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MEETING REPORT

Ellen Williams, Chair	Dec. 11, 2023 Date
Nathan Boll, Designated Federal Officer	Dec 11, 2023 Date

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Welcome and Introduction

Mr. Nathan Boll, Designated Federal Officer (DFO) of the NAC Science Committee (SC), called the committee to order and detailed the Federal Advisory Committee Act (FACA) rules governing the meeting. He introduced Dr. Ellen Williams, SC Chair.

Goals of the Summer 2023 Meeting

Dr. Williams reviewed the meeting agenda. Committee members introduced themselves around the table.

SMD Update

Ms. Sandra Connelly, Science Mission Directorate (SMD) Deputy Associate Administrator (DAA), presented a status of the directorate, first recognizing that two Science Committee members, Dr. Vinton Cerf and Mr. Marc Weiser, would soon be rolling off, and thanking them for their service.

Ms. Connelly displayed the current fleet of science missions, serving as a reminder of how each discipline Decadal Survey (DS) sets the priorities for NASA science, while helping to inform decision roles that help make the Agency make tough trades when budgets are constrained. A new Biological and Physical Sciences DS will be released soon. The Earth Science Division (ESD) is in the midst of its midterm review, and the Heliophysics Division (HPD) decadal is scheduled for release in 2024.

Ms. Connelly announced new hires at SMD: Dr. Lisa Carnell, the new Division Director for the Biological and Physical Sciences Division (BPSD). Dr. Carnell brings a wealth of experience from the biological, physical, and engineering perspectives. Dr. David Grinspoon has been appointed as a Senior Scientist and will be leading the Agency strategy for Astrobiology.

SMD mission launches this past quarter were Tropospheric Emissions: Monitoring Pollution (TEMPO), Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS), and the European Space Agency (ESA) Euclid spacecraft. TEMPO is a Venture-class mission focusing on pollution from the Gulf of Mexico up to Canada (species monitored include nitrogen dioxide, sulfur dioxide, ozone). TEMPO will provide hourly measurements of these pollutants with a several-square-mile resolution. The TROPICS mission is a four CubeSat mission that is collecting data on tropical cyclones, with 60 minute revisit times. TROPICS is also a Venture-class mission that is providing transformative science, as well as supporting the National Weather Service (NWS) and storm warning centers. The ESA/NASA Euclid mission launched on July 1, 2023 and will be studying dark matter.

Ms. Connelly displayed a first light image from TROPICS, representing a 1.5-day image collection over Hurricane Adrian. Euclid's transmitted its first light test images on July 31, 2023; the mission will help provide a 3D map of the universe, scanning a third of the sky with each pass. The James Webb Space Telescope (JWST) celebrated its one-year anniversary with an image of Rho Ophiuchi, a "nursery" of star formation. The image shows bright clouds of molecular hydrogen as well as protoplanetary disks. Another dark energy mission, X-ray

Imaging and Spectroscopy Mission (XRISM), a JAXA/NASA mission, has been delayed due to weather, but is expected to launch soon.

NASA opened the Earth Information Center at Headquarters. The EIC is a physical center that showcases big-screen images, interactive media, and stories and narratives that surround Earth Science, and is also a virtual presence online. NASA recently hosted the prime minister of Mongolia, who was able to zoom in to his country's map on a Hyperwall. Under the auspices of BPSD, NASA and the US Department of Agriculture (USDA) are conducting plant research at EPCOT, using plant-growing chambers with the ultimate aim of feeding space-dwelling humans in the future.

The Commercial Lunar Payload Services (CLPS) program has a number of scheduled deliveries through the end of this calendar year and through 2024: the Shackelton Connecting Ridge in November 2023; the Malapert A (Intuitive Machines) no earlier than the third quarter of 2023; and the Volatiles Investigating Polar Exploration Rover (VIPER; Astrobotic) in November 2024. It will be exciting to see how this NASA/commercial partnership will expand and develop.

NASA will be celebrating "Asteroid Autumn" this year. The OSIRIS-REx mission will be landing in the Utah desert on September 24, 2023, returning samples from the asteroid Bennu, which are expected to provide "baby pictures" of the Solar System's chemical constituents. A quarter of the samples will be analyzed immediately, and the remainder will be stored in advance of expected improvements in analytical technology. On October 5, 2023, the Psyche mission is due to launch from Kennedy Space Center (KSC). Psyche will visit a metal-rich asteroid/possible planetary core, the first asteroid of its kind to be examined by spacecraft. Psyche data may provide insight into the formation of terrestrial bodies. The spacecraft Lucy will also be doing a fly-by of the asteroid Dinkinesh, a "bonus" target for the probe as it makes its way toward Jupiter's Trojan asteroids.

NASA is also celebrating a "Heliophysics Big Year," beginning with an annular solar eclipse on October 14, 2023, followed by a total solar eclipse in April 2024. Both eclipses will be visible from much of the continental US; the total solar eclipse will be the last visible from the contiguous US states until 2044. The Sun itself is also approaching solar maximum, yielding expectations of more space weather phenomena connected with an increasing incidence of sunspots: coronal mass ejections (CMEs), and aurorae at Earth's poles. The Parker Solar Probe will also be making its closest approach to the Sun in December 2024.

Ms. Connelly addressed the two special topics for the SC meeting, the first surrounding issues regarding the Deep Space Network (DSN) and SMD. DSN is critical to the SMD, particularly for deep space communications, and is extremely stressed at present due to increasing demand and neglected infrastructure. Ms. Connelly requested SC's feedback on what NASA should be doing to maximize DSN usage, take advantage of efficiencies, etc. The other special topic for the current meeting is lowering the barriers to science: one project devoted to this concept is the Message in a Bottle, affiliated with the Europa Clipper mission. The mission will carry communications from Earth, notably a poem by the US Poet Laureate, as well as names submitted by the public. In another effort to lower barriers, NASA began the Tri-Agency Dashboard, a joint effort by ESA, NASA and JAXA to visually demonstrate how the COVID

lockdown affected citizens on Earth. The Open Science policy (SPD-41a) and a number of other initiatives are also under way at NASA to maximize science access.

Dr. Vinton Cerf suggested that the National Academies commission a DS study aimed at a better space communications environment, to influence the types of missions that can be designed. Ms. Connelly said that personally, she was not sure that the National Academies approach would help in this area, as the DS is more relevant to science priorities. She felt that the DSN problem was more a matter of how NASA ensures there is sufficient capacity to meet mission demand, but that a DS study certainly should be discussed. She added that a Deep Space Optical Communications (DSOC) demonstration would be flying with Psyche, which will also be helpful. Dr. Cerf noted that there was a big difference between point-to-point links and a network and asked how small satellites were handled (ground to small sat linkage). Ms. Connelly said she thought that communications were linked ground to satellite, subject to verification. Dr. Cerf asked if each CLPS mission would require its own lander, and whether a spacecraft could be delivered to Gateway that could subsequently act as a shuttle to the lunar surface. Ms. Connelly said that at present, CLPS is delivering only individual landers, but that as Gateway is a key part of the lunar architecture, a shuttle-like capability could exist in the future. Dr. Cerf urged NASA to look at other commercial sources of communication, especially for near-Earth applications. Ms. Connelly said she totally agreed and thought the DSN panel would include the idea. Dr. Cerf offered big applause for the Tri-Agency Dashboard and felt the concept should be expanded.

Dr. Noël Bakhtian asked if there were a link at the EIC for uploading large files and added that she was happy to see more female representation at NASA. She asked if TEMPO would be monitoring particular gas species that didn't seem to be part of the definition for pollution. Ms. Connelly took an action to verify which sources are being tracked for pollution. Dr. Bakhtian asked if the NASA EIC provided links where one can see all the satellites that are specifically linked to monitoring climate change, and whether CLPS, having logged no failures yet, represents truly high-risk/high-reward missions. Ms. Connelly said she thought that NASA recognizes the risks of landing on other celestial bodies, as well as the importance of learning from failures. She noted that the next round of CLPS missions is due to be awarded soon. Mr. Weiser asked if NASA had defined specific expectations for success or failure for CLPS. Ms. Connelly was not sure whether there are specific success criteria, but that getting to the Moon, demonstrating entry, descent and landing (EDL) capabilities, successful landings, delivering payloads, and transmitting data back to the Earth might be among some success criteria, and added that one CLPS failure will not make the entire program a failure. Mr. Weiser cited a data point that had been received from the Chandrayaan-3 lander, indicating water ice at the Southern lunar pole, and asked if NASA would be able to use such data to plan future missions. Ms. Connelly said that yes, NASA was definitely using these data points, and she welcomed more feedback from SC on what high-risk/high reward looks like in the CLPS program. Dr. Williams asked about SMD's specific philosophy on how to navigate the high-risk/high-reward approach in a budgetarily constrained environment. Ms. Connelly said that SMD tries to use the DS decision rules when the budget is tight, while taking into consideration life-cycle phases (e.g., delaying missions in formulation vs. missions in phase C/D), and geopolitical perspectives. Dr. Williams asked about SMD's alternative pathways for developing new concepts. Ms. Connelly noted that there are technology development initiatives, for the purpose of advancing instruments, in all the SMD divisions. As to full missions, in the event of budget cuts, SMD

might choose to re-compete or re-assign instruments or spacecraft for future opportunities. The process is not black and white. Dr. Williams said it would be nice for SMD to have some systematic thought on how to actively encourage innovation and new concepts. Ms. Connelly said that NASA absolutely encourages innovation, and that CLPS is a case in point. She offered to have SMD brief the SC to enumerate how NASA encourages innovation, in general.

