Technology Infrastructure Committee	Dr. Larry Smarr , <i>Director/Professor, California Institute for Telecommunications and Information Technology, University of California/San Diego</i>
Chair - Science Committee	Dr. Wesley Huntress , <i>Director Emeritus, Geophysical Laboratory, Carnegie Institute of Washington</i>
Chair - Technology and Innovation Committee	Dr. William F. Ballhaus Jr. , <i>President and Chief Executive Officer (Ret.), The Aerospace Corporation</i>
Ex Officio Members	Gen. Lester L. Lyles , <i>Chair, Aeronautics and Space Engineering Board, National Academies</i> Dr. Charles F. Kennel , <i>Chair, Space Studies Board, National Academies</i>

Appendix C: NASA Advisory Council Meeting Attendees

Wednesday, April 24, 2013

NASA Advisory Council members:

Steven Squyres, NAC Chair, Cornell University
Marion Blakey, NAC
Charles P. Holmes, NAC
Wesley Huntress, NAC, Carnegie Institute of Washington
Michael Montelongo, NAC
Matt Mountain, NAC, Space Telescope Science Institute
Lars Perkins, NAC
Patricia G. Smith, NAC

Diane Rausch, NAC Executive Director, NASA HQ

Other NASA attendees:

Barbara Adde, NASA HQ
Emma Antungs, NASA HQ
Jonathan Cirtain, NASA HQ
Douglas Craig, NASA HQ
T. Jens Feeley, NASA HQ
William Gerstenmaier, NASA HQ
John Guidi, NASA HQ
Shari Kamm, NASA HQ
Marla King, NASA HQ
Meredith McKay, NASA HQ
Dave Lengyel, NASA HQ
Erin Mahoney, NASA HQ
Michael Meyer, NASA HQ
James J. Miller, NASA HQ
Susan Minor, NASA HQ
Jeff Newrite, NASA HQ
Bette Siegel, NASA HQ
Gwyn Smith, NASA HQ

Other attendees:

Walt Faulconer, Strategic Space Solutions
Richard Keitre
Jon Malay, Lockheed Martin
Michael Maloney, National Research Council
Larry Richardson, United Launch Alliance

Thursday, April 25, 2013

NASA Advisory Council members:

Steven Squyres, NAC Chair, Cornell University
Marion Blakey, NAC
Charles P. Holmes, NAC
Wesley Huntress, NAC, Carnegie Institute of Washington
Michael Montelongo, NAC
Matt Mountain, NAC, Space Telescope Science Institute
Lars Perkins, NAC
Patti Grace Smith, NAC

Diane Rausch, NAC Executive Director, NASA HQ

Other NASA attendees:

Barbara Adde, NASA HQ
Marguerite Broadwell, NASA HQ
Joanthan Cirtain, NASA HQ
Mike Green, NASA HQ
Paul Mahaffy, NASA GSFC
Marla King, NASA HQ
Greg Mann, NASA HQ
Beth Siegel, NASA HQ
Kim Terrell, NASA HQ

Other attendees:

Tim Lochner
Larry Richardson, United Launch Alliance

Appendix D: Materials Presented

**NASA ADVISORY COUNCIL
NASA Headquarters
Washington, DC
April 24-25, 2013**

LIST OF PRESENTATION MATERIAL

- 1) Aeronautics Committee Report / Ms. Marion Blakey
- 2) Information Technology Infrastructure Committee Report / Dr. Charles Holmes
- 3) NASA FY 2014 Budget Estimates / Dr. Elizabeth Robinson
- 4) NASA Human Exploration and Operations Mission Directorate Overview / Mr. William Gerstenmaier
- 5) Human Exploration and Operations Committee Report / Mr. Richard Kohrs
- 6) Science Committee Report / Dr. Wesley Huntress
- 7) Technology & Innovation Committee Report / Dr. William Ballhaus
- 8) Commercial Space Committee Report / Ms. Patti Grace Smith
- 9) Audit, Finance, and Analysis Committee Report / Mr. Michael Montelongo
- 10) Education & Public Outreach Committee Report / Mr. Lars Perkins
- 11) Curiosity's Exploration of the Habitability of Ancient Mars: Overview of Early Mission Sample Analysis at Mars (SAM) Discoveries in Gale Crater / Dr. Paul Mahaffy