ASTROPHYSICS ADVISORY COMMITTEE

April 24-25, 2017
NASA Headquarters
Washington, DC

MEETING MINUTES

June 1, 2017

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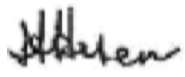
B. Scott Gaudi, Chair



June 1, 2017

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Hashima Hasan, Executive Secretary

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Prepared by Elizabeth Sheley
Ingenicomm

Monday, April 24, 2017

Introduction and Announcements

Dr. Hashima Hasan, Executive Secretary of the Astrophysics Advisory Committee (APAC), opened the meeting by welcoming the Committee members. She noted that a few APAC members had conflicts of interest with specific topics on the agenda. During those presentations, the conflicted members would be allowed to listen to the presentation, but they could not participate in discussion. Dr. Hasan then reviewed the Federal Advisory Committee Act (FACA) rules.

Dr. Scott Gaudi, APAC Chair, noted that this was the first meeting since the Astrophysics Subcommittee (APS) charter had been terminated and the APAC charter had been approved. Dr. Rachel Somerville had to step down as committee member and Vice Chair, due to other commitments, but all other APS members were now APAC members. APAC findings will go directly to the Director of NASA's Astrophysics Division (APD) instead of filtering up through the NASA Advisory Council (NAC) Science Committee.

Astrophysics Division Update

Dr. Paul Hertz, Director of APD, welcomed the APAC members, noting that APS had been newly chartered as a Federal advisory committee. As they now advise him, their letter with findings and recommendations should be addressed to him. He will respond at each meeting with an update on how APD is incorporating their advice. Dr. Gaudi added that he would take broader issues to the NAC Science Committee, which now focuses on topics that cut across the Science Mission Directorate (SMD) divisions. Dr. Hertz also thanked the members who agreed to extend their erstwhile APS appointments. Regular rotations will resume soon. He congratulated Dr. Natalie Batalha for being named as one of Time magazine's 100 Most Influential People, and noted that she is the first woman from NASA to be named to the list.

Science Results and Themes

One of biggest science results of the last few months was the discovery of seven planets orbiting TRAPPIST-1. This was the biggest NASA website and social media impact event since the beginning of social media, generating 3.2 billion non-unique views. Five of the top 10 Federal government Web pages during that time were NASA pages discussing the TRAPPIST planets. This means that NASA dominates the Internet when the Agency explains things well.

Dr. Hertz next showed 25 years of Hubble Space Telescope observations of Supernova 1987a, along with the multi-wavelength views from the Atacama Large Millimeter Array (ALMA) and Chandra X-ray Observatory. Other science highlights included determination of the age of the Milky Way galaxy's "Fermi bubbles," for which Hubble used quasar light to probe the outflow. The newest instrument on the Stratospheric Observatory for Infrared Astronomy (SOFIA) is the High-resolution Airborne Wideband Camera plus (HAWC+) imaging polarimeter. Hubble has looked at Europa's recurring plume. A Galileo heat map shows this to be the hottest area of Europa, indicating that these may be like geysers. There is no model to predict activity at this time, but that capacity would be valuable for the Europa Clipper mission.

Dr. Thomas Zurbuchen, the Associate Administrator (AA) of SMD, sees SMD as an integrated science organization with cross-cutting science. He believes there should be a place for all good science proposals. Dr. Zurbuchen's cross-cutting themes include: safeguarding and improving life on Earth; searching for life elsewhere; and, generally expanding our knowledge of the Earth, our Solar System, and our Universe.

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The new Deputy AA for SMD is Mr. Dennis Andrucyk, who had been Deputy AA for the Space Technology Mission Directorate (STMD). SMD now has all of its leadership positions filled. Dr. Hertz noted that this is not the case across all of NASA, and reviewed some of the open positions.

Funding and Legislation

At the time of the meeting, the Federal government was operating under a Continuing Resolution (CR) for Fiscal Year 2017 (FY17). This meant that APD budget was about the same as that for FY16. The James Webb Space Telescope is fully funded, as well as being on the plan for cost and schedule. Wide Field InfraRed Survey Telescope (WFIRST) formulation continued. A government shutdown was still possible. In the last government shutdown, NASA furloughed a high percentage of employees, and the Agency maintains a high bar for continuing work under a shutdown. As Webb would be between tests, APD would have nothing in a NASA thermal vacuum chamber that would warrant continuing work during a shutdown, but there were some items in contractor chambers, which would continue unless the contractors were to run out of Federal funding. The details of the FY18 President's Budget Request (PBR) were set to go to Congress in mid-May.

Dr. Hertz noted some of the astrophysics highlights from the NASA Transition Authorization Act of 2017. The Act includes language to balance the portfolio and follow the Decadal Survey (DS), notes the value of both Webb and WFIRST, and requires NASA to continue SOFIA through the end of 2017. The Agency now has 10 official purposes, as the Act added astrobiology. The Act changes the cadence of Senior Reviews (SRs) to every 3 years instead of every 2 years, which had been recommended by a recent National Academy of Sciences (NAS) study. NASA must contract with NAS to develop science strategies for astrobiology and for the study and exploration of extrasolar planets, and both reports were due in 18 months. There is also a requirement for a variety of other reports to Congress.

Research and Analysis (R&A) and Fellowships

Research and Analysis (R&A) funding is now just under $90 million, up about $12 million from 2010. Dr. Hertz presented graphics illustrating the relative sizes of APD's research areas. There is an agreement with the Planetary Science Division (PSD) to share funding of the Exoplanet Research Program (XRP). APD, which funds about 60 percent of XRP, tends to do spectroscopy and work that leads to observationally characterizing bodies. PSD funds theory, and interpretation of observations could be either division.

Dr. Hertz also showed graphics related to the budget, proposal pressure, and selection rates. For Research Opportunities in Space and Earth Science (ROSES) 2017, APD will begin alternate year calls for the Astrophysics Theory Program (ATP). APD will provide twice the amount of funding half as often as before, resulting in the same number of proposals funded at the same funding level, only with a

different cadence. There will be a second Theoretical and Computational Astrophysics (TCAN) call, though not with the National Science Foundation (NSF) this time.

There is a new process for the Roman Technology Fellowships (RTFs), as discussed at the last APS meeting. There were many early career proposers for the Astrophysics Research and Analysis (APRA) Program; such proposals are now a requirement for RTFs. Dr. Gaudi noted the APS recommendation that those proposals be judged by a different standard. Dr. Hertz replied that the reviewers will be informed which APRA proposers also applied for a RTF. There will be a separate review of RTF eligibility. He will ensure that there is a balance of early career proposers.

There is now a smaller number of astrophysics postdoctoral fellows overall. There will be a single selection process and a single application process. The new fellows will be called the Hubble Fellowships and there will be tracks accounting for what were previously the Sagan and Einstein fellows. The application will include a box for broad science themes. Applicants can check more than one theme for cross-cutting work. There will be no predetermined balance.

Dr. Gaudi thought that these points should be made very clear to the community. Some were surprised by the announcement, especially given that it was being enacted right away rather than having a grace period. Dr. Feryal Ozel added that she still gets questions about whether the fellowships are being eliminated. She would like emphasis on the fact that the fellowships cover all of the disciplines. Dr. Jason Kalirai noted that many potential applicants receive their information from university department heads. He suggested asking the department heads to lead a discussion, which Dr. Hertz considered a good idea. Dr. Gaudi said that APS had recommended that Dr. Hertz reconsider allocation of the saved funds to R&A funding opportunities other than APRA, as was originally suggested. Dr. Hertz acknowledged the recommendation, but pointed out that he cannot discuss future budgets until they go to Congress. Dr. Kartik Sheth said that informal feedback from fellows indicates concern about the funding reduction. Other feedback shows that potential applicants are pleased with the single application and the joint review.

Dr. Neil Cornish said that if the umbrella fellowships are called “Hubble,” that buries the message that the Sagan and Einstein fellowships still exist. Dr. Sheth replied that 70 percent of the Einstein and Sagan applicants applied for Hubble fellowships as well. The named fellows will go back to the alignment of science questions. Dr. Asantha Cooray asked about institutional diversity. Dr. Sheth explained that there will be no more than four fellowships per institution at any given time, which should increase diversity as the current limit is six.