Dr. Sara Tucker asked if there were some overlaps between the EIC and the Earth Science Dashboard and asked about the role of the National Oceanic and Atmospheric Administration (NOAA). Ms. Connelly noted that NOAA provides data for the EIC and is a key partner. NASA is also co-developing a Greenhouse Gas Center that may be functional in one more year. EIC will eventually be a "clearinghouse" for some of these data. Dr. Tucker suggested that NASA acknowledge both NOAA and the US Geological Survey (USGS) on the EIC website. Ms. Connelly assured the SC that the relevant agencies would be made visible on the website. Mr. Weiser asked after the status of a Science Discovery Engine, which had been discussed at a previous meeting. To his knowledge, the Engine is in beta format, and sits on top of NASA data: is NASA actively pushing the Engine to the scientific community to drive the discussion? Ms. Connelly said she didn't know what the current schedule was, but that if the project proves useful, NASA will continue with it. Dr. Serina Diniega asked if SMD used a set of decision-making rules or philosophy to make hard decisions in the event of reduced budgets. Ms. Connelly reiterated that SMD looks at life cycle status, honors commitments to its partners, and considers development phases when making these trades and applying the decadal decision rules. She said she could not comment on budget specifics at present, due to embargoed information, but that everyone knows what is being proposed in Congress. Even in the worst-case scenario, there is still a strong Science budget for NASA. SMD still might have to redirect funds or postpone projects and missions, of course. Dr. Diniega said she was concerned because newer initiatives tend to get kicked down the road (e.g., Inclusion, Diversity, Equity, and Accessibility, or IDEA) when budgets get cut. Ms. Connelly said that NASA clearly embraces IDEA as a core value because it is recognized as an innovation engine, and that there is much outreach going on in this area. She added that the next day's panel (Lowering Barriers to Science) would cover this topic, but offered an additional, specific briefing if SC desires. She noted that SMD Associate Administrator Dr. Nicola Fox is a big advocate for IDEA. Dr. Diniega felt that more could be done with communication with the community. Ms. Connelly said that each SMD division is sharing what it is doing across the board and thought that most of the communication is being done through meetings like the American Geophysical Union (AGU), and also intradivisionally. Dr. Tucker commented that she still thought the community needs a little more clarity on what exactly NASA is doing in IDEA.

<u>Deep Space Network Panel</u>
Mr. Philip Baldwin, Ms. Sandra Cauffman, and Ms. Suzanne Dodd collectively presented a status of the DSN.

Mr. Baldwin, Space Communications and Navigation (SCaN) Network Services Division Director, gave an update on the SCaN Program Office. SCaN oversees both DSN and Near-Space Network (NSN) operations and maintenance, looks at evolving technologies to support future missions, manages the spectrum for NASA, and supports the advancement of interoperability standards. SCaN also represents NASA broadly as the communications expert of

the organization, representing and negotiating on behalf of NASA. SCaN currently supports more than 100 networks.

DSN is a worldwide collection of ground-based stations located in Canberra, Australia; Goldstone (CA); Madrid, Spain, and most recently, Sardinia. The NSN is devoted to communications in low-Earth orbit (LEO), for both governmental and commercial concerns; NSN also supports real-time communications with the Hubble Space Telescope and the International Space Station (ISS). There are optical locations in White Sands and Maui (the Maui station is still up and running despite wildfire events). SCaN is within the Space Operations Mission Directorate (SOMD). SCaN has many acting roles right now and is in a very transformational period, but indications are that there will be a permanent Program Manager within the next year, pending interviews. Mr. Jeff Volosin is currently Acting Deputy AA of SCaN. Major initiatives under way include commercialization of space communications associated with the return to the Moon. There are now more than 5500 space-focused companies in the US (and 10,000 globally) with a combined value of $4T. The Office of Management and Budget (OMB) and National Space Policy are both big drivers of the commercial sector push. NASA has ceased to fly Tracking and Data Relay Satellite (TDRS) satellites and is currently exploring commercialization for this function. The Return to the Moon program will bring a cadence and complexity to network demand that has not been seen since Apollo. Higher data rates mean that higher capabilities will be needed. NASA has invested $278M in six companies who are already in the business of space relay communications, in an effort to leverage their capabilities. This investment is through a NASA Communications Services Program-funded Space Act Agreement. For direct-to-Earth (DTE) communications, NASA is tapping into the growing market of DTE commercial vendors.

SCaN has developed a Four-Point Plan for Artemis Support, which involves DSN; the Lunar Exploration Ground Sites (LEGS; three satellites); Lunar Communications and Navigation Relay Services; and international partnerships and contributions. Challenges that were identified during the Artemis I mission has helped to inform gap areas, as network services were shown to be limited and subject to interference with other missions. Orion is designed for 24/7 DSN support, and was adversely impacted by the DART mission, for example, illustrating how DSN needs more capacity and adjustment of staffing to accommodate human space flight.

Ms. Suzanne Dodd added some details of the Global DSN, which originated at Goldstone, the original deep space site in the early 1960s, now augmented by sites in Madrid, Canberra, and Sardinia. There is always a DSN antenna in view of Mars, and more antennae are being constructed at three of the four DSN sites. From the DSN, one can see everything beyond GEO, and can easily close the link for lunar missions. All the missions at GEO and beyond are using DSN. Artemis used DSN for 23.5 out of 24 days. JWST, Juno, Perseverance and Ingenuity are also tracked by DSN. At present, DSN is tracking 40 missions (including Chandrayaan-3) and is getting close to doubling this load. Artemis I and CubeSat missions: when Artemis came online, all other missions had to move out of the way. While mission load is increasing, the budget is decreasing; the Artemis missions represent much excess demand on the system. LEGS will help, but more for between the Artemis spikes for demand. This will be a significant challenge ("a mess") until human spaceflight gets its own network. NASA has taken notice of the issue; there have been three recent reports on the health of the DSN, including a report by the Inspector

General. Notably, the network experienced a 33-hour outage at the Goldstone Deep Space Communications Complex (GDSCC) during Orion's flyby of the Moon, due to PCA failure. This event illustrates how a DSN "bad day" can lead to loss of critical science, missions, or human lives. The road to a reliable future for DSN will require funding estimated at a total of about $100M per year for ten years. This includes funds needed to recover from decline ($45M/year); restoration of technology investment ($15M/year); and restoration of some assets (including some mothballed antennae) ($30M/year).

Ms. Sandra Cauffman addressed some of the continuing challenges for DSN, having briefed the NAC some months before on the same subject. She emphasized that the combination of the aging infrastructure and inadequate funding has brought the network to a critical point. Oversubscription remains an ongoing concern, not only because the SMD need is growing but also because the need is hard to predict. SMD will launch significant assets in 2024-26 that will pose a large demand on DSN. These near-term drivers are Euclid, Europa Clipper, Moon Mars Exploration (MMX, a JAXA mission), and several other arrivals at Mars in the 2025-26 time frame. Overall predicted DSN loading (details on slide).

Ms. Cauffman said she was working closely with SCaN as they increase capacity in three projects. Currently, SMD missions are not designed for LEGS. SMD and SCaN are actively cooperating in the DSN Futures Study, an 18 month study (slide). Ongoing coordination will involve the rechartering of a SCaN Board of Directors to reflect Agency reorganization. A member of the SCaN HQ staff is now part of the peer review process as a voting member of the TMC evaluation. Lastly, Ms. Cauffman addressed the commercialization of TDRS; the six companies are currently being evaluated by the Glenn Research Center (GRC), and thus far SMD has not been asked for requirements input. Thus, one major concern is when to turn off access to TDRS. And when should ScAN offer something totally different? This is a major concern as well.

Dr. Williams asked if the DSN study would include an evaluation of the increased capability due to LEGS. A member of Ms. Dodd's staff noted that as LEGS antennas are added, there is a one-for-one correspondence; LEGS will help but it will not solve the problem of demand spikes. This evaluation will be a part of the DSN Futures Study. There is still a shortage of 15 antennas predicted for the nearer-term Artemis missions. Mr. Baldwin said that the first three LEGS antennae are mostly for Gateway; the next four to six, designated as commercial, will help mitigate some of the demand spikes. Dr. Williams asked why this situation has been allowed to continue. Mr. Baldwin said that for some time, the approach has been to leverage what NASA already has. Follow the Sun has provided one efficiency, but is a pendulum swing, NASA is trying to readjust in that area. The budget posture continues to be challenging. There is often confusion about what DSN does and what the commercial market offers. In general, infrastructure doesn't get support; this is not just a NASA problem. The infrastructure approach is widespread in the government. Ms. Dodd added that one can't blame everything on Artemis; SMD has a large future appetite for large data sets associated with science missions.

Dr. Cerf suggested a finding stating that the DSN is in deep deficit, and that the only way to get out of it is to spend to both recover and increase capacity. Also, as NASA moves increasingly to commercial markets, the Agency should be careful not to compartmentalize that communication.

It is much better to have an integrated system that will accommodate both commercial and NASA systems. A delay-tolerant networking (DTN)-style system that incorporates all the communications assets possible would be ideal, and NASA should determine the dollar amounts necessary to achieve that ideal. Dr. Bakhtian asked whether the challenge resided at NASA HQ or in Congress. Mr. Baldwin said that NASA had gotten good appropriations from Congress for the SCaN Road to Green project, and lunar relay. There is visibility at the Congressional level, but it is still a work in progress. Visibility and advocacy will be key, and the DSN Futures Study will help NASA to understand the gaps, so that it can then clearly articulate the absolute needs for the Agency. Asked if there were any showstoppers, Ms. Dodd said that there are a dozen studies that go back a decade, describing decaying infrastructure and budget woes. There is nothing new here, but it is clear that "heroics" are unsustainable. As part of its report on DSN, NASA offered a fix, but got no funding for it. Ms. Dodd said that while these reports raise the issues, from where she sits, she does not see action from the Agency-level. Asked if NASA was partnering with other agencies, Mr. Baldwin said that NASA was planning to partner with ESA and JAXA for the Nancy Roman Space Telescope, and other missions, and was also looking at partnering with Korea and ISRO.

Mr. Weiser asked if NASA typically charged missions or partners for DSN time. Ms. Dodd said that the practice with international partners is exchange of services. Many SMD missions are international, so no dollars are exchanged. Chandrayaan-3 was treated as a reimbursable for aperture fees, but NASA is starting to see commercial companies asking for time for test demonstration missions (also reimbursable). For Artemis, it's a gray area. Mr. Baldwin noted that SCaN/DSN does not charge SMD for core NASA missions. Ms. Cauffman referenced an ongoing discussion about missions paying nominal fees; in the commercial sector, one might pay $300-500 for a 10-12 minute pass, or $2600/hour. Mr. Weiser termed the DSN situation a "five-alarm fire," and added that everybody should be made to bear the burden of fixing it. Mr. Baldwin said he appreciated that statement, and that NASA can't keep doing what is not working. Dr. Linda Godwin said she was almost speechless at how this issue has been neglected and looked to NAC advocacy for help. Mr. Baldwin said that based on what is going on with debt ceiling negotiations, he didn't see any additional funding coming. Proposed systems improvements, for example, did not get funded during the last pass. Dr. Tucker commented that CubeSats are often advertised as panacea, but they clearly present a nonnegligible burden in terms of the accumulated hours of DSN usage that they represent. Ms. Dodd noted that CubeSats are appealing to the Principal Investigator (quick, not well tested, they use little antennas but need big antennas to find them when they get lost) for the same reasons they are unappealing to DSN. She likened the CubeSats to a class D mission being assigned to a Class A antenna. There are other options; for instance, Morehead State University has its own 21m antenna to track its satellites. There are also commercial ground stations that can track these small sats, but PIs will call in the big guns to find lost spacecraft. Ms. Cauffman said she didn't know who prioritizes CubeSats, but it is a good question to answer. Ms. Dodd offered another editorial comment on CubeSats: CubeSat vendors tend to work with different parts of the Agency without informing SCaN of their plans. The new Board of Directors will fix some of this, but commitments get made before they come to the knowledge of SCaN or DSN. Ms. Dodd added that many of the 871 CubeSat hours were devoted to "finding" them, and that in the future, NASA shouldn't continue to do this. She felt there were other more viable avenues and networks that can be used for these tasks. Dr. Jamie Foster asked if there were any opportunity to expand beyond NASA to

DOD or Space Force to support these antennas. Mr. Baldwin said that while NASA does work with DOD, NSF, and NOAA, most of this communication is near-Earth/Moon. There is not much available for deep space.

Dr. Cerf suggested the SC issue a clear finding stating that the DSN is being abused by an increasing number of small satellites, and that perhaps NASA might create a ground-based network devoted to CubeSats only, as well as setting a requirement to make CubeSats more visible and discoverable. He added that he would endorse a recommendation to increase funding for the DSN at $100M/year for ten years. Ms. Dodd agreed that the number is accurate. Dr. Cerf suggested that NASA consider a space network based on the structure of the Internet, a good proportion of which is based on "handshake" cooperation between nodes. He also felt that billing per minute doesn't work that well and that a flat fee for usage would be preferable. Dr. Bakhtian asked if the DSN was using Lessons Learned (LL) from other infrastructure areas, such as the supercomputing world. Mr. Weiser asked if the DSN could use AI to optimize scheduling and planning. Ms. Dodd said that one LL from Artemis has provided new ways of attacking the low-hanging fruit. There are always conflicts, much of which are solved collegially, such as mutually giving up time for missions. NASA is working on both the process and software pieces, but it is not possible to automate the entire DSN scheduling system. SMD has been asked to provide some priorities, but maintenance still has to be factored in.

Asked what else could be helpful, Ms. Dodd said that DTN has been demonstrated at NASA, but it can't seem to get out of the starting block. There is also the possibility of assigning multiple spacecraft per uplink. This can already be done with downlinks at Mars, and it wouldn't be too costly to implement. Assigning more missions to Ka band is another way to get more data, as is deep space optical (testing is ongoing at Goldstone, and with mission tech demos). There needs to be a match between spacecraft and ground. Dr. Cerf said that an interplanetary special interest group has been running DTN on ISS for ten years; there needs to be more implementation in space. Terrestrial stuff is running at considerable scale at present. Mr. Baldwin said that DTN will be leveraged for lunar communications, and that NASA is getting there.

<u>Committee Discussion</u>
Dr. Williams initiated a general discussion, first suggesting findings recognizing the committee service of Dr. Cerf and Mr. Weiser, and the addition of two SMD staff.

Mr. Weiser raised the issue of how CLPS success is measured: the Intuitive Machines IM-1 mission has two payloads, one NASA, and one commercial, and they both have implications for the future. What metrics are we measuring? What does success look like for CLPS? Dr. Diniega encouraged NASA to consider other technical measures when measuring success, such as learning lessons, assessing communications, and determining whether the process was smooth. Dr. Bakhtian asked how NASA defines risk in terms of driving new science, beyond the question of "did it land or not." Dr. Diniega said the budget landscape was something to remain aware of but may not require a finding. Dr. Godwin suggested that the SC comment on the Tri-Agency resource. Dr. Tucker suggested a finding stating that EIC clearly recognizes its partners. Dr. Foster noted that Mars Sample Return (MSR), a top priority in the Planetary DS, is threatened by a potentially devastating budget cut. Dr. Diniega said she would bring up this subject in the Planetary Science Advisory Committee (PAC) report. Dr. Bakhtian suggested a finding on how

CLPS missions planned to protect lunar sites for future science. Dr. Tucker noted that landers create dust, which is a concern in addition to the Planetary Protection risks associated with backward or forward contamination. Dr. Williams, in the context of the discussion on how to balance innovation and risk in the face of budget uncertainties, noted that Ms. Connelly had taken an action to bring a rationale to the next meeting.