Suborbital Program and Explorers

Dr. Hertz described the sounding rocket program, noting that there would be a separate update on the balloon program. Dr. Zurbuchen is very interested in cubesats and wants an SMD-wide approach to ensure consistent, realistic processes and expectations, as well as a multi-disciplinary approach. APD has had cubesat launches through APRA. The cubesats cost about as much as balloons and other suborbital vehicles, and while astrophysics is not the most obvious place for cubesats, the technology has advanced to make them more feasible. APD has selected HaloSat to study the hot galactic halo, and the

Colorado Ultraviolet (UV) Transit Experiment (CUTE) to study UV emissions from "hot Jupiters" during transit in the UV.

Dr. Hertz showed the rideshare catalog for the recent Explorer Mission of Opportunity (MO) solicitation, making note of the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) ring. Every launch now must carry an ESPA ring. For the Explorer program, APD did a down-select from the Small Explorer (SMEX) Phase A studies. The Imaging X-ray Polarimetry Explorer (IXPE) will address questions about the polarization of X-rays from complex environments such as supernova remnants and accreting neutron stars. The Galactic/ Extragalactic Ultra-Long Duration Balloon (ULDB) Spectroscopic Terahertz Observatory (GUSTO) is the next ultralong duration balloon, which will launch from Antarctica and fly over the Southern Hemisphere. Dr. Hertz noted that balloon flights launching over an ocean have no trajectory control and no payload recovery, by design. The Mid-sized Explorer (MIDEX) program had a call in 2016, and the proposals were under review. APD will make selections for Phase A in summer 2017 and down-select in early 2019. The next Explorer Announcement of Opportunity (AO) will be in the winter of 2018/19, depending on the European Space Agency's (ESA's) M5 down-select. Future AOs will be released every 2.5 years, assuming an appropriate budget.

Dr. James Bock asked about the status of the question sent to the National Research Council (NRC) Committee on Astronomy and Astrophysics (CAA) regarding the mid-DS report and Explorers. Dr. Hertz replied that there had been no response as yet. Dr. Hertz asked the CAA to determine if there was still compelling astrophysics to be done in the SMEX class. It takes them a while to respond, but the answer will influence the SMEX cadence, particularly if they recommend going to MIDEXs or something else.

Civil Servant Scientists

Dr. Hertz next reviewed the internal funding model for NASA civil servant scientists working at NASA Centers. NASA employs about 1,000 civil servant scientists who contribute to missions, do original research, and more. It is important to maintain a science workforce that serves the community and nation in doing astrophysics. Only 15 percent of the Full-Time Equivalents (FTEs) are supported by competitive R&A. NASA plans to increase the amount of directed R&A, which will result in a decrease in R&A proposals from NASA Center scientists. This will have no impact on the external community. All directed R&A will be planned between the Centers and the Headquarters divisions, and will be peer-reviewed. Directed work will not be science that is easily done or competed. These will be strategic projects that can best be done at the Centers in order to enhance NASA objectives. There will be a new method for negotiating with the Centers, and NASA will put together an ad hoc peer review panel. Every 3 to 5 years, a visiting committee will look at the work to ensure that it is compelling.

APD will direct work to maintain capabilities and to continue work that could be infused, as with the WFIRST coronagraph. Dr. Gaudi observed that at the recent NAC Science Committee meeting, this topic engendered the most discussion, confusion, and criticism. However, the decision was not made by SMD; it came from the Agency's Executive Council. Dr. Gaudi remained concerned that the noncompetitive aspect limits the ability of the community to adjust, while also limiting the funds available to the community. Dr. Hertz said that this is an experiment that will be re-evaluated in 3 years. Dr. Hertz suggested that APAC could recommend evaluation criteria. Dr. Gaudi said that the Science Committee recommended getting more information on how this is being implemented.

Dr. Kalirai was concerned about unintended consequences, such as isolating the NASA science community and limiting their opportunities. Dr. Paul Scowen asked for clarity on the nature of the work involved. Dr. Hertz replied that NASA has a capabilities management system to ensure that NASA's capabilities remain available to industry and the community. He envisions directed work will involve stewarding particular capabilities and doing studies that the community wants NASA to do. The Centers want to put their ideas before peer review. He hopes to share the directed work package topics with APAC at the next meeting. As this is Agency-wide, the need is to evaluate how to do it to benefit astrophysics rather than harm it. The requirement is that the work be neutral from the perspective of the external community. SMD will determine ratios among the divisions in order to develop a single number by which to gauge neutrality. This is a hybrid between the direction taken by the Department of Energy (DOE) and NASA's open competition.

Dr. Brenda Dingus said that the DOE labs decide what is important, but they may not follow their decadal surveys. The result is creation of capabilities at the DOE labs, but there are also conflicting directions.

Mission Updates

APD has eight missions in development. The next to launch is the Neutron-star Interior Composition Explorer (NICER), which has been handed over to SpaceX for integration into the Dragon trunk and transport to the International Space Station (ISS) around the end of May. The Cosmic-Ray Energetics and Mass investigation (CREAM) was set to launch to ISS in August, also via SpaceX. The Transiting Exoplanet Survey Satellite (TESS) was in integration mode, with a launch planned for early 2018. NASA shipped the first set of detector subsystems for Euclid to ESA.

For WFIRST, APD will consider starshade compatibility, including a cost and impact review during an independent cost review of the entire WFIRST mission. NASA must decide by end of the year whether to fund design of starshade capabilities, which cannot be added in later. The question is whether to spend money to maintain the compatibility. The NAS Midterm Assessment said not to, as the starshade is not a high priority and keeping costs down is more important.

APD is studying three partner missions. The X-ray Astronomy Recovery Mission (XARM, pronounced "charm") has received approval in Japan, while APS, the NAC Science Committee, and the NAC all recommended that NASA move forward with the partnership. The Japanese Space Agency (JAXA) is setting up a formal project, and NASA will establish a project to rebuild the hardware designed for ASTRO-H. The U.S. community should expect a high level of involvement, as the science belongs to the community, as, unlike ASTRO-H, XARM is not a PI-led mission. There will be a Guest Observer program.

NASA is participating in ESA's formulation of Athena, but there was nothing to report at the moment. On the other hand, ESA's Laser Interferometer Space Antenna (LISA) has been an active area. NASA now has a study office and technology development program. ESA and NASA are discussing which agency will provide which instruments. There are 21 U.S. scientists in the total group of 82 listed as co-authors of the LISA proposal. NASA's L3 Study Team (L3ST) recently did a technology roadmap and is completing a

science roadmap. These detail the community's preferences for NASA contributions, which NASA will revisit.

2020 Decadal Survey
There are four science and technology definition teams (STDTs) for the large mission concepts that will go before the DS panel. The missions are: the Habitable Exoplanet Imaging Mission (HabEx), the Large UV/Optical/IR Surveyor (LUVOIR), Lynx (formerly the X-ray Surveyor), and the Origins Space Telescope (formerly the Far-IR Surveyor). There were 27 compliant proposals for probe studies, which were peer-reviewed, resulting in a selection of eight mission concept studies and two partial selections. The eight concept study teams will have the opportunity to further develop the concepts using the design labs at the Jet Propulsion Lab (JPL) and the Goddard Space Flight Center (GSFC), after which the concepts will be subject to cost assessment before submission to the DS.

Dr. Hertz presented the list of the mission concept studies. The first partial study is funded to develop the case for whether the ultra high-precision radial velocity measurements for exoplanets are better done from space or the ground. The second was to update the WFIRST starshade concept. The notional DS schedule has been delayed by 6 months, but it cannot be pushed back further without having a negative impact on the Planetary Science DS.

<u>Science Talk: TRAPPIST-1</u>
Dr. Michael Gillon described the Search for habitable Planets EClipsing ULtra-cOOl Stars (Speculoos) transit survey. Although ultracool stars are previously unexplored, they make up a significant fraction of the galactic population (10-15 percent), their habitable zones are close to the star, and atmospheric characterization of habitable zone, Earth-sized planets is possible through transit spectroscopy. Speculoos set out to study 800 stars and 200 brown dwarfs, with transit durations as brief as 10 minutes.

The project started with a prototype survey from Chile, where the team found three Earth-size, temperate planets at the end of 2015. The host star, TRAPPIST-1A, is very small, about the size of Jupiter, and has frequent flares. The team found a fourth planet in 2016, as well as new transits in a photometric follow-up. At that point, the limitations of ground observations became a factor, and the Spitzer mission became part of the project. After 20 days of nearly continuous observation, Spitzer found 34 transits. At that point, the Kepler 2 (K2) mission was added to the project, and the result was a complete understanding of the architecture of the TRAPPIST-1A system. Several of the seven planets observed are in the habitable zone, and three could have liquid water. Hubble and, eventually, Webb will conduct further investigations. Dr. Gillon detailed the estimated time needed for the Webb observations.