Dr. Williams reviewed findings and recommendations from May 2023. Dr. Cerf said that the SC might assert that SMD is absolutely at risk due to DSN oversubscription/infrastructure problems: it is a guaranteed failure waiting to happen. Mr. Weiser noted that the Administrator is required to respond to a recommendation, and that the presentation gave real examples of possible failure modes. Artemis already overshadows the capacity of the DSN and will require that everything else will be shut off during the mission. Dr. Williams suggested a finding that highlights the fact that a healthy, functioning DSN will require a serious commitment. Dr. Godwin said that really talented and heroic efforts have managed to overcome the current problem, which is the downside of people being so good at their jobs; that's a failing of NASA. Dr. Foster suggested that funding could be provided by missions allocating a portion of their budget to the infrastructure; the DSN could also add a requirement of consultation when a PI submits a proposal. A meeting participant said, similarly, that a proposer should come up with a plan and a budget, with room to make innovations on the business plan, technical plan, and system. Dr. Diniega suggested a budget decision framework that would push out planned future missions until the communication network is at some level of stabilization. Dr. Godwin noted that mission delays also cost money. Mr. Weiser liked the "road tax" idea, in that NASA needs to pull in all the stakeholders and solve this dire problem The public voice may have a greater impact in this case. DSN is definitely an international science and space issue. Dr. Williams agreed that the SC can't be prescriptive, but it must make some severe commentary. Dr. Cerf suggested that SMD should make the case to NASA HQ that SCaN/DSN is fundamental to SMD's success. The ideal outcome for SCaN overall is that its investments will result in an interoperable system for both commercial and governmental space communications, so that the eventual integrated network meets everyone's needs. In addition, Dr. Cerf recommended that the National Space Council be briefed on the matter. Can they take up the charge? Seems we need allies; in the end it is the PBR that must meet the needs. Dr. Williams said she would be happy to take these strong recommendations up to the NAC. Dr. Godwin felt DSN/SCaN needed stronger advocacy, perhaps from a different source. Mr. Weiser asked if an interagency discussion would be useful. Dr. Cerf noted that the DSN Futures Study is supposed to address the broad question of what DSN could look like in 2050; the SC could recommend an architectural approach be part of this study. In addition, Dr. Cerf felt the communications system should be another kind of mission, a "multimission mission." NASA has always used a mission-centric view of communications, which misses the concept of a multimission infrastructure. If the ground system and the space system are independently implemented, they don't get coherent results. Relegating the responsibility for communications to each individual mission misses the idea of a system-centric view. Dr. Tucker agreed that the issue goes beyond architecture and is more of a systems engineering problem. She added that the National Space Council (NSC) (which includes former NASA Administrator Charles Bolden) is largely made up of companies that are supplying spacecraft, rockets, etc., but not necessarily those using DSN. Dr. Cerf felt that as NSC is concerned with space strategy and policy, it is the right target to voice concerns.

Mr. Weiser commented that there are some people in the Administrator's office that the SC might engage, such as the new Chief Technology Officer (CTO), or maybe the Chief Scientist, and the leaders of each of the Centers.

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Mr. Boll re-opened the meeting and re-introduced the Chair, Dr. Williams, who reviewed the day's agenda.

NASA SMD Initiatives to Lower the Boundaries to Science Research: ESD Activities
Dr. Manil Maskey addressed ESD efforts in improving access to NASA science data. There are four pillars to the approach: the Trilateral Earth Observation Dashboard, VEDA, EIC, and the AI Foundation Model. Each pillar plays a crucial role in reducing barriers, but there are many other efforts in all the discipline sciences within SMD.

The Trilateral EO Dashboard is a NASA/ESA/JAXA effort that was created in early 2020 as a means to observe the environmental impact of COVID lockdowns. The Dashboard had multiple objectives: to demonstrate the joint capabilities of the three agencies to observe COVID- 19's impacts from space; convey indicators to the general public and decision makers; and maximize the value of curated information, engaging the wider public via outreach and competitions, such as hackathons. Key achievements to date include a rapid data release (three-month turnaround); presentation of indicators from 12 EO missions; achievement of a global presence (146 countries) and global awareness with access across the world; and citations by 251 websites; and participation with a number of community organizations, such as AGU. In late 2021, the three agencies agreed to continue and expand the Dashboard, including aligning activities around Open Science goals.

The Dashboard user community is large and diverse, and includes software developers, journalists, and policy makers. In May 2023, the Dashboard was recognized with special award at the International Astronautical Federation (IAF), for its exemplary use of remote sensing data. NASA has used components of the Dashboard to create Visualization, Exploration, and Data Analysis (VEDA), which brings together ES data sets and Open Source tools into a managed and more accessible computing environment. VEDA also takes advantage of Earth Science data that is being moved to the commercial Cloud environment. VEDA has an Explore feature that helps users find relevant data products, and interesting features; an Analyze feature that allows users to carry out computations in place without having to download data, and dynamically allocates resources. VEDA's Publish feature conveniently delivers data through existing interfaces, and the Communicate feature provides User friendly data-driven storytelling capabilities, as well as the ability to enrich science and applications narratives with interactive exploration. Capabilities supported by VEDA include the EIS, the Environmental Justice Initiative (EJI), US Greenhouse Gas Center (to be released soon), as well as the Trilateral EO Dashboard.

The Geospatial AI Foundation Model was created as a response to the widespread adoption of Artificial Intelligence (AI) in the science community, as well as to the evolution of AI itself. AI foundation models are pre-trained on a comprehensive dataset and used for various downstream tasks; and are aimed at substantially reducing the downstream effort for building AI applications, including the need for large, labeled training datasets. Creating a foundation model includes data

curation, training, validation, and large-scale computation. AI challenges and bottlenecks in Earth Science were identified as lack of large training sets, and generalization of models across space and time. Marshall Space Flight Research Center collaborated with IBM Corporation to develop the first Geospatial AI foundation model, which is now openly available at Hugging Face [[https://huggingface.co/]]. Thus far the model has been used for burn-scar mapping, flood detection, and multi-temporal crop identification. Currently there are 75 clones of the model, and several apps have already been built by community. Dr. Maskey cautioned that the apps are preliminary, and can be improved through continued in-house implementation, without using excessive resources.

Dr. Maskey briefly discussed NASA's Earth Information Center, which includes a Hyperwall that displays real-time Earth Science data, and an "Earth Pulse" feature. There will be an installation of the EIC at the Smithsonian and Kennedy Space Center later in the year. The key takeaways for the four pillars of lowering access to science are:

- Open data and open platforms ease scientific research barriers
- Standards and interoperability enable wider collaboration and maximize data use
- A core set of services based on open-source software offers agility needed for priority initiatives/projects
- Strategic partnerships accelerate research, especially through access to computation and technical expertise
- Community involvement enhances equitable and impactful scientific future

Dr. Curt Niebur addressed Planetary Science Division (PSD) efforts in lowering barriers to science access, noting first that NASA really stands out in government agencies for excelling in this area. PSD is engaging in novel science outreach efforts, such as the Europa Clipper Message in a Bottle campaign, in which the public is invited to submit their names, as well as poems, to include aboard the Clipper spacecraft. The US Poet Laureate was invited to craft a poem for the occasion as well, which was read at the Library of Congress. Dr. Niebur described the ceremony as quite moving and very well-attended.

Science engagement is about bringing diversity to planetary science, which is still very white male in nature, despite decades of effort. The Clipper Next Generation Initiative is looking to grow the next generation of science leaders and match the diversity of the science teams to the diversity in the US as a whole. Europa Clipper launches in 2024 and won't arrive at Europa until 2031. An extended mission will begin in 2035, providing a unique opportunity to "grow the scientists" needed to lead this mission in 2035. NASA is making sure it provides the steppingstones to sustain and train these new scientists. A key part of the process is mentorship; thus, the plan is for the Clipper science team to provide mentoring to these up-and-coming scientists. On this note, Dr. Niebur noted that mentoring is not free.

Here to Observe (H2O) is another initiative that opens doors to PSD missions, with the goal of sparking and maintaining an interest in planetary science for underrepresented students who are considering STEM careers. H2O was spearheaded and managed by Dr. David Smith. The pilot, originally associated with two planetary missions, was extremely successful, and NASA is

expanding H2O to six other NASA missions and has already paired up six undergrads at six institutions.

Dr. Tom Statler detailed activities for NASA's Asteroid Autumn, which will include public messaging about why asteroids are important. NASA has visited or is about to objects from the Main Asteroid Belt, Near-Earth Asteroids, Jupiter Trojan Asteroids, Centaurs, and the Kuiper Belt Objects (KBOs). DART and OSIRIS-REx targeted the Near Earth asteroids. Psyche will target the Main Asteroid belt. Lucy will visit Jupiter's Trojan asteroids, and New Horizons visited KBOs (and Pluto). Autumn mission milestones (slide). OSIRIS-REx will return samples from Bennu and will be touching down in Utah on 24 September. To date, the OSIRIS-REx mission has supported 150 undergraduates and 22 graduate students at the University of Arizona (the PI institution), where undergrad enrollment is at least 25% Hispanic.

The Psyche launch period opens on October 5, 2023. Psyche seems to be a unique object and is believed to be a possibly metallic core of a protoplanet. The spacecraft arrives at Psyche in 2029. The mission already has heavy student collaboration; the Senior Capstone program is in its sixth year and has engaged 1350 undergrads at 20 universities. The program includes an Innovation Toolkit, free online courses that include taking students through the process and life cycle of a space mission and providing teaching tools for building a positive team culture.

The Double Asteroid Redirect Test (DART) is coming to the end of its mission coming on 30 September, a year after impact. All DART and LICIACube data have been submitted to the Planetary Data System (PDS) in anticipation of release; thirty days after the data release, the community can then use the data to propose to ROSES. DART was also the subject of an article recently published in Nature. The DART Boarders Program was created to help students participate in Science Team meetings, with each student paired with a DART co-I. Dr. Statler thought the program was very successful.

Lucy will encounter the Main Belt Asteroid Dinkinesh for an engineering test on 1 November and will swing around Earth for a second gravity assist in 2025, after which it will visit a number of other asteroids before mission's end in 2033. NASA created the Lucy Student Pipeline Accelerator and Competency Enabler (L'SPACE), in which students can choose one of two academies, once per semester: the Mission Concept Academy (MCA), which provides skills training from NASA scientists and engineers, and the opportunity to collaborate with other students to design a mission-related team project, or the NASA Proposal Writing & Evaluation Experience Academy, which provides the experience the process of writing, reviewing, and scoring proposals through the lens of a NASA reviewer. Students can then compete for a $10,000 prize to continue developing the idea. Lucy is also part of the H2O program. L'SPACE program metrics to date include engagement through the Art-Science Interface, which produced Psyche-Inspired musical arrangements, and a Lucy Soundscape.

<u>Discussion</u>
Dr. Williams was pleased to see all the new ideas. Dr. Diniega applauded the release of the data and the higher-order data models and speculated about the consequences of the Open Science policy, including concerns about licensing, and guidance for individual researchers. Does NASA have a template for these researchers to use? Dr. Maskey said that NASA follows SPD 41-a

guidelines for source code and the like but was unsure whether there is a template. Dr. Diniega asked: how much are you engaging with individual researchers in the Earth Science community? Dr. Maskey said the intent is to allow or enable the community to develop novel applications, which can be enhanced by broader communication mechanisms offered by open platforms and growing with like-minded partners. Dr. Cerf asked if there was any expectation to expand the Trilateral Dashboard beyond its current partners. Dr. Maskey said that there had been much interest from other agencies during COVID, as well as outreach efforts through NASA. The Dashboard is evolving, and the Indian space agency (ISRO) has shown desire to join. Dr. Cerf asked about standardization of data sets. Dr. Maskey said that there have been several workshops that have brought in socioeconomic data sets to join with Earth Science models, which can be accessed under the public contribution icon on the Dashboard website. Dr. Cerf commented to Dr. Niebur that his described approach to the "non-geek" public was very impressive and took note of his passion for the subject. He thought the Clipper Next-Generation initiative was a good use of the mission's long-lead time and noted that many other missions have similar timelines. Dr. Cerf said there were two programs NASA should team up with to leverage diversity efforts: Team Up, an American Institute for Physics project whose goal is to double the number of Black Astrophysics students over the next five years), and InSTEM, a National Science and Technology Metals Foundation effort. Dr. Cerf asked how Bennu samples were being returned. Dr. Niebur said the sample return approach (sample entry through Earth atmosphere with parachute deployment) has been proven successful time and again, and that there would be a big difference between MSR and asteroid samples. Dr. Cerf strongly endorsed the use of the arts in engaging the public, and also asked if NASA would ever get away from superclean assembly for space probes. Dr. Niebur said there are two reasons for cleanliness (eliminate contamination and protect sample for science) but said he could imagine that someday NASA would visit a location that does not require cleanliness. As to arts engagement, Dr. Niebur noted that for diversity and innovation, NASA wants to create an environment to allow researchers to come up with creative ideas for science engagement. He thought that current efforts are finally allowing greater creativity. Dr. Statler commented that teams of students really excel when there is a cohort of students that can work together. He thought the final H2O project from University of Puerto Rico was spectacular and a true case in point for the importance of student cohorts.

Dr. Bakhtian commented to Dr. Statler that some programs seemed very "bottoms-up" and asked if there were a plan to have some cookie-cutter type programs, and to incorporate Lessons Learned. Dr. Statler said that things like Lucy Soundscape and DART Boarders were bottoms-up efforts, but L'SPACE was more of a two-way collaboration. The university hosting L'SPACE already had infrastructure in place, so there were some top-down efforts as well. Dr. Niebur felt it was NASA HQ's responsibility to create the framework and expectations for community involvement. Dr. Bakhtian suggested having a NASA playbook with principles, to create the ecosystem. Dr. Niebur said there are NASA missions already out there doing this type of engagement, and the intent is to avoid quashing creativity with government bureaucracy. Dr. Bakhtian worried about "dilution" from too many programs. Dr. Bakhtian asked Dr. Maskey if he used a set of principles for engagement, or definitions of desired outcomes. Dr. Maskey said that a bit of both top-down and bottoms-up efforts led to the AI Foundational Model. For the AI side, it was more of a bottoms-up effort, which then drove some strategic initiatives. Metrics are hard to do for *ad hoc* activities, however. Once the Foundational Model was deemed successful, it became part of the strategy.

Dr. Bakhtian worried that people don't know where to go to find the data and asked if there were some sort of Master Portal for these outreach efforts. Dr. Maskey thought that there was an effort to afoot to centralize some of these sites and agreed that are too many portals. Dr. Bakhtian commented to Dr. Niebur that it was a great idea to homegrown researchers for the Europa Clipper mission and asked how NASA could ensure that participating students would follow a planetary path. Dr. Niebur said it was not possible to ask a college sophomore whether he or she will be a planetary researcher, and would settle for: "this sounds neat, I will try it." NASA's job is simply to make sure the steppingstones exist. Dr. Diniega noted that many people who enter planetary science go on to other STEM careers and added that the Apollo era is often credited for creating the IT/coding career path. Dr. Niebur said it was important to demonstrate what the career path looks like. He said he had learned from the University of Puerto Rico H2O experience that parents were not necessarily supportive of a planetary researcher career; they were concerned about ability to support family. When NASA goes back to Puerto Rico, the plan is to better engage with the families of participating students, to acknowledge cultural influences as well as educational ones. Dr. Bakhtian mentioned a National Park Service Summer Science Program, a high-school level sleepaway camp that provides experiences like tracking asteroids; it was shown to greatly increase the number of students in STEM. Dr. Niebur said that MUREP is already associated with the National Park Service science programs. Mr. Weiser urged panelists to identify the best engagement strategies and expand them, and to avoid reinventing the wheel; note the failures but keep the knowledge. He added that there should be a master list of what people are doing and encouraged Dr. Maskey to work with Kevin Murphy's Science Discovery Engine. Dr. Maskey said he was part of the SDE and works closely with Dr. Murphy.

Dr. Tucker asked panelists to comment on how often students step away, and how to build on the cohort solution. Dr. Niebur added that bad mentoring is an additional dimension to the problem. He felt that financial compensation was important here; NASA can't expect these students to do internships for free. There should be good-sized compensation. Also, students can participate remotely; it's not necessary to get a NASA badge. Many students don't have the luxury of relocating or working for free. Dr. Diniega asked if mentors are being trained to recognize cultural sensitivities. Dr. Niebur said that NASA was funding workshops on this subject at present and agreed that part of the NASA funding for these mentors must be devoted to training in this area; NASA does not have the expertise and recognizes it. Dr. Diniega asked if H2O and other programs had codes of conduct, to outline expectations of behavior. Dr. Niebur said the fact that NASA needs these rules is disturbing, and that the effort to implement codes of conduct is largely bottoms-up. Dr. Michael New, SMD DAA for Research, is attempting to implement a Code of Conduct, but Dr. Niebur felt it would be necessary to change the terminology. Dr. Statler said that the missions have been very proactive about implementing their own codes of conduct; it doesn't always have to be a top-down effort. Dr. Niebur said that "Code of Conduct" is now part of the proposal language. Dr. Diniega commented that the "don't be a jerk" approach is not sufficient because the definition changes over time, which is why a framework is important. Dr. Niebur agreed and noted that two sociologists are studying NASA teams right now. Dr. Diniega asked if some of the existing teams be asked to develop inclusion plans, and if so, NASA could evaluate them and adopt as templates, if successful. Dr. Niebur said that NASA is close to developing language for inclusion plans. Dr. Tucker observed that more privileged universities can write better proposals, which is why it is so important to help underserved

students understand how to write papers and choose topics. Dr. Niebur NASA recognizes that this will be necessary, and that submitting a successful proposal is tantamount to a technical achievement (re: Paul Hertz). Dr. Niebur credited JPL, Dr. David Smith, and others, for the success of engagement/outreach programs to date.