The project is now moving into its second phase, using an observatory in Mexico. Two or three additional telescopes are needed, for which the program is seeking funds. One important lesson is that Spitzer played a key role, as it was the only facility that could provide long, high-precision observations. On that basis, the project team would ask NASA to prolong Spitzer's life. The Chilean observatory was the best option for ground-based investigation, but Spitzer obtained unique, precise, and critical data, and no ground-based telescope can compete with that. Dr. Gaudi thought that was a pessimistic view,

noting that NASA cannot keep Spitzer going indefinitely. Dr. Gillon said that the precision Spitzer provided was essential, and some of the transits were too small to be observed from the ground. The project team is still missing some measurements and is working on completing the target list.

ExoPAG Report

Dr. Alan Boss began his update of the Exoplanet Program Analysis Group (ExoPAG) activities by showing the changes in the Executive Committee (EC). Some of the Study Analysis Groups (SAGs) have completed their work, and SAG12 is likely to wind down soon, with a presentation serving as the final report for purposes of shutting down the SAG. That leaves seven active SAGs, numbers 13 through 19. SAG14 is on hold until TESS moves forward, and the rest are making progress. The annual technology gap list and prioritization began about a year ago, and the PAG is planning for the next cycle. Future activities include the active SAGs, technology gap list, and monthly EC telecons. There will be an ExoPAG meeting at the Kepler conference in mid-June, with some smaller splinter sessions. The community wants more focus on their interests and less on what APD is doing, so the splinter sessions will reflect that.

The action request for APAC was to accept the close-out of SAG12. The final closeout presentation was circulated to the Committee prior to the meeting. Approval of the request was unanimous.

PhysPAG Report

Dr. Mark Bautz gave an update on the Physics of the Cosmos PAG (PhysPAG), which covers a wide range of subjects. PhysPAG has six Science Interest Groups (SIGs). Five of the 10 mission probe concepts selected by NASA are related to Physics of the Cosmos (PCOS). The inflation probe SIG has had a number of meetings, while the gravitational wave SIG has been energized by recent discoveries. It is following the L3 Study Team (L3ST), as well as the LISA concept studies. The X-ray SIG will be following NICER, IXPE, XARM, and several X-ray probe concept studies. The Lynx study is another topic of interest. The Gamma-ray SIG did not have a probe study selected but the community is proceeding with a concept nonetheless. The Cosmic ray SIG is awaiting the launch of CREAM. The CALorimetric Electron Telescope (CALET) is providing some data from the ISS. There was also a probe mission study selected. Finally, the cosmic structure SIG is supporting large-structure science in the flagship mission concept studies.

PhysPAG had no need for action by APAC.

COPAG Report

Dr. Scowen reported changes on the Cosmic Origins PAG (COPAG) EC. At the last APS meeting, the Subcommittee asked COPAG to defer to this meeting a request for approval of a Technology Interest Group (TIG). APD has since given COPAG verbal approval to begin populating the TIG. COPAG sought the TIG in order to pull in more expertise for the annual review of the technology gap list. The COPAG EC is tracking the STDT activities, and COPAG has members on three of the four teams. For the fourth, Lynx, the PAG has members on the working groups.

There were no open SAGs at the moment and no requests to create new ones. There were three open SIGs. SIG1 is focused on far-infrared astronomy. SIG2 addresses UV visible astronomy from space, and its members are interested in both the LUVOIR and the HabEx large mission concepts. Many members of SIG2 are involved in instrument design, science, and technology. SIG3, emphasizing the cosmic dawn,

focused on needed technologies at a recent meeting. There was also discussion of the state of the field, as well as a summary of the technology program and how the community might contribute going forward. COPAG is eager to promote the upcoming Webb proposal deadlines, and continues to discuss the various STDT activities. Finally, COPAG is interested in smallsat development for astrophysics.

The COPAG asked APAC to approve establishment of the TIG in time for the technology gaps exercise that was to start in a few weeks. Dr. Hertz said that he had initially wanted COPAG to defer this TIG because he was concerned about how well it would fit in with the technology assessment activities of the other PAGs. However, he was no longer concerned that it would break parity. All of the PAGs are reviewing the technology gaps, and they do not have to do it the same way. Dr. Boss said that ExoPAG hears from the program managers in real time at a face-to-face meeting. He thought the proposal from COPAG was fine. Dr. Gaudi said that they would vote on it the next day and include the recommendation in the APAC letter to Dr. Hertz.

Dr. Scowen next said that Dr. James Green of PSD had explained how that division was looking at the role of smallsats in furthering PSD priorities. Dr. Hertz pointed out that PSD smallsats must be enabled by a mission (since they operate around other solar system worlds than Earth), while APD did not have that as a standard. The Division was seeking ideas for the use of cubesats in astrophysics. He cautioned that smallsats are not as cheap as many people think they are. Compelling astrophysics will require smallsat missions of around $5 million, which is quite a bit more than the $100,000 cubesats that go up as education projects. He wondered if APAC might want to recommend that SMD hold a workshop to connect cubesat experts with scientists across all SMD disciplines. Dr. Scowen said that he would support it, but was not sure how to move it forward.

Dr. Gaudi suggested that APAC recommend that Dr. Hertz pass along to Dr. Zurbuchen a recommendation that SMD have a workshop to connect cubesat capabilities to the science community. Dr. Hertz advised connecting the recommendation to the SMD initiative to do more with smallsats, and Dr. Gaudi agreed to put that in the letter.

Discussion of PAG Reports

Dr. Batalha asked whether the PAGs might address the technology gaps in interpreting the data from these missions. Dr. Scowen then asked where the responsibility would fall for gaps that are identified. Dr. Gaudi advised first determining the magnitude of the gap. Where there is a significant gap, the PAGs can come up with a gap list and vet it, at which point it could be part of the process.

Dr. Gaudi wanted to discuss the extent to which the PAGs might bring younger members of the community into these planning bodies. Dr. Kalirai said that it is important to get them involved and to have them get credit for their work. Dr. Gaudi noted that younger people are often quite invested in these priorities and, if they stay in the field, they will be using these technologies and science programs. Dr. Hasan added that NASA sees the PAGs as training grounds for future advisory committee members.

Dr. Boss explained ExoPAG's approach to diversity across several axes, including age. There is a lot of interest. Dr. Scowen said that this was true of COPAG as well, which has brought in some early career people to keep it fresh. Dr. Bautz agreed. He and Dr. Scowen specified that they have not added

postdocs, however. Dr. Hertz explained that NASA is unlikely to select postdocs for its committees, but values experience at the PAG and peer review panel levels. One option might be for the PAGs to add an extra seat on the ECs for such individuals, though Dr. Bautz said he would prefer not to do that.

WFIRST Update

Dr. Jeff Kruk, the Acting Project Scientist for WFIRST, said that the mission's nominal launch date is in 2025, though no launch vehicle has been identified yet. Due to concern about potential cost growth of the coronagraph, NASA is obtaining four independent cost assessments, two of which are internal and two of which are external. Dr. Hertz pointed out that this is traditional for large missions, in order to get a range. Dr. Kruk said that thus far NASA has generally been in agreement with Aerospace Corp. The current cost management agreement holds the mission to $3.2 billion in real-year funds. This includes the coronagraph, Guest Observer (GO) support, and the launch vehicle, but not starshade readiness. The $350 million for the coronagraph is considered reasonable, but that amount should not grow. The coronagraph is essentially a technology demonstration. The team is currently studying starshade compatibility, which is not part of the core mission but could be pertinent information for the upcoming DS panels. Should a starshade be approved, it must be relatively low-cost pending direction from the next DS. He thinks the science would be compelling, as it permits detection and characterization of habitable zone planets.

Dr. Kruk noted the passing of Dr. Neil Gehrels, the WFIRST Project Scientist.

WFIRST has been supporting a 3-year directed technology development effort, completing the early phase in January. Detector testing demonstrations have provided a reasonably good yield. The tests reflect radiation testing on the detector characterization. Dr. Kruk provided persistence data, which reliably exceed requirements. He also presented two coronagraph designs and their contrast models. No observing time has been allocated yet, and the decision has been made to have no proprietary period. Dr. Boss asked about post-processing data for the coronagraph. Dr. Kruk replied that that is still being assessed, as is the wide field infrared data processing. The team is looking at what they can make available to the public and how quickly. Dr. Gaudi said that the notional plan is to have a significant GO program with substantial availability to the community. He thought that should be very clear. Dr. Hertz said that the data will be made public at the same time that it will go to the selected scientists. All competitions will be fully open.