DAC Reports

Biological and Physical Sciences Advisory Committee (BPAC)

Dr. Foster, Biological and Physical Sciences Advisory Committee (BPAC) Chair, said the newly re-organized Committee was still waiting for its charter to be signed, and will formally meet for the first time in October. She gave highlights of program, formerly part of the human exploration program. Dr. Lisa Carnell was appointed a month ago as Deputy Director of the Biological and Physical Sciences Division (BPSD). The BPS mission is devoted to pioneering science discovery and enabling human space flight exploration, involving much expertise in ground-based laboratories and experiments in low-Earth orbit (LEO), studying the ways in which spaceflight affects living systems using numerous organisms and platforms. On the International Space Station (ISS), projects growing *Arabidopsis* in lunar soil (taken from Apollo samples) have shown significant growth differences between plants grown in lunar simulants and lunar soil. Other experiments are testing the growth of food crops in microgravity. As ISS reaches capacity, BPS is beginning to increase efficiencies in preparation for fitting payloads with commercial destinations. Physical sciences are also the purview of BPS, including biophysics, combustion phenomena, and materials sciences. One exceptional outcome in this area is the Cold Atom Laboratory (CAL) aboard ISS, which has demonstrated the creation of Bose-Einstein condensates in the absence of gravity. It is not certain whether the CAL will transition beyond ISS to a commercial destination, or whether it can attract collaboration or funding from other agencies. BPS is very small, funded at under $100M per year, but has a strong commitment to Open Science, as reflected in open platforms such as the Task Book, an online resource which features current and upcoming research projects, and GeneLab, a source for molecular biology, "omics" data and metadata. A BPS Decadal Survey will be released on 12 September and will offer guidance to the division going forward. Dr. Diniega asked if BPS had sufficient connections with the lunar and Mars communities. Dr. Foster said that there is much lunar science expertise on the current committee and expected that the DS will weigh in on these necessary collaborations.

ESAC

Dr. Tucker presented an update on the Earth Science Advisory Committee (ESAC), which held its last full meeting in October 2022; its next meeting will focus on a government performance review in October of this year. There is no recent status report from ESAC. Dr. Tucker provided science highlights in lieu of an ESAC status report. The Earth Science fleet continues to carry out a tremendous amount of work, many details of which can be accessed through EIC's Eyes on the Earth app (https://eyes.nasa.gov/apps/earth/#/). The TROPICS mission is demonstrating multiple small satellite microwave sounders. The Earth System Explorer competition had its proposals submitted on 2 August and will focus on Earth System Observatory targeted observables (atmospheric winds, ice elevation, etc.), recommended by the DS. NASA can select up to four proposals from this competition, but one selection must cover greenhouse gases. The recently launched NASA TEMPO mission is a geostationary spectrometer that can scan across

the US about once an hour and monitor several trace gases (NO2, ozone, formaldehyde), which will result in better understanding of the diurnal cycles for these species. Atmospheric winds monitoring is important for forecasting and can be selected if it is proposed. Dr. Tucker said she had a strong interest in the subject, especially since there are new ways to increase observations of these winds. NASA has worked very hard to demonstrate how important Earth Science is to climate change/weather. Dr. Tucker agreed that ESA's AEOLIS program has had incredible impact on forecasting, but NASA is not working toward this type of system, specifically. Dr. Williams expressed surprise that the ESAC has been unable to meet, and asked Dr. Tucker what she would have liked the ESAC to have addressed. Dr. Tucker said that the execution of the Earth Science DS was a major subject of note to be addressed by the ESAC.

Planetary Science Advisory Committee (PAC)

Dr. Diniega, Chair of the Planetary Science Advisory Committee (PAC), touched on OSIRIS-REx, Psyche, the first CLPS launches to the Moon, and the progress of the Europa Clipper mission (currently being livestreamed from the High Bay). The Near-Earth Object (NEO) Surveyor is still on path for launch in 2028. The last PAC meeting was held in June, and the next meeting will be in November; it will be the last meeting for three members, including Dr. Diniega herself.

At the most recent meeting, the PAC discussed the uncertainties about the federal budget, which led to some specific findings regarding budget challenges. These findings included: protect and continue to grow the Research and Analysis (R&A) program; support ongoing confirmed missions; and support missions that have been selected (including a re-start of the Venus mission, VERITAS). While the PAC endorsed these budget priorities, there was much disappointment that the New Frontiers Announcement of Opportunity (AO) has been delayed. PAC also requested regular reports on budget impacts, including Mars Sample Return cost management plans, and concern about the continuing cost growth in MSR. Currently, the community is waiting for an Independent Review Board (IRB) to develop a better estimate for MSR. The PAC also recommended that PSD provide early study funds for the Uranus Orbiter and Probe, and the Lunar Endurance Rover. The PAC also discussed the use of Extended Missions (EM) as part of the budget considerations.

Other PAC findings include a recognition of new elements in R&A starting in FY25, budget permitting; a new fieldwork policy (Dr. Diniega invited PAC to read briefing slide at length); an Inclusion Plan requirement definition and attendant communications; and a statement of issues identified by the Psyche IRB, including an Agency internal review of the Standing Review Board (SRB) process. FY25 new programs; Mission: IDEA (slide). Next meeting in November will include status reports from PSD, MEP, MSR, community AGs, R&A update, PDCO, Astrobiology RCNs, ESSIO/Lunar Science. Tentative- SRB review, MSR IRB.

Heliophysics Advisory Committee (HPAC)

Dr. Nicole Duncan, Chair of the Space Weather Council (SWC; a subcommittee to HPAC) reported for the HPAC Chair. There have been no HPAC meetings since November 2022, and a re-organization of the HPAC is ongoing. Dr. Duncan provided updates on SWC, which acts as a community-based forum to coordinate community input and provide advice to the NASA Heliophysics Division (HPD) via HPAC. HPAC has provided four tasks to SWC. Task 1 is to

examine the coordination between Space Weather groups: SWORM (interagency working group led by the White House), SWAG (academia, commercial space weather, and user group members), Roundtable (brainstorming group that generates ideas but no written suggestions or recommendations, and SWC. All these groups are interdependent and related, but they have different mechanisms for communicating findings, as well as different focus topics. At the time of the SWC evaluation, a Decadal Survey panel was also in place. SWC issued a number of findings associated with this task, and the Chairs of the different groups are working on a white paper that delineates the connection points in the space weather advisory space, to avoid conflicting guidance. Highlights from SWAG, SWORM, and Roundtable were provided to HPAC and included Lessons Learned, and best practices gleaned from research to operations to research (R2O2R) observations.

Dr. Duncan described Task 4, a call to examine R2O2R interagency coordination in Space Weather (SWx) AOs and decision-making, and also the roles of industrial partners. SWC is requesting that HPAC explore NASA-NSF collaboration opportunities, including the new NSF Technology Innovation and Partnerships (TIP) program, the Decadal Survey's output, and joint funding opportunities. Dr. Diniega asked if there were any subjects in SWC deliberations that could include DSN issues. Dr. Tucker observed that many Space Weather missions are closer to Earth, but many HP missions will need DSN, and that this may be a good point to add to the findings. Dr. Duncan agreed that SW and HP use DSN quite a bit, ranging from the Sun to beyond to interstellar space. She said she knew that missions submitted to the DS would heavily use the DSN and would need beyond-Earth-range communications. Dr. Cerf mentioned that in addition to NSF and TIP, there is an NSF Research Data Alliance. He asked, particularly as the solar maximum approaches, if there is a robust system in place for detection and warning for Space Weather events. Dr. Duncan said that while there is always room for improvement, warnings are well-covered at the baseline level. Several spacecraft are capable of providing those alerts, but they do rely on the DSN. She added that NOAA is building its first SWx satellite, which will have a dedicated ground system and a downlink for alerts. Dr. Williams asked how much HPAC is focused on SWx. Dr. Duncan said she felt it was a small focus that touches a broad base of science and communities. She said that the SWC would like to examine the connections between international and domestic roles and would also like to see a more thorough gap analysis for SWx; she felt there was significant gap analysis needed for modeling. There is concern in the community that current models cannot capture what very extreme events look like, and that there may be an opportunity to improve models based on historical events. There is also a concern for defining roles and responsibilities for operations and research. Who is responsible, for instance, for the safety of commercial-crewed missions in the event of SWx events? Dr. Tucker said she liked the discussion of how the committees fit in the overall structure, how the work fits into the larger context, beyond the US to global and the importance of noting the integral roles of the international community.

<u>Astrophysics Advisory Committee (APAC)</u>

Dr. Kelly Holley-Bockelmann, Chair of the Astrophysics Advisory Committee (APAC), provided details of APAC's most recent meeting, in late June. SpaceX launched the ESA/NASA Euclid mission on 1 July; Dr. Holley-Bockelmann displayed a commissioning image taken by the NASA instrument, a near-infrared (NIR) spectrometer/photometer. The JAXA XRISM launch is imminent, pending cooperative weather. Euclid and XRISM illustrate the importance of

international partnerships to APD. NASA's Open Science/Open Data policy can cause some conflicts with international partners, however. Euclid had negotiated a limited number of US members in the consortium, contrary to SPD-41a principles, which has been noted by APAC. The hope is to have more equity and inclusion in future international joint ventures.