Dr. Batalha observed that open science goes beyond data, to include pipelines. It can be more challenging than expected. Writing code is healthy for innovation and for identifying problems early. Dr. Kruk replied that WFIRST is not far enough along to discuss that topic in detail, but he expects the mission to do the same as Webb. There will be multiple opportunities, including science investigation teams, GO, Guest Investigator (GI), and imaging programs. International partnership discussions are in progress with ESA, the Canadian Space Agency (CSA), JAXA, and Australia.

Dr. Kruk noted the key technology items that have changed since the last update. The telescope temperature is now down to 260K; the tertiary optics (mirror) moved to the telescope, which enlarges the filter wheel option; there is the option of passive detector cooling; two additional reaction wheels

have been added; antenna size has increased; and the wide field infrared detector sampling rate has gone to 200kHz, for twice as many samples. These are the new baselines, though they can be revisited.

The instruments have not changed, but both the layout and shape are different. Dr. Kruk summarized filter information and presented photographs of the existing primary mirror. The team has reviewed 11,018 artifacts of the inherited telescope, identifying 26 that require rework, some of which would have to change anyway. The mirror coating might change, as well. Simulations have been going on and are now operational for all science objectives. The team is working on detailed assessments supporting design efforts, and is also developing instrument prototypes.

Dr. Cornish asked about starshade compatibility. Dr. Hertz replied that he gave the team very clear direction because he wanted as little starshade capability as possible to go onto WFIRST, with as much as possible going onto the starshade itself. Orbit determination would come from the starshade or ground control, for example. WFIRST would need a filter and a few more wheel positions. He has not yet seen anything that concerns him. Preliminary cost estimates are pending.

Webb Update

Drs. Eric Smith and Nikole Lewis presented an update on Webb. Dr. Smith said that the mission team is down to two hardware flows: the Optical Telescope element/Integrated Science (OTIS) module, and the spacecraft/& sunshield (known as the spacecraft element or 'spacecraft' for short). The critical path is a tie between the telescope and the spacecraft. OTIS was being prepared for packing and shipping to Johnson Space Center (JSC) for integration and cryotesting. The other piece is the spacecraft bus, which includes the sunshield. The radiator shields are the pacing items. There are 4.75 months of funded critical path schedule reserve, and some liens on both the OTIS and spacecraft schedule reserves.

The team continues watching the nonexplosive actuators used for releasing the telescope from its stowed position on the spacecraft, which had issues and had to be redesigned. There was a vibration anomaly in the telescope vibe test that had a ripple effect, and a problem with a test of the propulsion system in the spacecraft. The ground system passed mission operations review, which was a NASA Headquarters milestone. There is still a lot of verification that must take place with the testing program. Because Webb is too big to test fully assembled, NASA is testing piecemeal and conducting analysis. This results in a larger test program than what is typical.

The optics have to be very clean. The amount of ground support equipment constructed for testing deployment is quite extensive and intricate. There are many elements that will be deployed, more than in other missions. There have been several cryogenic testing steps, and the team must verify launch survival by vibration and acoustics testing. There will be additional testing, including many prelaunch hardware tests, about half of which are done. Everything is on track, but the project is moving into a difficult period of testing.

Dr. Gaudi asked for more details on the anomaly with vibration. Dr. Smith explained that the wings are folded back during launch. The team found that one of the launch restraint mechanisms (LRMs) did not lock its interlocking teeth flush prior to the vibration test. That was the source of the noise heard during the test. (Northrop-Grumman, did an experiment in which they recreated the shock from the LRM.) The

team redid the axis that experienced the anomaly and this second test was successful. In answer to another question, Dr. Smith explained that early release science will be limited and done toward the end of commissioning. It is possible that some of the Guaranteed Time Observers (GTOs) will waive some of their limited data access time in order to make it public.

Dr. Lewis, the Webb Project Scientist at the Space Telescope Science Institute (STScI), reviewed the Institute's Science and Operations Center (S&OC) flow, which will enable outreach to both the science community and the public. The observatory test bed simulator has been tested, a suite of proposal tools was released. The Cycle 1 solicitation for GTOs was released. She next went over the timeline for GTO proposals. Many GTO teams will make their plans public. S&OC is now ramping up for GO proposals and the Director's Discretionary Early Release Science (DD-ERS). There was a big kickoff at the American Astronomical Society (AAS) meeting in January, with a workshop, a booth on Webb, and a town hall.

Dr. Lewis described the Astronomer's Proposal Tools (APTs), which should be familiar to Hubble users. There is an exposure time calculator, and investigators can test different observing modes to see what is produced. There have been more than 100,000 calculations since this became available in January. The Webb Help Desk will support users by helping to pinpoint the area needed. The documentation system is called JDox, and it is extensively hyperlinked. There are 230 pages of documentation at this point.

The DD-ERS will accelerate diffusion of data and expand early opportunities for the community to gain experience with Webb data. The program received 200 notices of intent to propose. Proposal teams had an average of 18 scientists per team, and came from 24 countries and 34 states. Dr. Lewis listed their topics. Galaxy assembly and evolution is largest, along with star formation and black holes. The website has been evolving. There is a proposal planning toolbox, as well as an events page with archives of past webinars. The next AAS meeting will have a Webb event, along with six sessions and a pre-meeting proposal planning workshop.

Dr. Gaudi said that everyone seems to have a different concept of the DD-ERS program. Dr. Lewis said that it is purposefully vague. The goal is to inform Cycle 2 proposals by getting out data from the most widely used modes. It will involve community input, and it is not likely that every mode will be tested due to concerns about time allocation. There is so much community input and excitement that it will be hard to compose peer review panels.

Public Comment Period

The meeting provided an opportunity for the public to comment, but no one came forward.

Discussion

Dr. Yun Wang said that community members have told her that it would be helpful to host high-level software at the NASA Centers, particularly state-of-the-art software developed by individual investigators who could share their work if they had some support and structure. She wondered if NASA could offer a modest investment for this purpose. Dr. Hertz said that NASA has been discussing with NAS whether codes should be made public similar to the way data are made public. The first step would be to have an NAS study of the cost-effectiveness and science benefit of having a NASA-funded repository for supporting codes. He said that he would get the status of these discussions, adding that Dr. Zurbuchen had asked this very question.

Dr. Hertz added that he had learned that the NAS was going to answer the question about continuing SMEX opportunities no later than May 15. There had not yet been an official response to the mission extension study, but there were some APD-specific responses that he would present the next day. Regarding a question about civil servant scientists, he said that the intent is to allow them to focus on larger or longer-term projects than those funded by APRA. They will participate in larger, group efforts that are tied to strategic goals and capabilities management. There will still be some individual science activities, however. This will be part of the budget process. It is likely that the strategic capabilities and objectives will be shareable. APD is writing an implementation plan for this process, to include the impact on community funding.

Adjourn Day 1

The first day of the meeting was adjourned at 4:44 p.m.

Tuesday, April 25, 2017

Opening Remarks

Dr. Gaudi reminded those present that the meeting was operating under FACA rules. He then reviewed the agenda for the day.

TESS Update

Dr. Stephen Rinehart, TESS Project Scientist, explained that TESS is NASA's next Explorer mission, with a launch date no earlier than March 20, 2018. TESS has a 2-year nominal lifetime, during which it will search for small and new exoplanets around bright, nearby stars. The goal is to measure the masses of 50 small planets. A GI program will support community science. TESS fits into a timeline of missions, between Kepler and Webb; Webb will launch a few months after TESS.

Dr. Rinehart described the camera coverage and observing sectors for the mission's four cameras. The 2-year sky coverage map will have some overlap with the Webb continuous observing zone, as planned. TESS will do full-frame images every 30 minutes. There will be no period of exclusive use on the data. The expected yield is about 70 Earth-size planets, plus thousands of giant planets and more than 500 Super Earths. All of the small planets will be around bright, nearby stars. The modeling data are based on extrapolating Kepler results. Dr. Rinehart explained that the numbers he presented are for at least three transits; there will also be single and two-transit events, some of which will call for follow-up to remove the false positives. That will be followed by precision Doppler spectroscopy by the TESS team using ground observatories. The team expects many proposals to combine Hubble and Webb for additional observations.