At APAC's last meeting, members discussed Time Domain and Multimessenger Astronomy (TDAMM), Open Science, and the maturation of APD's Great Observatories. The last Astrophysics DS did not recommend a Flagship mission but recommended that APD get its technology ready in ultraviolet, optical, infrared and X-ray to prepare for the next Flagship mission. The priority would be an optical mission, the Habitable Worlds Observatory. The Astro2020 DS recommended TDAMM as the highest priority, with an investment of $500-$800M this decade. TDAMM activities in APD thus far include a TDAMM workshop, which issued a white paper, and the creation of a cross-PAG SAG. APD is also discussing infrastructure investment (DSN, centralized alerts, coordination with NSF, MMA software), and recasting its current fleet as TDAMM missions.

In March 2023, APAC issued a finding and recommendation expressing concern about the level of priority and funding for TDAMM, and recommended higher prioritization of TDAMM, first through a re-analysis of the current portfolio, and an evaluation of data analysis tools. In June, APAC issued another finding and recommendation, with a finding recognizing the TDAMM work that has already been done by Fermi, Swift, and NuStar. APAC recommended that APD develop a mitigation plan for the aging fleet of TDAMM capabilities, and to prepare a long-term strategy to prioritize TDAMM within the budget profile. Dr. Williams asked about any small mission recommendations from Astro2020. Dr. Holley-Bockelmann said that some small mission AOs, such as Pioneers, were just cancelled, as were CubeSat opportunities, but that there are other small missions that are going forward. She thought there would be a downselect from four missions. Also under way is an effort to improve SW alerts from existing APD assets (e.g., Swift and gamma ray burst detection).

Public Lecture: Heliophysics Big Year

Dr. Therese Jorgensen, Acting Deputy Director of the SMD HPD, introduced a lecture on NASA's current initiative, Heliophysics Big Year, delivered by Dr. Gina DiBraccio. The Big Year will celebrate two upcoming solar eclipses, an annular eclipse on 14 October, and a total eclipse on 8 April 2024. NASA has created an online map showing the path of the eclipses across the continental US. These will be the last of the US-visible eclipses until 2045. NASA is providing many Heliophysics Citizen Science opportunities and encourages everyone to travel to view the eclipses. The Big Year will close out with Parker Solar Probe's closest approach to the Sun (4 million miles, or 9 solar radii). PSP will enter the corona of the Sun. The next Heliophysics DS will be released in 2024. Solar maximum expected in 2025, but the current activity of the Sun already exceeds what is expected in solar max.

NASA aircraft will be chasing the totality path and will obtain about 6 minutes of observations. There will also be airborne NIR imagery, which will enhance the understanding of the solar wind composition, topology of magnetic fields, dust ring around the Sun, and the search for asteroids near the Sun. Ham radio Citizen Science participants will study eclipse impacts on radio signals with a "Listening Party." Three instrumented sounding rockets will be launched for each eclipse,

as well as balloon payloads. In the meantime, the HPD fleet continues to grow. The Atmospheric Waves Experiment (AWE) will launch to ISS, where it will measure atmospheric gravity waves in the infrared help obtain global understanding of how terrestrial weather affects space weather in a dynamic region of Earth's upper atmosphere. Escape and Plasma Acceleration and Dynamics Explorers (ESCAPADE) will launch to Mars during the Heliophysics Big Year, where it will observe how energy and momentum are transported from the solar wind through Mars' magnetosphere, and what processes control the flow of energy and matter into and out of the atmosphere. ESCAPADE is a good complement to the MAVEN mission.

Asked about the high-resolution Daniel K. Inouye telescope on Haleakala (DKIST), Dr. Jorgensen said that while the telescope is owned by NSF, it will of course play a role in the Big Year, in just one of many collaborations that will occur. Individual research groups will use the resultant data, and part of the new Heliophysics DS will be devoted to the integration and use of data. Dr. DiBraccio stressed the importance of cooperation amongst the ground-based communities, NSF, DOD, and other agencies during the Big Year. Asked if any Lessons Learned were being incorporated into HPD, Dr. Jorgensen said that these are very much part of current data analysis and modeling efforts. The Heliophysics Data Resource Library is just one example. Dr. Nicola Fox added comments on the close work and joint solicitations that are ongoing with the NSF telescope, and how they are incorporating Lessons Learned from all the SMD divisions. Dr. Diniega asked if there were plans for incorporating more diversity and inclusion in HPD and bringing more students into this line of work. Dr. DiBraccio said the most recent HP Senior Review included IDEA statements, which described how missions were providing an inclusive environment, generating ideas for succession planning, and how to train the next generation. She said she knew that PSD was doing great work in this area, and that HQ is pushing these efforts as well. Goddard Space Flight Space Center (GSFC) has its own IDEA lead who is connected to the HBCUs and MSIs. Dr. Jorgensen added that IDEA is a review criterion for everything HPD does. Dedicated Citizen Science opportunities are also helpful here. Dr. DiBraccio said that Early Career funding were also useful in this area. Dr. Diniega encouraged NASA to increase its engagement with HBCUs and MSIs that are in the path of totality. Dr. Jorgenson said she believed that is something already being incorporated.

Public comment period
No comments were noted.

Discussion
Ms. Joy Burkey read out her notes and the Committee refined findings and recommendations.

The SC's two main findings were:
1. Oversubscription and deferred maintenance, and poor prioritization of usage of the DSN is the biggest threat for space exploration.
2. Past IDEA efforts are important steps, but continuing strategies must include cohorts, mentors, and culture considerations.

Recommendations
Show DSN funding needs over time

Alternative sustainable DSN model
Where is advocacy for DSN funding
Capture IDEA practices
Use existing funded IDEA programs
Centralize and share list of all satellites related to climate change
Create DS on communication engineering
Discuss at next NAC: share SMD approach to incorporate IDEA
Share NASA approach to balance innovation and risk (e.g., CLPS)
What does CLPS success look like? What is the measure of success? (Weiser)
Identify a plan to preserve the integrity of planetary bodies re: exploration
Centralize the SW information portal
Lower the Boundaries initiatives could benefit from overarching set of principles, Lessons Learned, best practices, etc.

Dr. Tucker suggested a finding on identifying the true cost of CubeSats to DSN, in terms of time and opportunity costs. Dr. Weiser noted that tech demo CubeSats are different from those that are part of established missions (e.g., Mars). Dr. Cerf said the SC might recommend that the DSN become part of a public/private, multi-stakeholder, sustainable Solar System Internet. NASA/SMD might want to inject this concept into the DSN Futures Study.

Dr. Williams suggested a finding noting the fact that neither the ESAC nor the HPAC have met in the last year. Dr. Bakhtian felt that the definition of risk should be used in a way that everyone understands, with respect to the CLPS discussion. Dr. Cerf asked: what happens when commercialization occurs in the lunar program? How is science protected in this case? Do the Artemis Accords address this? Dr. Williams asked: what is the SMD climate change strategy for present and future missions and programs? Dr. Tucker asked: what is NASA doing for the country and the world, with regard to climate change? She suggested the SC ask the NAC for a review of the advisory committees. Dr. Diniega suggested a finding on developing more standardization of the advisory committees and added that having a POC for a Lowering the Barriers repository of best practices could also be useful. Dr. Williams suggested requesting a future SC topic on the number of SMD small projects/programs that are not going forward this year. Dr. Diniega commented that while certainly new efforts have been deferred, these decisions have been consistent with DS recommendations. Dr. Tucker said that it is true that a number of missions are being delayed, but that many others are still going. This could be a topic for a future discussion on budgetary challenges.

<u>Debrief to SMD AA</u>
Dr. Williams presented preliminary findings and recommendations to Dr. Fox. In response to SC findings on the DSN, Dr. Fox agreed that the DSN state of affairs is shocking, and that prior efforts to address the issue have been tantamount to "duct tape and bandaids." She asked for specific solutions and recommendations and said that SMD has been getting its needs accurately documented, and recently made a status presentation to OMB on this topic (but not a budget pitch). She saw the SMD role as supportive of the Space Operations Mission Directorate (SOMD) in their requests as well. Dr. Cerf commented that SMD is deeply dependent on DSN, which is now incapable of supporting all SMD missions, thus it is clearly in SMD's interest to advocate for change. Secondly, SMD has an interest in growing a [communications] capacity

that is not dependent on DSN (e.g., Solar System Internet concept), so it's in SMD's best interests to support the DSN Futures Study. Dr. Fox said she resonated with the Internet concept, and thought it was the right way to think about it. Ms. Connelly noted that there are pros and cons associated with all the recommendations. Dr. Williams said she hoped to bring these recommendations on the DSN to the NAC, because DSN is a NASA-wide issue. Ms. Connelly commented that NASA/SCaN does have plans to cover all communications needs, and not just DSN, but she conceded that DSN will need funds for investment.