The solar array installation is going well. The critical path goes through the Ka band transmitter; the data handling unit is on the critical path as well. Instruments have been built and are in testing. Dr. Rinehart showed upcoming milestones and mission reviews. The mission has just over $5 million in reserves, which is 25 percent of the cost to go, which is consistent with GSFC's reserves target. The schedule is healthy as well.

The TESS Input Catalog (TIC) includes all known targets that TESS will see; the team will assign priorities to the stars in this input catalog. Dr. Rinehart showed graphics of the top 2.33 million targets, the top

200,000 targets, areas of emphasis, and gaps in the input catalog. The first data will be available within 6 months of collection, after which the goal will be 4 months. The time delay is to ensure that the data are high-quality, and the goal is to shorten the time as much as possible.

Dr. Rinehart described astronomy areas that could be subjects of proposals, in addition to exoplanets. The GI program schedule has been set. While a wide range of investigations are permitted within the GI program, the focus of proposals must be on TESS data. There are multiple extended mission options, as the orbit for TESS will be extremely stable and could last for years. With the SR cadence yet to be determined, the project team wants to be prepared.

Dr. Gaudi noted that TESS is a demographics mission, and it will be sensitive to regions of planet parameter space already covered by Kepler. Dr. Cornish added that if TESS is looking for things to be viewed by Webb and Hubble, it would be important to view diverse systems rather than look at small transits. Dr. Rinehart replied that it would be great to get long views, but that is not the focus of TESS in its prime mission. Dr. Gaudi asked if it might be possible to release full-frame images immediately to enable follow up of single and two-transit events. Dr. Rinehart said that that is an aspiration, not a requirement. The full frames are bonus data that the team wants. The question is how to best achieve that.

TESS will have four reaction wheels, and the team spent a lot of time selecting them. They are not from the same manufacturer as those on Kepler. Dr. Cornish said that the proposed targets seemed to include some stars that would be visible to the naked eye. Dr. Rinehart explained that this is part of public outreach. Amateur astronomers will be able to point to certain stars and say that they have exoplanets.

SOFIA Update

Dr. Kimberly Ennico Smith, who recently became the SOFIA Project Scientist, said that SOFIA is the only APD mission in its prime operating phase. SOFIA traces our chemical origins. She described the mission's science and technology, pointing out that it offers opportunities for switching out instruments and training the next generation of scientists, engineers, and educators. It is a human-directed, hands-on mission, and the only community-access observatory in its wavelength. SOFIA is a tool for revealing the molecular universe, detailing the Galactic Center, and measuring magnetic fields in star-forming regions and the Intra-Cluster Medium (ICM).

Dr. Ennico Smith showed the baseline research hours and actual hours by year. It was in May 2014 that there was a transition from development to operations. Since then, the mission has met or exceeded the Level 1 requirements. The efficiency shows a positive trend. However, the baseline for Cycle 5 is lower than that for Cycle 4, due to issues with the HAWC instrument. Once the HAWC issues are addressed, the team will retrieve the hours, but not until then. The operating budget is not quite $85 million per year.

The program was subject to several external reviews in the 2013-14 period. There were common areas of focus and recommendations: science productivity, community outreach, balance, science instrument development, and operational productivity. In response, the SOFIA team modified policies and processes to optimize science productivity. GO funding has more than tripled, and funding for science instrument development has gone up to increase deployment of new capabilities to every few years. There is improved planning in science outreach and more focus on reporting. The project is now working on a transition plan to transfer the SOFIA science data archive to the Infrared Science Archive (IRSA),

while also improving data delivery performance. Finally, the mission team changed policies to mitigate lost observations, including contingency flights to improve completion of science projects.

In terms of metrics, they are tracking the number of papers and hours per paper, as well as the use of instruments. The GO program awards grants of $10,000 per observing hour, up to a certain number at which the ratio changes. The team hopes to do 800 observing hours per year. A single flight is about 9 hours, and programs run to as many as 30 hours, involving multiple flights. The average program is 5 hours. Dr. Kalirai said that although the program tripled the GO hours, it still seems small for the operating cost. Dr. Ennico Smith said that the Inspector General (IG) did not specify a number of hours. Fuel is quite expensive, which is a factor. The mission is meeting the science demand and developing new instruments. They received over 100 proposals.

Most of the flights from the previous year were out of California, with some from New Zealand. Cycle 4 was completed in early February and accomplished 80 percent of the planned research hours. There are now seven instruments. Science highlights since 2014 include confirmation of evidence for haze in Pluto's atmosphere. SOFIA also filled in wavelength gaps in Type 1a Supernova. SOFIA data helped redefine the Galactic Center, part of the quest to find out what fuels the black hole at the center of our galaxy. SOFIA probed the warm dust and followed the gas flow. The mission also showed that dust survives a supernova, and explained the warm emission in a debris disk. SOFIA also found different star formation phases in galactic spiral arms. The mission studied Venus in January, creating the first disk map of the D/H ratio in water at this altitude in an effort to determine the fate of the Venusian oceans. For the foreseeable future, SOFIA will be the only mission capable of studying Venus. Other science highlights include identification of a water source in a young stellar object, building on work from the Herschel mission. Detection of TeraHertz water masers was an example of the usefulness of having the investigator on board to adjust the instrument during the observations. An Orion survey needing 50 hours included about 15 flights. Data are still arriving.

Cycle 5 started in February, with a plan for 505 GO hours and another 100 for GTOs, as well as 45 directed hours and 108 hours for calibration. Dr. Ennico Smith showed a graphic of proposed GO cycle time by theme. Recent proposals show a new demand for extragalactic observations, with continued large demand for the interstellar medium. High priority science for 2017 includes a look at Europa, which would provide input to a future Europa Clipper mission. A deployment from Florida will measure the atmosphere of Triton during a stellar occultation, and another effort will look at the Galactic Center and do mapping with upGREAT, an upgrade of the German Receiver for Astronomy at Terahertz Frequencies (GREAT). Four programs will look at the gas to understand mass density and other aspects of our nearest black hole. The Echelon-Cross- Echelle Spectrograph (EXES) instrument is a high-resolution, mid-infrared instrument to look at hot core organics. Its molecular line survey could affect astrochemistry in understanding star formation.

Dr. Ennico Smith described new instrumentation and upgrades, then detailed the Cycle 6 proposal schedule and program allocations. The mission will have approximately 500 hours allocated for GO, and there will be some changes to flight series/cadences to enhance the science return. There is a gap in instrument capabilities, and she is working on the science case for the needed instruments. The team is also preparing for the 2019 SR.

She invited APAC members to join the weekly science call-in conversations, colloquia via WebEx, and other events. The call-ins give the status of the observatory and recent discoveries. The mission is the

prime access point to its portion of the electromagnetic spectrum. There will be a graduate thesis-enabling program in Cycle 6 as part of an effort to encourage graduate programs to use SOFIA.

Dr. Gaudi said that it seems like there has been a lot of time commissioning new instruments, which made him wonder about the reasons for bringing in new ones. Dr. Ennico Smith said that the mission team is seeking balance. In 2016, they realized that they spent equal time doing scheduled maintenance and swapping among the current suite of instruments. On the other hand, SOFIA will need to complement Webb, possibly by looking elsewhere in order to achieve scientific balance.

Dr. Kalirai said that a couple of years ago, it looked like user engagement and instrument use were not where they should have been. Now it appears that about half of the proposals are being selected. That is relatively high, and he wondered if it was a concern. Dr. Ennico Smith replied that the oversubscription rate is about three, and they have to take the German side into account (noting that Dr Hertz' presentation only shows the US numbers). In addition, by design, SOFIA's scheduling challenges require a high selection rate to create a healthy pool of observable targets. She offered to bring in data on hours and the number of independent PIs. They also track new PIs, and found an increase of nearly 20 percent in the previous last year. She offered to provide the data on hours per paper. Dr. Hasan added that the SOFIA Airborne Astronomy Ambassadors program is a competed program for STEM education within SMD's STEM Activation Project, which is valuable.