In response to SC's finding on how the exemplary Lowering the Barriers (LTB) projects might benefit from a set of principles, a centralized repository and a point of contact to capture consolidated best practices, Dr. Fox agreed, and commented that NASA's Bridge program, and its many activities in general STEM outreach, are also related to LTB efforts.

Dr. Williams and Dr. Fox discussed findings on the two advisory committees that have not met for the last year, as well as recommendations for topics for the next meeting: balancing risk; the status of protecting planetary integrity; SMD's climate research strategy; and the philosophy and execution of advisory committees. Dr. Fox- concurred with these comments, adding that HPD had been busy with resolving conflicts of interest for Decadal Survey panels, and is now reconstituting HPAC. She welcomed thoughts on the advisory committee situation and felt it could be resolved through a dialogue instead of a presentation. Ms. Connelly suggested that Dr. Karen St. Germain present on NASA's climate strategy. Ms. Connelly listed completed actions, including a working link to the EIC, and the status of the Science Discovery Engine. Dr. Fox expressed her appreciation for the Committee's time and advice.

Mr. Boll adjourned the meeting at 6:02 pm.

Appendix A
Attendees

Science Committee Membership
Ellen Williams, **Chair**, University of Maryland
Noël Bakhtian, Bezos Earth Fund
Vinton G. Cerf, Google
Serina Diniega, JPL
Jamie Foster, University of Florida
Linda Godwin, University of Missouri
Kelly Holley-Bockelmann, Vanderbilt University
Sara Tucker, Ball Aerospace
Marc Weiser, RPM Ventures
Nathan Boll, NASA, Designated Federal Officer

Other Attendees

Alexandra Witze
Alina Bedrossian
Ashlee Wilkins
Becky Castano
Bradley Williams
Carla de la Paz
Cynthia Dinwiddie
Christopher Caisse
Dann Garcia
David Gaba
David Millman
Dennis Feerick
Emmet Ryan
Erica Montbach
Francesco Bordi
Gerardo Orozco
Heather D. Smith
Jack Kiraly
Jani Radebaugh
Janine Harris
Jason Callahan
Jeff Foust
Jennifer Kearns
Joan Zimmermann
John D Rummel
John Huthmaker
Jonathan Rall
Joy Burkey
Kelsie Krafton
Kenneth Hansen
Kirsten Petree
Leonard Dudzinski
Lilibeth Delgado
Linda Karanian
Marcia Smith
Michela Munoz
Mike Robinson
Moses Milazzo
Noam Izenberg
Philip Baldwin
Richard Rogers
Richard Watanabe
Robins Mdoka
Sandra Cauffman
Sandra Connelly
Shannon Fitzpatrick
Stacey Boland
Stephen Clark
Sylvie Espinasse
Tammy Dickinson
Tim Crain
B Harvey
John Huthmaker
Richard Watanabe
Lilibeth Delgado
Heather D. Smith
Kennda Lynch
Max Bernstein
Carla De La Paz
Tom Statler
Manil Maskey
Jamie Foster
Lori Glaze
Ryan Park
Julie Rathbun
Jennifer Kearns
Jeff Foust
Richard Rogers
Pamela Whitney
Kelsie Krafton
David Sheely
Irma Rodriguez
Yogita Shah
Andrew Rowe
C. Alex Young
Mike Robinson
Sheri Klug Boonstra
Robins Mdoka
Erica Montbach
Matthew McClure
Theodore Kronmiller

Hope Ishii
Francesco Bordi
David Sheely
Nicole Duncan
Eric Smith
John Wisniewski
Dennis Feerick
Janet Kozyra
Diane Rausch
Ryan Hickox
Sky Bischoff-Mattson
Kunio Sayanagi
Abigail Conners
Alvin Robles
Peg Luce
Corey Cochrane
Andrea Hughes
Ha-Hoa Hamano
Nicky Fox
Griffin Lewis-Burke
Jessica Lopez
Nathaniel Freeman
Erica Alston
Liz MacDonald
Mary Slade
Sandra Connelly
Joan Zimmermann

Appendix B
NAC Science Committee Membership

Dr. Ellen Williams
Chair, University of Maryland

Dr. Noël Bakhtian
Bezos Earth Fun

Dr. Vinton G. Cerf
Google

Dr. Serina Diniega
NASA Jet Propulsion Laboratory

Dr. Jamie Foster
University of Florida

Dr. Linda Godwin
University of Missouri

Dr. Kelly Holley-Bockelmann
Vanderbilt University

Dr. Sara Tucker
Ball Aerospace

Mr. Marc Weiser
RPM Ventures

Mr. Nathan Boll
Designated Federal Officer, NASA HQ

Appendix C
Presentations

1. Science Mission Directorate Update; *Sandra Connelly*
2. Deep Space Network Panel; *Philip Baldwin, Suzanne Dodd, Sandra Cauffman*
3. NASA SMD Initiatives to Lower the Boundaries to Science Research; *Manil Maskey, Curt Niebur, Tom Statler*

Division Advisory Committee Reports

4. Astrophysics Advisory Committee (APAC); *Kelly Holley-Bockelman*
5. Biological and Physical Sciences Advisory Committee (BPAC); *Jamie Foster*
6. Earth Science Advisory Committee (ESAC); *Sara Tucker*
7. Planetary Science Advisory Committee (PAC); *Serina Diniega*
8. Heliophysics Advisory Committee (HPAC); *Nicole Duncan*

9. Heliophysics Big Year! *Therese Jorgensen, Gina DiBraccio*

Appendix D
Agenda

Public Agenda Day 1

Tuesday, August 29, 2023 (Pacific Time)

9:05-9:10	Call to Order	Nathan Boll
9:10-9:15	Introduction of Members/Summary of Activities	Ellen Williams
9:15-10:15	SMD Update Sandra Connelly, Deputy Associate Administrator, Science Mission Directorate	
10:15-10:30	*Break*	
10:30-12:00	Deep Space Network Panel Discussion Philip Baldwin, Acting Director, Network Services Division Suzanne Dodd, Director, Interplanetary Network Directorate, JPL Sandra Cauffman, Deputy Director, SMD Astrophysics Division	
12:00-1:00	*Lunch*	
1:00-2:00	Committee Discussion	
2:00	*Adjourn*	

Public Agenda Day 2

Wednesday, August 30, 2023 (Pacific Time)

8:30-8:35	Call to Order	Nathan Boll
8:35-8:40	Summary of Itinerary/Introduction of Panelists	Ellen Williams
8:40-10:10	NASA SMD Initiatives to Lower the Boundaries to Science Research Manil Maskey, Senior Research Scientist, SMD Earth Science Division/OCSDO Curt Niebur, Lead Scientist for Flight Programs, SMD Planetary Science Division Tom Statler, Program Scientist, SMD Planetary Science Division	
10:10-10:30	*Break*	
10:30-12:00	Division Advisory Committee (DAC) Reports Kelly Holley-Bockelman, Astrophysics Advisory Committee (APAC) Jamie Foster, Biological and Physical Sciences Advisory Committee (BPAC) Sara Tucker, Earth Science Advisory Committee (ESAC) Serina Diniega, Planetary Science Advisory Committee (PAC) Nicole Duncan, Heliophysics Advisory Committee (HPAC)	
12:00-12:30	*Break*	
12:30-1:15	Public Lecture: *Heliophysics Big Year!* Therese Jorgensen, Acting Deputy Director, SMD Heliophysics Division Gina DiBraccio, Deputy Director, GSFC Heliophysics Science Division	
1:15-1:30	Public Comments	
1:30-2:30	Committee Discussion	
2:30-3:00	Briefing to NASA	Ellen Williams Nicky Fox, Associate Administrator, Science Mission Directorate
3:00	*Adjourn*	

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On Tuesday, August 29, the event address for attendees is:
https://jpl.webex.com/jpl/j.php?MTID=m742b75802dbcf587c50a95bc7fed41b2
The event number is 2763 795 4022 and the event password is NACSC1 (622721 from phones and video systems). If needed, the U.S. toll conference number is 1-510-210-8882 and access code is 27637954022#622721#.

On Wednesday, August 30, the event address for attendees is:
https://jpl.webex.com/jpl/j.php?MTID=m2b6abac21fe56294e2edab2d93eddde6
The event number is 2763 503 8009 and the event password is NACSC2 (622722 from phones and video systems). If needed, the U.S. toll conference number is 1-510-210-8882 and access code is 27635038009#622722#.

**** All times are Pacific Time ****