Balloons and Suborbital

Dr. Thomas Hams, Deputy Program Scientist for the Balloon Program, provided an update on the balloon and suborbital program. Suborbital payloads provide rapid, low-cost access to space for all of SMD, helping to develop and validate technologies, while also training new PIs, who can participate in the entire mission lifecycle during their graduate school tenure. In addition to the cubesats discussed by Dr. Hertz the day before, the Suborbital Program includes sounding rockets and balloons. Dr. Hams described each and gave their parameters. Some of the differences are in payload expendability and recovery, and the provision of the platform. SMD's Heliophysics Division (HPD) manages the Sounding Rocket Program for all of NASA, while APD manages the Agency's Balloon Program. Dr. Hams reviewed the launch sites, schedule, and APD's sounding rocket portfolio. An example of an astrophysics need for a sounding rocket would be a study of the extragalactic background light.

He next presented the status of the Balloon Program, which launches up to 12 balloons annually, involving more than 300 students and over 40 research institutions. Launches from the Texas and New Mexico sites fly for about 1 day, while those from Antarctica typically last more than 21 days. Dr. Hams showed the trajectory of a Long Duration Balloon (LDB) flight from Antarctica, as well as the facilities available. Payloads recovered from land can be reused, while those that go over water are designed to be lost. The trajectories are increasingly accurate. Three LDB Antarctic payloads will go forward for FY18.

Most balloons have been conventional, zero-pressure balloons. For these balloons, there are significant altitude changes due to, for example, the amount of sunlight on the balloon. Over time, gas is lost and the balloons come down. In order to fly balloons at night, the program uses Super Pressure Balloons (SPBs), one of which recently flew for 46 days after being launched from New Zealand. Dr. Hams made note of the Extreme Universe Space Observatory (EUSO) that just launched, then showed the number of flights by discipline.

The Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory (GUSTO) was selected as a Mission of Opportunity (MO) Explorer to do a large-scale survey and spectral diagnostics of the Interstellar

Medium (ISM). The PI is now negotiating how to use this with more stringent mission assurance success. GUSTO has some wavelength overlap with SOFIA, and is equal to 300 dedicated SOFIA flights. The plan is to go for 100 days, but the instrument can operate for 160 days. Overall, trajectory remains an area for improvement. The goal is to avoid dropping payloads in populated areas, and this criterion informs the launches.

Dr. Kalirai said that he has heard a lot about this program over the years, but he would like to hear more results from the launches and the new science that has been done. Dr. Gaudi noted that APS had requested an overview of the science and technology, and would like that in the future. When Dr. Hams said that the request would involve a group presentation from across SMD, Dr. Gaudi advised presenting themes. After some discussion, Dr. Hertz said it would be possible to share a page per PI. Dr. Dingus suggested using CREAM and its history as an example of a success story. Because of the technology development component of the program, it can be hard to evaluate success based purely on science.

Dr. Hams explained that science is one of three components, and it is broad-ranging at this scale. Suborbital missions also train investigators, and the third component is technology development. The value of the program goes beyond science per dollar. Dr. Dingus asked about the budget. Dr. Hertz estimated $25 million annually for payload development, mostly from APRA. APD does not pay for sounding rockets, which are managed by HPD. The annual balloon program budget is just over $37 million.

Aerospace Costing and Technical Evaluation

Dr. Debra Emmons, Principal Director of NASA Science and Technology Programs at The Aerospace Corporation, reviewed the Cost and Technical Evaluation (CATE) process. Aerospace has supported the CATE process for the last cycle of decadal surveys – beginning with astrophysics 2010 survey, planetary, heliophysics, and currently earth science. The process is relatively new, having started after Congress mandated in 2008 the NAS use an independent process to evaluate technical readiness and cost of all recommended mission concepts. Realistic CATEs are needed for planning, taking into account such elements as the schedule, design, and launch vehicle.

CATEs are important for future consideration of NASA's budget. One of the key products from the CATE process - the "C" in CATE - is the cost-distribution function, which provides information about the cost range and uncertainty. There must be consistency across diverse concepts. The understanding of technology development is essential. The technical risk assessment is top-level, and the cost and schedule assessment feeds into high-level budget estimates. The design growth threat is the area of biggest disconnect with project teams, which tend to focus on specific items without considering future modifications and growth.

Dr. Emmons described the technical risk and maturity assessment approach. It is important to understand deviations from state-of-the-art performance. Often, the further a project goes beyond the state-of-the-art, the more risk is entailed. Evaluating the technical risk is key to determining whether a technology is available to initiate a particular activity or for a particular measurement. Through the "T" in the CATE process the technical readiness and feasibility of implementation are examined. Threats receive a lot of focus. Dr. Emmons presented an example of historical project data which demonstrated the project evolution, where mass has grown throughout the lifecycle. The CATE contingency values are an extrapolation of the historical mission data. The cost estimating process begins with estimates for instruments and spacecraft, then other elements and cost reserves. The CATE team looks at what drives the technology development requirements. Factors include the mass and power contingency, the

schedule, and the integration results and technology readiness levels (TRLs). There is also a cost risk assessment.

When giving feedback about CATE considerations, design growth and launch vehicle threats become areas of discussion. CATE estimates grow out of the project team inputs, and there is a need to ensure that immature projects do not have an unfair advantage, as there could be a wide range in the maturity of the concepts, as notional or paper concepts may look easier or cheaper than ones that are real. Dr. Emmons gave an example of payload mass contingency values for a threat estimate. Based on a prior APD mission, the CATE team found the area in which past mission contingencies actually landed, and asked the project team to be more conservative as a result. The prime objective for CATE support to large mission concept teams is to have a better understanding of technical, cost-risk trades and the impacts on large concepts. Each concept team has an allowance for Aerospace consulting on the mission concept studies. Aerospace is now doing trade studies, providing feedback on concepts, mission architectures, and technology roadmaps, as well as also giving feedback when needed. Considerations for trades and costing include the launch vehicle, on-orbit servicing, and international partnerships.

Dr. Kalirai said that there are technologies still being validated for the first time with Webb. He wondered how CATE teams accounted for that. Dr. Emmons replied that they have tried to understand the Webb process and have some interactions planned with the mission team to learn its history and processes. Each mission concept team has some low-to-mid TRL technologies that will need to go through a similar process. This speaks to a need to understand funding and timing models.

The CATE teams are trying to help the mission concept teams envision what the partnerships might be, and in as much detail as possible. Aerospace has also had a lot of discussion to prevent any conflicts of interest. The CATE reviews evaluate both the TRLs and the payload. While the process might not change, they need to hear about important elements that require particular attention. Aerospace faces an ongoing challenge to calibrate its estimates against the reality of some missions. Dr. Emmons referred to a public paper with a data set from Phase B that did this type of calibration. It is hard to do this for the DS mission concepts. Dr. Scowen pointed out that they are essentially trying to evaluate emerging technologies 10 years in advance. Dr. Emmons agreed that this is a challenge. They follow technology development processes and provide the best support they can, giving feedback about viability. They do see trends. The estimates are probabilistic, and error bars reflect estimates from both the project team and Aerospace. Work that has already been done constitutes important input to a CATE process.

Public Comment Period

The meeting provided another opportunity for the public to comment, but no one came forward.

Universe of Learning

Dr. Denise Smith discussed the SMD-funded science education program, NASA's Universe of Learning (UofL), which operates through a Cooperative Agreement (CA) from NASA. SMD seeks to enable NASA scientists and engineers to engage more effectively with learners of all ages. SMD selected 27 teams which include external evaluation partners. The UofL team is one of these 27 teams, and spans all of astrophysics.

Phase 1 of Universe of Learning involves laying the foundation. The vision is to engage learners of all ages and backgrounds in exploring the universe for themselves. The target audience is informal and outside of the classroom. Dr. Smith described the needs of the education community, as well as the logic model inputs, outputs, and outcomes. The work is grounded in the themes of astrophysics, and the

model is to integrate NASA astrophysics into audience-driven programs. The focus is on four categories: data tools and participatory experiences; multimedia and immersive learning experiences; exhibits and community programs; and professional development. Dr. Smith described projects within each category.

The UoL partnership between the Space Telescope Science Institute, Smithsonian Astrophysical Observatory, IPAC at Caltech, JPL Exoplanet Exploration Program, and Sonoma State University provides a direct connection to science, which in turn enables guided interactions with data. Dr. Smith described a prototype of this and of visualizations. She also described the resources that lead to the education programs, using the example of TRAPPIST-1. Subject Matter Experts (SMEs) play a key role in these programs. After describing Museum Alliance briefings, Dr. Smith turned to the goal of broadening audiences, noting partnerships in areas of special needs, rural areas, and minority-serving institutions. One initiative targets girls and their families in STEM. There is also a considerable amount of work with libraries. At the moment, the partnership was targeting 72 libraries in 27 states. Celebrity involvement draws in another segment of the population that otherwise might not be interested. UofL is exploring emerging technologies, like virtual and augmented reality, and is almost ready to deploy a browser-based version of their ViewSpace multimedia program. Finally, evaluation looks at all of the activities and how well the processes work, including the degree of impact.

Dr. Gaudi said that while the networking with libraries was impressive, he wondered about the extent to which they are visited and asked how people are brought in, particularly in rural areas. Dr. Smith said that many individuals in underserved audiences do not have regular or reliable access to technology, and therefore they access it at libraries. This is a critical role of libraries in rural communities, where libraries are centers of community activity. Dr. Gaudi said that he could see that in rural areas, and asked if there are other ways to connect libraries to the Internet. Dr. Smith explained that the UofL works with networks of networks. In a rural area, the library, the Girl Scout troop, or another source will be the home away from home. The community-based organizations know how to reach their children. The partnership presents multiple ways to reach out, like the celebrity videos.

Ms. Kristin Erickson of SMD said that she wanted to acknowledge Dr. Smith's leadership, noting that she had accomplished a great deal in a short time.

Ground Based Support for Space Missions Discussion

Dr. Debra Fischer, an APAC member, described ground support for space missions, noting that mission scientists often feel they have to absorb ground-based observation costs. She reviewed highlights of a presentation Dr. Hertz gave in 2014, discussing NASA's strategic needs for ground-based optical and infrared astronomy. In that presentation, he described uses and facilities. While NASA Headquarters understands the need for ground-based observations, there are potential gaps in the future. Dr. Fischer described what TESS, Webb, and WFIRST are likely to need in the way of ground-based observations. U.S. community access to Precision Radial Velocity (PRV) spectrographs is insufficient in the long term.

There are concerns that the LUVOIR mission could spend almost all of its time detecting planets and less than 10 percent of its time characterizing them. This type of situation is a concern and points to the need for a system of ground-based support. The two primary issues are access and technology development. While it would be possible to get a higher radial velocity precision, that would require a system engineering approach. There is not currently a strategic path forward to develop some of this technology. Dr. Fischer gave the example of what Kepler might have done with greater precision. Astrophysics is moving into a new era of more ambitious goals and a corresponding requirement for ambitious technology development. At the same time, PIs are reluctant to say that they need such

support. In addition, there are concerns about conflict of interest among those who already use ground support, which makes them hesitant to ask for more. If APAC wants to consider this, the Committee should identify the information needed for a more complete discussion.

Dr. Gaudi asked the APAC members to discuss this, noting that in some cases, investments in the $100 millions could save billions. Dr. Hertz said that this is a difficult topic. NASA is funded to do space missions, and Dr. Fischer captured the occasional requirement for ground support. When Congress votes on the budget, they tell NASA how to spend the funds. NASA cannot spend the money elsewhere. He gave some examples of exceptions that are implemented for specific, articulated, strategic reasons. Partnerships for ground support are undertaken to enable key projects for strategic reasons. Mission-enabling key projects are conducted using ground observatories. NASA will partner to get what is needed for WFIRST. For example, JAXA is proposing ground support as part of its WFIRST contribution. There is also some access to the Keck Observatory. NASA is commissioning a study on an exoplanet roadmap and strategy, to be presented to both NASA and Congress, and to be used as input to the DS. The study will not set priorities.

Dr. Boss supported waiting for the report. Dr. Hertz made it clear that he was open to APAC discussion and input, but this was a nuanced topic, and he cannot fit everything into the budget. Dr. Fischer said that she appreciated the constraints. She wondered about partnering with NSF and others. The mission balances might depend on it. Dr. Kalirai recalled a presentation to APS regarding Keck. That program has been successful, and APS recommended renewing that partnership and even broadening it if possible. The most obvious opportunity to him is the complementarity of the Large Synoptic Survey Telescope (LSST) with WFIRST. Dr. Hertz said that DOE, NSF, and NASA have begun a study of joint pixel processing, which could be valuable.

Dr. Cornish was concerned with the scale and the corresponding need for greater alignment of science priorities across agencies. Dr. Gaudi observed that none of the missions being proposed to the DS are small. He understood that this is an important issue, but the direction was unclear. Dr. Hertz said that NASA does use ground facilities and data when they are needed to advance the space-based program. If something is not being done enough, it becomes a higher priority than something else. If APAC views the bar as too high, then the concern is with his policies, and he welcomed the discussion.

Discussion

Dr. Gaudi continued the discussion of ground-based support by stating that there was a proposal to move forward. He would work on that with Dr. Fischer and send a request to APD. It would be interesting to quantify the investments in this area.

Regarding approval of the TIG for COPAG, Dr. Patricia Boyd pointed out that Drs. Scowen and Boss gave presentations indicating that the technology gaps had not been considered in a consistent way. Dr. Boss explained that ExoPAG had just started the technology gap reviews. After going through the exercise and consulting with their members, the three PAGs would ultimately create a joint list. Dr. Scowen added that COPAG has a year-round request for contributions, with a reminder in the spring. COPAG members wanted a more formal process, however, so now all claims must be backed up with a published paper. The members sought to develop a new group because they were concerned that they were not qualified for this task. Dr. Bautz said that PhysPAG is similar. The PAG tries to put forth a coherent summary without priorities, but he planned to check with the EC in case they might also want a dedicated group for the gap analysis.

Dr. Cornish was concerned about the gap analysis groups becoming too advocacy-oriented. He also wondered about gaps in the gaps. Dr. Gaudi said that the PAGs should represent the entire community, which the chair and the EC ought to ensure. It is an imperfect process. He thought that COPAG was trying to improve the situation. He would approve the TIG, then ask the other PAGs to observe how it goes, with an eye to replication if the TIG succeeds. There is no need to enforce uniformity, but it would be good to have the PAGs in sync. Dr. Scowen said that one reason COPAG wanted to do this was to tamp down the advocacy.

Dr. Gaudi recommended approval of the TIG. APAC voted to approve the TIG.

Dr. Hertz explained that he misspoke when he said that SMD had responded to the NAS study regarding SRs. He then responded to specific recommendations of the NAS Extended Missions study from an APD viewpoint. He noted that it is not possible to fund all of the missions in a SR, and that, as discussed previously, the plan was to go to a 3-year cadence. Regarding inclusion of early career scientists on the review panels, this is something that SMD does not do, though input would be welcome. However, there is a need for expertise on the panels, which is one reason they are called "senior" reviews. There are typically eight members on a SR board. There was a recommendation to continue anticipating funding needs for these missions, which NASA does, but it is not possible to anticipate everything. There is also the reality of flat funding or even decreasing budgets.

Dr. Hertz mentioned Dr. Wang's suggestion about supporting investigators' codes related to missions. A NAS study has been initiated to determine whether NASA should archive codes that the community uses, and that study will be available within a year. Just that day, APD amended the ATP call to allow investigators to purchase computing. In the last few years, the demand has exceeded NASA capacity, so proposers can react to that by proposing to purchase high-end computing resources. The ramp-up of computing at Ames Research Center (ARC) will not happen quickly enough to obviate the need for these additional resources.

The Science Committee will advise Dr. Zurbuchen on how to ensure that high-risk research proposals have a better chance of selection. Dr. Hertz will report on this at the next APAC meeting. Dr. Gaudi added that there was discussion about high-risk science and technology during the previous NAC Science Meeting, and the tendency to conservatism in a strained funding environment. For astrophysics, this relates to the R&A and GO programs.

Dr. Hertz announced that Dr. Ozel will be vice-chair of APAC.

Dr. Gaudi said that Dr. Bock would write the request for the next suborbital update, to specify more science examples and information on how the technology flows into larger missions, as well as how that might be used in the selection process for proposals to the suborbital program.

<u>Recommendations, Actions</u>

Dr. Kalirai asked that the next meeting include an update on the STDTs. Dr. Gaudi agreed to add that to the list of topics to discuss with Dr. Hertz in setting the agenda. He noted the concern about the civil servant change and suggested a recommendation stating that APAC is concerned about the new change and wants more information on implementation at the next meeting. The Committee also wanted SMD to have a workshop to connect cubesats with the larger community. Dr. Ennico Smith said that ARC might be interested in that, as they have a virtual center for smallsats.

Dr. Gaudi said that APAC would recommend that the PAGs consider including early career members on the ECs without increasing EC size significantly. There was some resistance to adding early career scientists to the SRs. In addition, there were questions about when the 3-year cadence would start. There will be an update on suborbital science. APAC approved closing ExoPAG's SAG 12 and starting COPAG's TIG. Dr. Ennico Smith will send information on SOFIA's science metrics to Dr. Hasan, who will then forward the information to the APAC.

The next meeting will be in July, on the 19th and 20th. That meeting will include the annual Government Performance and Results Modernization Act (GPRAMA) review. Dr. Gaudi then made a quick review of Committee assignments for the letter to Dr. Hertz. He would summarize Dr. Hertz's presentation, Webb, and UofL, as well as thanking the presenters. The PAG chairs would summarize their results. Dr. Wang would summarize WFIRST, Dr. Cooray would take on SOFIA, Dr. Kalirai would write up TESS, Dr. Dingus would discuss suborbital programs, Dr. Ozel would describe the CATE presentation, and Dr. Fischer would summarize ground support.

Adjourn

The meeting was adjourned at 2:58 p.m.

Appendix A
Attendees/Participants

Committee members
B. Scott Gaudi, Ohio State University, *Chair, Astrophysics Advisory Committee*
Nathalie Batalha, NASA Ames Research Center
Marshall (Mark) Bautz, Massachusetts Institute of Technology (via teleconference)
James J. Bock, California Institute of Technology
Alan Boss, Carnegie Institution for Science
Patricia Boyd, NASA Goddard Space Flight Center
Asantha Cooray, University of California, Irvine
Neil John Cornish, Montana State University
Brenda Dingus, Los Alamos National Laboratory
Debra Fischer, Yale University (via teleconference)
Jason Kalirai, Space Telescope Science Institute
Feryal Ozel, University of Arizona (via teleconference)
Paul Scowen, Arizona State University
Yun Wang, California Institute of Technology

NASA attendees
Paul Hertz, NASA HQ, *Director, Astrophysics Division*
Gabriel Adler, NASA HQ
Dominic Benford, NASA HQ
Max Bernstein, NASA HQ
Theresa Brandt, NASA GSFC
Joan Centrella, NASA GSFC
Tony Comberiate, NASA JPL
Kimberly Ennico Smith, NASA ARC
Kristen Erickson, NASA HQ
John Gagosian, NASA HQ
Michael Garcia, NASA HQ
Shahid Habib, NASA HQ
Thomas Hams, NASA HQ
Hashima Hasan, NASA HQ, *Executive Secretary, APAC*
Steve Howell, NASA ARC
Douglas Hudgins, NASA HQ
W. Vernon Jones, NASA HQ
Jeff Kruk, NASA GSFC
Susan Neff, NASA GSFC
Mario Perez, NASA HQ
Stephen Rinehart, NASA GSFC
Rita Sambruna, NASA HQ
Kartik Sheth, NASA HQ
Mary Sladek, NASA HQ
Eric Smith, NASA HQ

Martin Still, NASA HQ
Harley Thomson, NASA GSFC

Non-NASA Attendees
Francisco Bordi, Aerospace
Debra Emmons, Aerospace
William Jones, Princeton
Janice Lee, CalTech
Nikole Lewis, STScI
Bradley Peterson, STScI
Elizabeth Sheley, Ingenicomm
Denise Smith, STScI

Webex/Telecon
Mary Atwood, Ingenicomm
Louis Barbier, NASA HQ
Gary Blackwood, JPL
Taylor Chonis, Ball Aerospace
Mark Clampin, NASA GSFC
Steven Clark, Space Flight Now
Dominick Conte
Patricia Dawes, NASA AFRC
Jonathan Gardner, NASA GSFC
Michael Gillon, University of Liège
Kevin Grady, NASA GSFC
Richard Harms, RJH Scientific Inc
Ben Kallen, Lewis Burke Associates LLC
Jennifer Kearns, NASA HQ
Jeanette Lee, NASA
Roberta Leftwich-Vann, USRA
Jim Lochner, USRA
Stephan McCandliss, JHU
Tracy Osborne, NASA HQ
Joel Parriott, American Astronomical Society
Bill Purcell, Ball Aerospace
George Ricker, MIT
Richard Rogers, Stellar Solutions
Kendra Short, JPL
Marcia Smith, spacepolicyonline.com
Karl Stapelfeldt, JPL
Steve Thompson, Millennium Space Systems
Stephen Unwin, JPL
Azita Valinia, NASA GSFC
Angela Williams, Ingenicomm
Ana Wilson, Zantech
Alexandra Witze, Nature Magazine
Harold Yorke, USRA
Eddie Zavala, NASA ARC

Appendix B
NAC Astrophysics Advisory Committee Members

B. Scott Gaudi, APAC Chair
Department of Astronomy
Ohio State University

Hashima Hasan, Executive Secretary
Astrophysics Division
Science Mission Directorate
NASA Headquarters

Natalie Batalha
NASA-Ames

Marshall (Mark) Bautz
Massachusetts Institute of Technology

James J. Bock
Jet Propulsion Laboratory

Alan Boss
Carnegie Institution for Science

Patricia Boyd
Goddard Space Flight Center

Asantha Cooray
Department of Physics and Astrophysics
University of California, Irvine

Neil John Cornish
Department of Physics
Montana State University

Brenda Dingus
Los Alamos National Laboratory

Debra Fischer
Department of Astronomy
Yale University

Jasonjot (Jason) Singh Kalirai
Space Telescope Science Institute

Feryal Ozel
University of Arizona

Paul Scowen
Arizona State University

Yun Wang
California Institute of Technology

Beth Willman
LSST/Steward Observatory
University of Arizona

Appendix C
Presentations

1. *Astrophysics Division Update*, Paul Hertz
2. *TRAPPIST-1 & SPECULOOS Planets*, Michael Gillon
3. *ExoPAG Report*, Alan Boss
4. *PhysPAG Report*, Mark Bautz
5. *COPAG Report,* Paul Scowen
6. *WFIRST Status,* Jeff Kruk
7. *James Webb Space Telescope,* Eric Smith, Nikole Lewis
8. *TESS Update, Stephen Rinehart*
9. *SOFIA Science Update,* Kimberly Ennico Smith
10. *Astrophysics with Suborbital Payloads: Sounding Rockets and Balloons*, Thomas Hams
11. *Universe of Learning*, Denise Smith
12. *Ground-Based Facilities as Part of the NASA Portfolio*, Debra Fischer

Appendix D
Agenda

Astrophysics Advisory Committee
April 24-25, 2017
NASA Headquarters, Washington D.C., Rm. 3H42

Monday April 24

9:40 a.m.	Introduction and Announcements	Scott Gaudi/Hashima Hasan
9:45 a.m.	Astrophysics Division Update	Paul Hertz
11:45 a.m.	Discussion	
12:00 p.m.	Working Lunch	
12:30 p.m.	Science Talk: TRAPPIST-1	Michael Gillon
1:15 p.m.	ExoPAG Report	Alan Boss
1:35 p.m.	PhysPAG Report	Mark Bautz
1:55 p.m.	COPAG Report	Paul Scowen
2:15 p.m.	Discussion of PAG Reports	APAC members
2:45 p.m.	WFIRST Update	Jeff Kruk
3:15 p.m.	Break	
3:30 p.m.	Webb Update	Eric Smith/Nicole Lewis
4:30 p.m.	Public Comment Period	
4:35 p.m.	Discussion	APAC Members
5:00 p.m.	Adjourn Day 1	

Tuesday April 25

9:00 a.m.	Opening Remarks	Scott Gaudi
9:10 a.m.	TESS Update	Stephen Rinehart
9:45 a.m.	SOFIA Update	Kimberly Ennico Smith
10:45 a.m.	Break	
11:00 a.m.	Astrophysics with Suborbital Payloads	Thomas Hams
11:30 a.m.	Aerospace Costing & Technical Evaluation	Debra Emmons
12:00 p.m.	Public Comment Period	
12:05 p.m.	Lunch	
1:00 p.m.	Universe of Learning	Denise Smith
1:30 p.m.	Ground Based Support for Space Missions Discussion	Debra Fischer
2:00 p.m.	Discussion	APAC Members
3:00 p.m.	Recommendations, Actions	Scott Gaudi

3:50 p.m.	Brief to Hertz	Scott Gaudi
4:00 p.m.	Adjourn	